DREXEL UNIVERSITY
College of
Engineering

# CATALOG
## 2014-2015

UNDERGRADUATE & GRADUATE

catalog.drexel.edu

# College of Engineeing

The College of Engineering curriculum is designed to provide students a thorough understanding of scientific, mathematical, and engineering fundamentals--as well as the ability to apply these areas of knowledge creatively to a wide variety of engineering problems.

## Majors

- Architectural Engineering
- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Construction Management
  - Real Estate Concentration
- Electrical Engineering
- Engineering
- Engineering Technology
  - Biomedical Engineering Technology
  - Electrical Engineering Technology
  - Industrial Engineering Technology
  - Mechanical Engineering Technology
- Environmental Engineering
- Materials Science and Engineering
- Mechanical Engineering
- Property Management

## Minors

- Architectural Engineering
- Computer Engineering
- Construction Management
- Electrical Engineering
- Engineering Management
- Engineering Policy Analysis
- Entertainment Engineering
- Environmental Engineering
- Global Engineering
- Materials Science and Engineering
- Mechanical Engineering
- Nuclear Engineering
- Property Management
- Real Estate

## Certificates

- Affordable Housing Administration
- Commercial Property Management
- Construction Management (I, II, III, IV)
- Fundamentals of Property Management
- Housing for an Aging Population
- Residential Property Management

## About the College

Drexel University's College of Engineering has emphasized its strengths in engineering, science and technology to train students to become the leaders of the future. In little over a century, Drexel University has transformed itself into a large, comprehensive institution committed to excellence in education, research and service to the engineering society and to the broader community. Although much has changed, the original mission of the University still rings true today.

The College of Engineering offers students a diverse academic learning and research environment embodying the highest standards of knowledge and preparing them to impact society's greatest challenges. Through entrepreneurial risk-taking and exploration, students are encouraged to find innovative solutions that promote economic development and improve life

In addition to the traditional engineering curriculum, the college offers Project Management (http://www.drexel.edu/engmgmt/program-areas/project-management) , Engineering Technology , Construction Management and Property Management .

## Objectives of the traditional Undergraduate Engineering Program

The profession of engineering is concerned with turning the natural elements and energies to the service of mankind. The objectives of the undergraduate program in the College of Engineering (http://www.drexel.edu/coe) are:

- *To offer an education that will give graduates the flexibility to adjust to future changes in technology*
- *To develop a sense of professionalism and entrepreneurship*
- *To provide a framework for concentrated study in a professional area*

To implement those objectives the curricula of the College of Engineering are designed to provide a firm grounding in basic science and liberal arts, along with broad-based engineering sciences and professional engineering subjects.

## Cooperative Education

In five-year cooperative programs, engineering majors spend a total of 12 terms in school and six terms on co-op assignment. Freshmen attend classes for three terms. During their sophomore, pre-junior, and junior years, students generally attend class for two terms and are assigned a cooperative employment position for two terms each year.

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

## About the Traditional Engineering Curriculum

### Degree Requirements

The degree of Bachelor of Science in the engineering specialities requires a minimum of 192 credits of academic work and six terms of co-op or engineering experience for the five-year program. For the four-year program, only two terms of co-op are required. Transfer students must complete a minimum of two terms of co-op or engineering experience

in order to earn a cooperative engineering degree accredited by ABET (http://www.abet.org) .

Engineering student must maintain an overall grade point average of 2.0 in all required courses in their major.

The Bachelor of Science in Engineering (BSE) program is a customizable undergraduate engineering degree program offered in the College of Engineering. The program is designed for students who are seeking an interdisciplinary education rooted in engineering. The degree is structured so students achieve a strong foundation in science, math and engineering. Upper level engineering electives can be chosen to fit the student's individual interests and career objectives. The BS in Engineering program allows the student to create their own engineering curriculum path with the assistance of their BSE advisors. The program is also flexible enough so that students can complete up to two minors in areas which may include but are not limited to environmental studies, finance, entrepreneurship, music, legal studies or pre-med. To learn more about the Bachelor of Science in Engineering program, please visit the Program Overview webpage (http://www.drexel.edu/engineering/programs/undergrad/Engineering/BSE/ProgramOverview) .

## Curricular Organization

Students in the traditional engineering programs study the same subjects during the three terms in the first year. During the two terms of the sophomore year, students begin taking department specific coursework.

The first five terms are devoted to those subjects that form the foundation of the engineering curriculum. Courses in the core engineering curriculum are organized and taught to provide an integrated view of the basic sciences and an introduction to the art of engineering through group projects that deal with open-ended problems characteristic of the practice of engineering. Students also learn to use the modern tools of engineering both on the computer and in the laboratory.

The college considers it essential that students entering the Drexel Engineering Curriculum be placed in courses that take advantage of their abilities and prior training. Student preparation level is determined by a review committee that evaluates the student's high school record, standardized test scores, and placement tests administered during freshman orientation.

Students who demonstrate the preparation and skills to succeed in our integrated engineering calculus course immediately will be placed in the course starting in the fall term. Students who are not prepared for this sequence may participate in a special "pre-engineering" program before the fall term. These students may also have a modified fall schedule and may need summer school during the following summer.

In the second year, two professional subjects are introduced, and all the first-level professional courses are completed by the junior year. The senior year in all curricula contains at least one elective sequence so that students can study some aspect of engineering more deeply. In addition, all curricula provide a design experience in the senior year. Recognizing the importance of general education studies in the education of an engineer, all curricula require that courses be taken in this area. These requirements are described in more detail in the General Education Requirements .

## The Common Curriculum

**University Requirements**

| | | |
|---|---|---|
| UNIV E101 | The Drexel Experience | 2.0 |

**Foundation Requirements**

| | | |
|---|---|---|
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| BIO 141 | Essential Biology | 4.5 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 121 | Computation Lab I | 2.0 |
| ENGR 122 | Computation Lab II | 1.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |

In addition, engineering students complete ten (10) General Education Requirements.

## Electives

In addition to the electives in the General Education electives there are two types of elective sequences in the engineering curricula: technical electives and free electives.Technical electives are courses in engineering, science, or management that build on the required professional courses and lead to a specific technical specialization. Possible elective sequences should be discussed with and approved by advisors before the end of the junior year.Free electives are any courses for which students are eligible and that are not remedial in nature for engineering students.

## Withdrawal from the College of Engineering

It is the policy of the College of Engineering that an engineering student who withdraws from the University cannot petition for readmission to the College of Engineering until at least one complete term has elapsed.

## General Education Requirements

The General Education Program is designed to give engineering students an opportunity to take a set of courses that complement their technical studies and satisfy their intellectual and/or career interests. All engineering majors must take ten (10) courses. Three of the ten courses are designated as follows and must be completed by all majors:

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |

The remaining seven (7) General Education course requirements are not designated and can be chosen from the disciplines listed below. Any course of three credits or more selected from the categories below meets this requirement, except as noted.

## Course Subjects

This following list is a sampling of subject codes for courses that can be taken to fulfill General Education requirements; other courses may be accepted upon advisor approval.

Accounting (ACCT), Africana Studies (AFAS), Anthropology (ANTH), Arabic (ARBC), Architecture (ARCH), Art History (ARTH), Business Law (BLAW), General Business (BUSN), Chinese (CHIN), Communication (COM), Criminal Justice (CJ), Culinary Arts (CULA), Customer Operations (CUST), Dance (DANC), Economics (ECON), English (ENGL, except 101, 102, 103 & 105), Entertainment & Arts Management (EAM), Education (EDUC), Entrepreneurship (ENTP), Film Studies (FMST), Finance (FIN), French (FREN), German (GER), Greek, (GREC), History (HIST), Hotel & Restaurant Management (HRM), Humanities (HUM, except 106, 107, & 108), International Area Studies (IAS), International Business (INTB), Italian (ITAL), Japanese (JAPN), Korean (KOR), Language (LANG), Leadership (LEAD), Management ( MGMT), Marketing (MKTG), Music (MUSC), Operations Management (OPM), Operations Research (OPR), Organizational Behavior (ORGB), Philosophy (PHIL), Photography (PHTO), Production Operations Management (POM), Political Science (PSCI), Psychology (PSY, except 330, 337, 364 & 365), Russian (RUSS), Screenwriting & Playwriting (SCRP), Sociology (SOC, except 364 & 365), Spanish (SPAN), Sports Management (SMT), Business Statistics (STAT), Taxation (TAX), Theatre (THTR), Women's Studies (WMST), and Writing (WRIT).

Environmental Policy (ENVP) courses can be chosen by Architectural Engineering, Civil Engineering, and Environmental Engineering programs.

Architectural engineering students' general studies requirements are slightly different. The three-course ARCH 141–ARCH 143 (Architecture and Society) sequence, offered through the Antoinette Westphal College of Media Arts and Design, is required of all architectural engineering students.

Some engineering majors require a study in basic economic principles, the history of the engineering profession and its impact on modern society, and ethical standards required for the practice of the profession. Check curriculum guidelines for requirements. Any required economics, history or ethics courses will replace general education requirements on a course-for-course basis.

General Education electives must be non-technical. All Computer, Math, Engineering & Science related courses will NOT count as General Education electives.

## Special Programs

## Accelerated Programs/ Bachelor's/Master's Dual Degree Program

The Accelerated Program of the College of Engineering provides opportunities for highly talented and strongly motivated students to progress toward their educational goals essentially at their own pace. Primarily through advanced placement, credit by examination, flexibility of scheduling, and independent study, the program makes it possible to complete the undergraduate curriculum and initiate graduate study in less than the five years required by the standard curriculum.

Students enrolled in this program may take advantage of the five-year Bachelor's/Master's Dual Degree Program described on the College of Engineering's Accelerated: BS /MS (http://drexel.edu/engineering/programs/special_opp) web page.

## Lincoln University/Drexel 3-3 Plan

Drexel participates in a program with Lincoln University under which a student may attend Lincoln University for three years, taking liberal arts subjects and pre-engineering courses in mathematics, science, and related areas; transfer to Drexel; and receive a degree in engineering after three additional years at Drexel. This is similar to the conventional 3-2 program in which other colleges and universities participate; the extra year is necessitated by Drexel's co-operative education plan.

## Facilities

## Core Engineering Facilities

The Freshman Engineering Design Laboratories encompass three laboratories. They include two newly renovated spaces: a double laboratory room in the Bossone Research Center, which accommodates two lab sections, and another laboratory room that accommodates a single lab section in the LeBow Engineering Center.

Freshman Design courses taken by all new freshmen are held exclusively in these newly renovated rooms, which were completed in the fall of 2011. A team of Drexel faculty and staff designed these rooms to promote open communication within and across groups of students. Each room is equipped with Media:Scape tables manufactured by SteelCase. Each table has two 32-inch monitors that are connected to a MacMini computer, which is housed in the furniture, contributing to the overall clean look and feel of the classroom. The classroom design fosters and supports teamwork.

The Freshman Engineering Design Laboratories are a great example of Drexel's commitment to undergraduate education, by providing up-to-date, high-quality technology to facilitate the kind of experiential learning that keeps Drexel at the cutting edge.

## Department Facilities

Departments within the College of Engineering have laboratory equipment appropriate for required lab coursework within curriculum. Most engineering department webpages describe their specialized facilities in detail.

# Architectural Engineering

## About the Program

*Bachelor of Science in Architectural Engineering (BSAE): 193.0 quarter credits*

The architectural engineering major prepares graduates for professional work in the analysis, design, construction, and operation of residential, commercial, institutional, and industrial buildings. The program develops engineers familiar with all aspects of safe and economical construction. Students study the principles of structural support and external cladding, building environmental systems, and project management and develop depth in at least one area.

The program integrates building disciplines, including coordination with architects, construction managers, civil, mechanical, and electrical engineers, and others. Students use computer-aided design tools to

understand system interactions, perform analysis, design, scheduling, and cost analysis, and present their work.

The first two years of the curriculum cover fundamentals necessary for all engineers. The pre-junior and junior years emphasize building systems and the principles governing their performance. In addition to the core engineering and science, students learn architectural approaches through studio design. Seniors focus on either structural or building environmental systems design, as well as a full-year realistic design project. The academic program is complemented by exposure to professional practice in the co-op experience.

A special feature of the major is senior design. A group of students works with a faculty advisor to develop a significant design project selected by the group. All architectural engineering students participate in a design project.

## Mission Statement

The civil and architectural engineering faculty are responsible for delivering an outstanding curriculum that equips our graduates with the broad technical knowledge, design proficiency, professionalism, and communications skills required for them to make substantial contributions to society and to enjoy rewarding careers.

## Program Educational Objectives

Architectural engineering graduates will become professionals who analyze, design, construct, manage, or operate residential, commercial, institutional and industrial buildings and systems, or advance knowledge of the field.

## Student Outcomes

The department's student outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

a) an ability to apply knowledge of mathematics, science, and engineering;

b) an ability to design and conduct experiments, as well as to analyze and interpret data;

c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

d) an ability to function on multidisciplinary teams;

e) an ability to identify, formulate, and solve engineering problems;

f) an understanding of professional and ethical responsibility;

g) an ability to communicate effectively;

h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;

i) a recognition of the need for, and an ability to engage in life-long learning;

j) a knowledge of contemporary issues;

k) an ability to use the techniques, skills, and modern engineering tools necessary for architectural engineering practice.

## Concentration Options

### Mechanical Concentration (HVAC)

Students who choose the mechanical concentration (HVAC) prepare for careers dealing with the building environment. As co-ops and graduates, they will be involved in the many design aspects of building environmental control, including:

- building load definitions
- equipment selection and design
- distribution system design
- control systems design
- energy analysis and system optimization
- building operation for safety, economy and maximum performance

### Structural Concentration

Students who choose the structural concentration prepare for careers dealing with the building structure. As co-ops and graduates, they will be involved in the design of the many aspects of building structure including:

- building load definitions
- structural system design
- foundation system design

### Digital Building Concentration*

Students who choose the digital building concentration prepare for careers dealing with the role of computer technology in building design, construction and operation. As co-ops and graduates, they will be involved in:

- development and use of Building Information Models (BIM) and databases
- configuration and operation of building sensor and actuator networks and monitoring systems
- developing and maintaining construction schedules, databases and monitoring systems

*Available for enrollment starting in academic year 2014-2015.

### Additional Information

The Architectural Engineering program is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

For more information about this major, contact the program director:
James E. Mitchell
Professor
Civil Arch & Environmental Engineering
james.mitchell@drexel.edu

## Degree Requirements

**General Education/Liberal Studies Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| General Education requirements * | | 12.0 |

**Foundation Requirements**

| | | |
|---|---|---|
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| BIO 141 | Essential Biology | 4.5 |
| CS 121 | Computation Laboratory I | 1.0 |
| CS 122 | Computation Laboratory II | 1.0 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |

**Major Requirements**

| | | |
|---|---|---|
| AE 220 | Introduction to HVAC | 3.5 |
| AE 340 | Architectural Illumination and Electrical Systems | 3.0 |
| AE 390 | Architectural Engineering Design I | 4.0 |
| AE 391 | Architectural Engineering Design II | 4.0 |
| AE 544 | Building Envelope Systems | 3.0 |
| ARCH 141 | Architecture and Society I | 3.0 |
| ARCH 142 | Architecture and Society II | 3.0 |
| ARCH 143 | Architecture and Society III | 3.0 |
| ARCH 191 | Studio 1-AE | 3.0 |
| ARCH 192 | Studio 2-AE | 3.0 |
| CAE 491 [WI] | Senior Design Project I | 3.0 |
| CAE 492 [WI] | Senior Design Project II | 3.0 |
| CAE 493 [WI] | Senior Design Project III | 3.0 |
| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| CAEE 211 | Measurements in Civil, Architectural and Environmental Engineering II | 4.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| CIVE 250 | Construction Materials | 4.0 |
| CIVE 330 | Hydraulics | 4.0 |
| CIVE 320 | Introduction to Fluid Flow | 3.0 |
| MEM 202 | Statics | 3.0 |
| MEM 230 | Mechanics of Materials I | 4.0 |
| ENGR 361 | Statistical Analysis of Engineering Systems | 3.0 |

**Concentration Courses** · 29.0

**Students select one of the following concentrations for a total of 29.0 credits:**

**Mechanical Concentration**

| | | |
|---|---|---|
| AE 430 | Control Systems for HVAC | |
| CIVE 370 | Introduction to Structural Analysis | |
| CIVE 371 | Introduction to Structural Design | |
| CIVE 372 | Structural Laboratory | |
| MEM 345 | Heat Transfer | |
| MEM 413 | HVAC Loads | |
| MEM 414 | HVAC Equipment | |
| Three professional electives | | |

**Structural Concentration**

| | | |
|---|---|---|
| CIVE 300 | Structural Analysis I | |
| CIVE 301 | Structural Design I | |
| CIVE 310 | Soil Mechanics I | |
| CIVE 400 | Structural Analysis II | |
| CIVE 401 | Structural Design II | |
| CIVE 402 | Structural Design III | |
| CIVE 410 | Foundation Engineering | |
| Two professional electives | | |

**Digital Building Concentration**

| | | |
|---|---|---|
| AE 510 | Intelligent Buildings | |
| CIVE 370 | Introduction to Structural Analysis | |
| CIVE 371 | Introduction to Structural Design | |
| CIVE 372 | Structural Laboratory | |
| CMGT 361 | Contracts And Specifications I | |
| CMGT 467 | Techniques of Project Control | |
| INFO 210 | Database Management Systems | |
| INFO 203 | Information Technology for Engineers | |

| | |
|---|---|
| **Total Credits** | **193.0** |

\* General Education Requirements.

# Sample Plan of Study

## BS Architectural Engineering, Mechanical Engineering

### 5 YR UG Co-op Concentration/Mechanical Engineering

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| CS 121 | Computation Laboratory I | 1.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **15.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| CS 122 | Computation Laboratory II | 1.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |

| | | |
|---|---|---|
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 4** | | |
| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 5** | | |
| ARCH 191 | Studio 1-AE | 3.0 |
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| MEM 202 | Statics | 3.0 |
| | **Term Credits** | **18.0** |
| **Term 6** | | |
| AE 340 | Architectural Illumination and Electrical Systems | 3.0 |
| ARCH 141 | Architecture and Society I | 3.0 |
| ARCH 192 | Studio 2-AE | 3.0 |
| CIVE 320 | Introduction to Fluid Flow | 3.0 |
| MEM 230 | Mechanics of Materials I | 4.0 |
| | **Term Credits** | **16.0** |
| **Term 7** | | |
| AE 220 | Introduction to HVAC | 3.5 |
| ARCH 142 | Architecture and Society II | 3.0 |
| CAEE 211 | Measurements in Civil, Architectural and Environmental Engineering II | 4.0 |
| CIVE 250 | Construction Materials | 4.0 |
| CIVE 330 | Hydraulics | 4.0 |
| | **Term Credits** | **18.5** |
| **Term 8** | | |
| AE 390 | Architectural Engineering Design I | 4.0 |
| ARCH 143 | Architecture and Society III | 3.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| CIVE 370 | Introduction to Structural Analysis | 3.0 |

| | | |
|---|---|---|
| MEM 345 | Heat Transfer | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 9** | | |
| AE 391 | Architectural Engineering Design II | 4.0 |
| CIVE 371 | Introduction to Structural Design | 3.0 |
| CIVE 372 | Structural Laboratory | 1.0 |
| Professional elective* | | 3.0 |
| General Education elective* | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 10** | | |
| AE 544 | Building Envelope Systems | 3.0 |
| CAE 491 [WI] | Senior Design Project I | 3.0 |
| ENGR 361 | Statistical Analysis of Engineering Systems | 3.0 |
| MEM 413 | HVAC Loads | 3.0 |
| General Education elective* | | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 11** | | |
| CAE 492 [WI] | Senior Design Project II | 3.0 |
| MEM 414 | HVAC Equipment | 3.0 |
| Professional elective* | | 3.0 |
| General Education elective* | | 3.0 |
| | **Term Credits** | **12.0** |
| **Term 12** | | |
| AE 430 | Control Systems for HVAC | 3.0 |
| CAE 493 [WI] | Senior Design Project III | 3.0 |
| Professional elective* | | 3.0 |
| General Education elective* | | 3.0 |
| | **Term Credits** | **12.0** |

**Total Credit: 193.0**

*    See degree requirements.

## BS Architectural Engineering, Structural 5 YR UG Co-op Concentration/Structural

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| CS 121 | Computation Laboratory I | 1.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **15.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| CS 122 | Computation Laboratory II | 1.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |

| ENGR 102 | Engineering Design Laboratory II | 2.0 |
|---|---|---|
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 4** | | |
| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 5** | | |
| ARCH 191 | Studio 1-AE | 3.0 |
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| MEM 202 | Statics | 3.0 |
| | **Term Credits** | **18.0** |
| **Term 6** | | |
| AE 340 | Architectural Illumination and Electrical Systems | 3.0 |
| ARCH 141 | Architecture and Society I | 3.0 |
| ARCH 192 | Studio 2-AE | 3.0 |
| CIVE 320 | Introduction to Fluid Flow | 3.0 |
| MEM 230 | Mechanics of Materials I | 4.0 |
| | **Term Credits** | **16.0** |
| **Term 7** | | |
| AE 220 | Introduction to HVAC | 3.5 |
| ARCH 142 | Architecture and Society II | 3.0 |
| CAEE 211 | Measurements in Civil, Architectural and Environmental Engineering II | 4.0 |
| CIVE 250 | Construction Materials | 4.0 |
| CIVE 330 | Hydraulics | 4.0 |
| | **Term Credits** | **18.5** |
| **Term 8** | | |
| AE 390 | Architectural Engineering Design I | 4.0 |
| ARCH 143 | Architecture and Society III | 3.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| CIVE 300 | Structural Analysis I | 3.0 |

| CIVE 310 | Soil Mechanics I | 4.0 |
|---|---|---|
| | **Term Credits** | **17.0** |
| **Term 9** | | |
| AE 391 | Architectural Engineering Design II | 4.0 |
| CIVE 301 | Structural Design I | 4.0 |
| Professional elective[*] | | 3.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 10** | | |
| AE 544 | Building Envelope Systems | 3.0 |
| CAE 491 [WI] | Senior Design Project I | 3.0 |
| CIVE 400 | Structural Analysis II | 3.0 |
| ENGR 361 | Statistical Analysis of Engineering Systems | 3.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 11** | | |
| CAE 492 [WI] | Senior Design Project II | 3.0 |
| CIVE 401 | Structural Design II | 3.0 |
| CIVE 410 | Foundation Engineering | 3.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **12.0** |
| **Term 12** | | |
| CAE 493 [WI] | Senior Design Project III | 3.0 |
| CIVE 402 | Structural Design III | 3.0 |
| Professional elective[*] | | 3.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **12.0** |

**Total Credit: 193.0**

[*] See degree requirements.

## BS Architectural Engineering, Digital Building

### 5 YR UG Co-op Concentration/Digital Building

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| CS 121 | Computation Laboratory I | |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **14.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| CS 122 | Computation Laboratory II | 1.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |

| | | |
|---|---|---|
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 4** | | |
| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 5** | | |
| ARCH 191 | Studio 1-AE | 3.0 |
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| MEM 202 | Statics | 3.0 |
| | **Term Credits** | **18.0** |
| **Term 6** | | |
| AE 340 | Architectural Illumination and Electrical Systems | 3.0 |
| ARCH 141 | Architecture and Society I | 3.0 |
| ARCH 192 | Studio 2-AE | 3.0 |
| CIVE 320 | Introduction to Fluid Flow | 3.0 |
| MEM 230 | Mechanics of Materials I | 4.0 |
| | **Term Credits** | **16.0** |
| **Term 7** | | |
| AE 220 | Introduction to HVAC | 3.5 |
| ARCH 142 | Architecture and Society II | 3.0 |
| CAEE 211 | Measurements in Civil, Architectural and Environmental Engineering II | 4.0 |
| CIVE 250 | Construction Materials | 4.0 |
| CIVE 330 | Hydraulics | 4.0 |
| | **Term Credits** | **18.5** |
| **Term 8** | | |
| AE 390 | Architectural Engineering Design I | 4.0 |
| ARCH 143 | Architecture and Society III | 3.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| CIVE 370 | Introduction to Structural Analysis | 3.0 |

| | | |
|---|---|---|
| MEM 345 | Heat Transfer | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 9** | | |
| AE 391 | Architectural Engineering Design II | 4.0 |
| CIVE 371 | Introduction to Structural Design | 3.0 |
| CIVE 372 | Structural Laboratory | 1.0 |
| INFO 210 | Database Management Systems | 3.0 |
| General Education Elective[*] | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 10** | | |
| AE 544 | Building Envelope Systems | 3.0 |
| CAE 491 [WI] | Senior Design Project I | 3.0 |
| ENGR 361 | Statistical Analysis of Engineering Systems | 3.0 |
| INFO 203 | Information Technology for Engineers | 3.0 |
| General Education Elective[*] | | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 11** | | |
| AE 510 | Intelligent Buildings | 3.0 |
| CAE 492 [WI] | Senior Design Project II | 3.0 |
| CMGT 467 | Techniques of Project Control | 4.0 |
| General Education Elective[*] | | 3.0 |
| | **Term Credits** | **13.0** |
| **Term 12** | | |
| CAE 493 [WI] | Senior Design Project III | 3.0 |
| CMGT 361 | Contracts And Specifications I | 3.0 |
| Professional Elective[*] | | 3.0 |
| General Education Elective[*] | | 3.0 |
| | **Term Credits** | **12.0** |

**Total Credit: 193.0**

[**]   Students are asked to speak with their program advisor before registering for the INFO elective.

# Co-op/Career Opportunities

The major in architectural engineering prepares students for professional work in residential, commercial, institutional, and industrial building systems, in cooperation with architects and other engineers.

## Sample Co-op Experiences

When students complete their co-op jobs, they are asked to write an overview of their experiences. These brief quotes are taken from some recent student reports:

Project technician, major university: "Studied and surveyed existing buildings and facilities for: their compliance with the Americans with Disabilities Act, heating and air conditioning equipment sizing, electrical loads, and their planning and usage of space. Designed improvements from the field surveys taken, and developed construction drawings. Worked closely with the workforce in implementing these changes."

CAD technician, private engineering firm: "Prepared computer generated construction plans for various water and sewer reconstruction

projects. . . .Was able to expand my knowledge of Auto CAD to include Advanced Design Modules."

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

## Dual/Accelerated Degree

The Accelerated Program of the College of Engineering provides opportunities for highly talented and strongly motivated students to progress toward their educational goals essentially at their own pace. Primarily through advanced placement, credit by examination, flexibility of scheduling, and independent study, the program makes it possible to complete the undergraduate curriculum and initiate graduate study in less than the five years required by the standard curriculum.

## Dual Degree Bachelor's Programs

A student completing the Bachelor of Science degree program in architectural engineering may complete additional courses (specified by the department) to earn the Bachelor of Science degree in civil engineering. (The reverse is difficult because of prerequisites in the sequence of architectural studio design courses, which begins in the sophomore year.)

**Required Courses for Dual Degree in Civil Engineering**

| CIVE 430 | Hydrology | 3.0 |
|---|---|---|
| CIVE 477 [WI] | Seminar | 2.0 |
| CIVE 478 [WI] | Seminar | 1.0 |
| ENVE 300 | Introduction to Environmental Engineering | 3.0 |
| Technical Elective (200-level or above) * | | 3.0 |
| **Required Courses for Mechanical Concentration** | | |
| CIVE 310 | Soil Mechanics I | 4.0 |
| CIVE 410 | Foundation Engineering | 3.0 |
| **Required Courses for Structural Concentration** | | |
| CIVE 375 | Structural Material Behavior | 3.0 |

\* Check with the Department for Technical elective options.

## Bachelor's/Master's Dual Degree Program

Exceptional students can also pursue a master of science degree in the same period as the bachelor of science. Exceptional students can also pursue a master of science degree in the same period as the bachelor of science. For more information about this program, visit the Department's BS/MS Dual Degree Program (http://www.cae.drexel.edu/dual_degree.asp) page.

## Minor in Architectural Engineering

The minor in architectural engineering, designed to broaden the professional capabilities of students, offers the building systems portion of the architectural engineering curriculum with enough attention to structural components for completeness. Pursuing a minor in architectural engineering can be of interest to mechanical engineering students who wish to learn the application of HVAC systems within the building context; to civil engineering students who require knowledge of large-scale infrastructure systems; and to chemical engineering students who wish to understand the energy and distribution aspects of process plant design.

The minor consists of a minimum of 24 credits total, with five required core courses. Students take a minimum of eight additional credits taken from a list of optional courses.

While this minor is primarily designed to provide technical knowledge and skills to other engineers, with the appropriate prerequisites students from other disciplines—such as architecture—can also complete this minor.

### Prerequisites

The common engineering core curriculum prerequisites are required of all students in the College of Engineering. Students from other colleges will need the appropriate background prerequisite courses in physics, mathematics and thermodynamics.

**Required Courses**

| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
|---|---|---|
| AE 220 | Introduction to HVAC | 3.5 |
| AE 340 | Architectural Illumination and Electrical Systems | 3.0 |
| or ARCH 263 | Environmental Systems III | |
| AE 390 | Architectural Engineering Design I | 4.0 |
| CIVE 370 | Introduction to Structural Analysis | 3.0 |
| Select two of the following: | | 8.0 |
| CIVE 250 | Construction Materials | |
| CIVE 371 | Introduction to Structural Design | |
| MEM 413 | HVAC Loads | |
| MEM 310 | Thermodynamic Analysis I | |
| ARCH 191 | Studio 1-AE | |
| or ARCH 101 | Studio 1-A | |
| AE 391 | Architectural Engineering Design II | |
| CIVE 240 [WI] | Engineering Economic Analysis | |
| **Total Credits** | | **24.5** |

## Facilities

The Department is well equipped with state-of-the-art facilities:

- The department computer labs are in operation: a computer-assisted design (CAD) and computerized instructional lab; and a graduate-level lab (advanced undergraduates can become involved in graduate-level work).
- External labs are used for surveying, building diagnostics, and surface and ground-water measurements.

## Civil, Architectural and Environmental Engineering Faculty

Abieyuwa Aghayere, PhD, P.Eng *(University of Alberta)*. Professor. Structural design - concrete, steel and wood; Structural failure analysis and retrofitting of existing structures; New structural systems and materials.

Emin A. Aktan, PhD *(University of Illinois at Urbana-Champaign) John Roebling Professor of Infrastructure Studies*. Professor. Structural engineering; infrastructure; evaluation; intelligent systems.

Ivan Bartoli, PhD *(University of California, San Diego)*. Assistant Professor. Non-destructive evaluation and structural health monitoring; dynamic identification, stress wave propagation modeling.

Robert Brehm, PhD, PE, FASCE *(Drexel University).* Associate Teaching Professor. International infrastructure delivery; response to natural catastrophes; risk assessment and mitigation strategies; project management techniques.

S.C. Jonathan Cheng, PhD *(West Virginia University).* Associate Professor. Soil mechanics; geosynthetics; probabilistic design; landfill containments.

Peter DeCarlo, PhD *(University of Colorado).* Assistant Professor. Outdoor air quality, particulate matter size and composition instrumentation and measurements, source apportionment of ambient particulate matter, climate impacts of particulate matter.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute).* Associate Professor. Soil mechanics; geoenvironmental; ground improvement; sustainability.

Patrick Gurian, PhD *(Carnegie-Mellon University).* Associate Professor. Risk analysis of environmental and infrastructure systems, novel adsorbent materials, environmental standard setting, Bayesian statistical modeling, community outreach and environmental health.

Charles N. Haas, PhD *(University of Illinois-Urbana) L. D. Betz Professor and Department Head, Civil, Architectural and Environmental Engineering.* Professor. Control of human exposures to and risk assessment of pathogenic organisms; water and waste treatment; homeland security.

Ahmad Hamid, PhD *(McMaster University).* Professor. Engineered masonry; building; cladding; prestressed concrete.

Y. Grace Hsuan, PhD *(Imperial College).* Professor. Polymeric and cementitioius materials; geosynthetic reliability and durability.

Joseph B. Hughes, PhD *(University of Iowa) Dean of the College of Engineering.* Distinguished Professor. Biological processes and applications of nanotechnology in environmental systems.

Roger Marino, PhD *(Drexel University).* Associate Teaching Professor. Fluid Mechanics, Water Resources, Engineering Education, Land Development

Joseph P. Martin, PhD *(Colorado State University).* Professor. Geoenvironmental engineering; urban environmental hydrology; transportation.

James E. Mitchell, MArch *(University of Pennsylvania).* Associate Professor. Architectural engineering design; building systems.

Franco Montalto, PhD *(Cornell University).* Associate Professor. Effects of built infrastructure on societal water needs, ecohydrologic patterns and processes, ecological restoration, green design, water interventions.

Franklin Moon, PhD *(Georgia Institute of Technology).* Associate Professor. Full-scale structural testing, structural dynamics, evaluation and rehabilitation of existing structures.

Joseph V. Mullin, PhD *(Pennsylvania State University).* Senior Lecturer. Structural material behavior, engineering economy and design.

Mira S. Olson, PhD *(University of Virginia).* Associate Professor. Groundwater; environmental fluid mechanics; hydrology.

Anu Pradhan, PhD *(Carnegie Mellon University).* Assistant Professor. Infrastructure management, construction engineering, transportation engineering, sensing system, geographic information system, statistical machine learning.

Yared Shifferaw, PhD *(Johns Hopkins University).* Assistant Professor. Computational and experimental mechanics, structural stability, optimization, health monitoring and hazard mitigation, sustainable structures, emerging materials, thin-walled structures and metallic structures.

Kurt Sjoblom, PhD *(Massachusetts Institute of Technology).* Assistant Professor. Laboratory testing of geomaterials, geotechnical engineering, foundation engineering.

Sabrina Spatari, PhD *(University of Toronto).* Assistant Professor. Research in industrial ecology; development and application of life cycle assessment (LCA) and material flow analysis (MFA) methods for guiding engineering and policy decisions; specific interest in biomass and bioenergy, biofuels, and urban infrastructure.

Michael Waring, PhD *(University of Texas-Austin).* Assistant Professor. Indoor air quality and building sustainability; indoor particulate matter fate and transport; indoor chemistry and particle formation; secondary impacts of control technologies and strategies.

Jin Wen, PhD *(University of Iowa).* Associate Professor. Architectural engineering, building control systems, indoor air quality.

Aspasia Zerva, PhD *(University of Illinois).* Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

## Interdepartmental Faculty

Eugenia Ellis, PhD *(Virginia Polytechnic State University).* Associate Professor. Registered architect; interior design, extended-care facilities design, research on spatial visualization, perception and imagination.

Bakhtier Farouk, PhD *(University of Delaware) Billings Professor of Mechanical Engineering.* Professor. Heat transfer; combustion; numerical methods; turbulence modeling; materials processing.

Tony H. Grubesic, PhD *(The Ohio State University) Director of the Center for Spatial Analytics and Geocomputation (CSAG).* Professor. Geographic information science, spatial analysis, development, telecommunication policy, location modeling.

## Emeritus Faculty

Harry G. Harris, PhD *(Cornell University).* Professor Emeritus. Structural models, dynamics of structures, plates and shells, industrialized building construction.

Robert M. Koerner, PhD *(Duke University).* Harry Bownam Professor Emeritus. Geosynthetic engineering; soil mechanics; water resources.

Richard Weggel, PhD *(University of Illinois) Samuel S. Baxter Professor Emeritus; Civil and Environmental Engineering.* Professor Emeritus. Coastal engineering; hydraulics engineering; hydrology.

Richard Woodring, PhD *(University of Illinois) Dean of Engineering Emeritus.* Professor Emeritus. Structural engineering, reinforced concrete.

# Courses

**AE 220 Introduction to HVAC 3.5 Credits**
This course includes a review of thermodynamics, moist air properties and processes, basic heat transfer, solar radiation, heating and cooling losses and load calculation, types of air conditioning systems, infiltration and ventilation, air motion and distribution.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CAEE 201 [Min Grade: D] and (ENGR 210 [Min Grade: D] or TDEC 202 [Min Grade: D])

**AE 340 Architectural Illumination and Electrical Systems 3.0 Credits**
This course covers building electrical systems, including power demand, distribution and control; building illumination techniques, including lighting demand, layout and energy analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CAEE 201 [Min Grade: D] and (PHYS 102 [Min Grade: D] or TDEC 115 [Min Grade: D])

**AE 380 Special Topics in Architectural Engineering 0.5-12.0 Credits**
Various topics of interest in the field of architectural engineering. See program director for details on topics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**AE 390 Architectural Engineering Design I 4.0 Credits**
Establishes a base of building systems design concepts, knowledge and performance criteria, with emphasis on the thermal, electrical, illumination and structural aspects of buildings.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** AE 220 [Min Grade: D] and AE 340 [Min Grade: D] and ARCH 192 [Min Grade: D] and MEM 202 [Min Grade: D]

**AE 391 Architectural Engineering Design II 4.0 Credits**
Emphasizes the development of insight into the solution of building system design problems, development of in-depth understanding of building systems design synthesis, and integration in a single building of modest scale and complexity.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** AE 390 [Min Grade: D]

**AE 399 Independent Study in Architectural Engineering 12.0 Credits**
Independent study on a topic selected by the student. Independent study is supervised by a faculty member and guided by a plan of study.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**AE 430 Control Systems for HVAC 3.0 Credits**
This course introduces basic control concepts with applications to HVAC systems; direct digital control, control loops; system modeling; transfer functions; selecting and locating sensors and actuators; design and tuning control algorithms; design and programming of HVAC control systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** AE 220 [Min Grade: D] or MEM 413 [Min Grade: D]

# Chemical Engineering

*Bachelor of Science in Chemical Engineering (BSCHE): 192.5 quarter credits*

## About the Program

The department of Chemical and Biological Engineering's chemical engineering curriculum is structured so that students progress through sequences in the fundamental physical sciences, humanities, engineering sciences, and engineering design.

Chemical engineers are concerned primarily with process engineering, the conversion of raw materials into valuable products. The products can include pharmaceuticals, specialized plastics, petrochemicals, materials for biomedical applications, and energy. The processes, which usually start out at a small laboratory scale, must be developed for production at a large chemical plant scale. The large change in scale requires careful engineering to minimize environmental contamination and to ensure public safety.

The Department of Chemical and Biological Engineering is responsible for equipping our graduates with the broad technical knowledge and teamwork skills required for them to make substantial contributions to society.

## Sample Senior Design Projects

A special feature of the major is senior design. A student — or group of students — works with a faculty advisor to develop a significant design project. Some recent examples include:

- Design of a process to make petrochemical intermediates
- Plastics recycling design
- Process design for antibiotic products

## Program Educational Objectives

The chemical engineering major has four goals for its students:

- Our graduates will succeed in careers requiring strong skills in engineering, science, communication, and teamwork.
- Our graduates will continue to upgrade their technological skills through life-long learning involving self- or group-study.
- Our graduates will conduct their work with an understanding of its global impact and ethical consequences.
- Our graduates will contribute to research and development at the forefront of chemical engineering and related fields.

To help students reach these goals, the curriculum is structured so that they progress through sequences in the fundamental physical sciences, humanities, engineering sciences, and design.

The department's student outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

a) an ability to apply knowledge of mathematics, science, and engineering;

b) an ability to design and conduct experiments, as well as to analyze and interpret data;

c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

d) an ability to function on multidisciplinary teams;

e) an ability to identify, formulate, and solve engineering problems;

f) an understanding of professional and ethical responsibility;

g) an ability to communicate effectively;

h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;

i) a recognition of the need for, and an ability to engage in life-long learning;

j) a knowledge of contemporary issues;

k) an ability to use the techniques, skills, and modern engineering tools necessary for chemical engineering practice.

## Additional Information

The Chemical Engineering program is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

For more information about this program, visit Drexel University's Department of Chemical and Biological Engineering (http://www.chemeng.drexel.edu) web page.

# Degree Requirements

**General Education/Liberal Studies Requirements**

| | | |
|---|---|---|
| HIST 285 | Technology in Historical Perspective | 3.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| General Education Requirements [*] | | 15.0 |
| Free Electives | | 3.0 |
| **Foundation Requirements** | | |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |

| | | |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| BIO 141 | Essential Biology | 4.5 |
| CS 121 | Computation Laboratory I | 1.0 |
| CS 122 | Computation Laboratory II | 1.0 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| **Sophomore Engineering Elective Options** | | |
| Select one of the following: | | 3.0 |
| BIO 214 | Principles of Cell Biology | |
| CHEM 230 | Quantitative Analysis | |
| ENVS 260 | Environmental Science and Society | |
| MATH 221 | Discrete Mathematics | |
| PHYS 202 | Fundamentals of Physics IV | |
| **Professional Requirements** | | |
| CHE 201 | Process Material Balances | 3.0 |
| CHE 202 | Process Energy Balances | 3.0 |
| CHE 206 | Basic Chemical Engineering Thermodynamics | 3.0 |
| CHE 301 | Process Thermodynamics | 3.0 |
| CHE 302 | Process Fluid Mechanics | 4.0 |
| CHE 303 | Process Heat Transfer | 3.0 |
| CHE 304 | Process Mass Transfer | 4.0 |
| CHE 305 | Process Separations | 4.0 |
| CHE 307 | Process Modeling I | 4.0 |
| CHE 308 | Process Modeling II | 4.0 |
| CHE 332 [WI] | Chemical Engineering Laboratory | 2.0 |
| CHE 333 [WI] | Chemical Engineering Laboratory II | 2.0 |
| CHE 334 [WI] | Chemical Engineering Laboratory III | 2.0 |
| CHE 335 | Statistics and Design of Experiments | 3.0 |
| CHE 420 | Process Systems Engineering | 3.0 |
| CHE 424 | Chemical Kinetics and Reactor Design | 4.0 |
| CHE 481 | Process Design I | 3.0 |
| CHE 482 [WI] | Process Design II | 3.0 |
| CHE 483 [WI] | Process Design III | 3.0 |
| CHEC 352 | Physical Chemistry and Applications II | 4.0 |
| CHEC 353 | Physical Chemistry and Applications III | 4.0 |
| CHEM 241 | Organic Chemistry I | 4.0 |
| CHEM 242 | Organic Chemistry II | 4.0 |
| CHEM 356 | Physical Chemistry Laboratory | 2.0 |
| Concentration Electives | | 14.0 |
| **Total Credits** | | **192.5** |

[*]     General Education Requirements.

Graduate-Level Electives

| Course | Title | Credits |
| --- | --- | --- |
| CHE 502 | Mathematical Methods in Chemical Engineering | 3.0 |
| CHE 513 | Chemical Engineering Thermodynamics | 3.0 |
| CHE 525 | Transport Phenomena I | 3.0 |
| CHE 543 | Kinetics & Catalysis I | 3.0 |
| CHE 554 | Process Systems Engineering | 3.0 |
| CHE 562 | Bioreactor Engineering | 3.0 |
| CHE 564 | Unit Operations in Bioprocess Systems | 3.0 |
| CHE 614 | Chemical Engineering Thermodynamics II | 3.0 |

# Sample Plan of Study

### 5 YR UG Co-op Concentration

| Term 1 | | Credits |
| --- | --- | --- |
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| CS 121 | Computation Laboratory I | 1.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **15.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| CS 122 | Computation Laboratory II | 1.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 4** | | |
| CHE 201 | Process Material Balances | 3.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |

| Term 5 | | |
| --- | --- | --- |
| CHE 202 | Process Energy Balances | 3.0 |
| CHE 206 | Basic Chemical Engineering Thermodynamics | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| Sophomore Engineering Elective* | | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 6** | | |
| CHE 301 | Process Thermodynamics | 3.0 |
| CHE 307 | Process Modeling I | 4.0 |
| CHEM 241 | Organic Chemistry I | 4.0 |
| CHEM 356 | Physical Chemistry Laboratory | 2.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 7** | | |
| CHE 302 | Process Fluid Mechanics | 4.0 |
| CHE 332 [WI] | Chemical Engineering Laboratory | 2.0 |
| CHE 335 | Statistics and Design of Experiments | 3.0 |
| CHEM 242 | Organic Chemistry II | 4.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 8** | | |
| CHE 303 | Process Heat Transfer | 3.0 |
| CHE 305 | Process Separations | 4.0 |
| CHE 333 [WI] | Chemical Engineering Laboratory II | 2.0 |
| CHEC 352 | Physical Chemistry and Applications II | 4.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 9** | | |
| CHE 304 | Process Mass Transfer | 4.0 |
| CHE 334 [WI] | Chemical Engineering Laboratory III | 2.0 |
| CHE 308 | Process Modeling II | 4.0 |
| CHEC 353 | Physical Chemistry and Applications III | 4.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **17.0** |
| **Term 10** | | |
| CHE 420 | Process Systems Engineering | 3.0 |
| CHE 424 | Chemical Kinetics and Reactor Design | 4.0 |
| CHE 481 | Process Design I | 3.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **13.0** |
| **Term 11** | | |
| CHE 482 [WI] | Process Design II | 3.0 |
| Free Elective | | 3.0 |
| CHE Concentration Electives | | 7.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 12** | | |
| CHE 483 [WI] | Process Design III | 3.0 |
| CHE Concentration Electives | | 7.0 |

| | |
|---|---|
| General Education Elective[*] | 3.0 |
| **Term Credits** | **13.0** |

**Total Credit: 192.5**

[*]    See degree requirements.

# Co-op/Career Opportunities

Chemical engineers tend to work for large corporations with such job assignments as process engineering, design engineering, plant operation, research and development, sales, and management. They also work for federal and state government agencies on projects related to environmental problems, defense, energy, and health-related research.

Some major employers of Drexel's chemical engineering graduates are DuPont, Merck, BASF, ExxonMobil, Rohm & Haas, and Air Products. A number of graduates go on to pursue master's and/or doctoral degrees. Graduate schools that Drexel's chemical engineers have attended include the University of California at Berkeley and Massachusetts Institute of Technology, among others.

## Co-Op Experiences

Drexel is located in downtown Philadelphia with easy access to major pharmaceutical, chemical, and petroleum companies. When students complete their co-op jobs, they are asked to write an overview of their experiences. These brief quotes are taken from some recent student reports:

*Research assistant, chemicals manufacturer*: "Conducted research in a developmental polyamide process. Aspects included scale-up from bench-scale to batch demonstration, installation and calibration of on-line composition sensors, off-line analytical techniques to assess product quality, and interfacing with plant sites to define and standardize a critical quality lab procedure. Documented results in technical memos and in a plant presentation . . .I had a lot of freedom and responsibility. It was great interacting with other researchers and technicians. Everyone was so helpful. "

*Co-op engineer, chemicals manufacturer*: "Created material safety data sheets, which involved chemical composition, hazard communication, occupational safety and health, emergency response, and regulatory issues for numerous products and wastes. Handled domestic and international regulatory reviews. Determined hazardous waste reporting requirements, handling and disposal procedures. Evaluated toxicological and ecological data for assessment of hazard ratings. Provided input on product safety technical reports. "

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

## Facilities

The Department of Chemical and Biological Engineering occupies the 2nd, 3rd, and 4th floors of the Center for Automation Technology. Approximately 35,000 square feet (gross) are available for the department.

Two thousand square feet of laboratory facilities are designated for the pre-junior and junior year laboratory courses. Experiments in these laboratory courses (CHE 332 [WI] , CHE 333 [WI] , CHE 334 [WI] ) focus on applying concepts in thermodynamics, fluid mechanics, heat and mass transfer, separations, and reaction engineering. Laboratory courses are run with class sizes of 18 or less.

The department also has two computer laboratories. The senior design laboratory features nine booths designed for team projects. Each booth contains a work station loaded with the latest process simulation software produced by Aspen, Simulation Sciences, and HYSYS. Seniors use the room heavily during their capstone design experience (CHE 481, CHE 482 [WI] , CHE 483 [WI] ), although pre-junior courses in separations and transport also include projects requiring use of the process simulation software. A second computer lab contains over 30 individual work stations with general and engineering-specific software.

Many undergraduate students participate in research projects in faculty laboratories as part of independent study coursework or BS/MS thesis work. Chemical engineering faculty are engaged in a wide range of research activities in areas including energy and the environment, polymer science and engineering, biological engineering, and multiscale modeling and process systems engineering. Further details can be found at http://www.chemeng.drexel.edu/research .

# Dual/Accelerated Degree

## Accelerated Program

The Accelerated Program of the College of Engineering provides opportunities for highly-talented and strongly-motivated students to progress toward their educational goals essentially at their own pace. Through advanced placement, credit by examination, flexibility of scheduling, and independent study, the program makes it possible to complete the undergraduate curriculum and initiate graduate study in less than the five years required by the standard curriculum.

## Bachelor's/Master's Dual Degree Program

Drexel offers a combined MS/BS degree program for our top engineering students who want to obtain both degrees in the same time period as most students obtain a Bachelor's degree. In chemical engineering, the course sequence for MS/BS students involves additional graduate courses and electives.

# Chemical and Biological Engineering Faculty

Cameron F. Abrams, PhD *(University of California, Berkeley)*. Professor. Molecular simulations in biophysics and materials; receptors for insulin and growth factors; and HIV-1 envelope structure and function.

Nicholas J. Alvarez, PhD *(Carnegie Mellon University)*. Assistant Professor. Photonic Crystal Defect Chromatography; Extensional rheology of polymer/polymer composites; Surfactant/polymer transport to fluid and solid interfaces; Aqueous lubrication; Interfacial Instabilities.

Jason B. Baxter, PhD *(University of California, Santa Barbara)*. Associate Professor. Solar cells, semiconductor nanomaterials, ultrafast spectroscopy.

Richard A. Cairncross, PhD *(University of Minnesota)*. Associate Professor. Effects of microstructure on transport and properties of polymers; moisture transport and degradation on biodegradation on biodegradable polymers; production of biofuel.

Nily R. Dan, PhD *(University of Minnesota)*. Associate Professor. Design of synthetic gene and drug carriers; design of polymeric drug carriers;

metal cluster formation in polymeric matrices; colloidal absorption in patterned surfaces.

Aaron T. Fafarman, PhD *(Stanford University)*. Assistant Professor. Colloidal nanocrystals; solution-processed solar cells; electrical and spectroscopic characterization of nanomaterials.

Vibha Kalra, PhD *(Cornell University)*. Assistant Professor. Electrodes for Energy Storage and Conversion; Supercapacitors, Li-S Batteries, Fuel Cells, Flow Batteries; Electrospinning of Nanofibers; Molecular Dynamics Simulations

Kenneth K.S. Lau, PhD *(Massachusetts Institute of Technology)*. Associate Professor. Surface science; nanotechnology; polymer thin films and coatings; chemical vapor deposition.

Raj Mutharasan, PhD *(Drexel University) Frank A. Fletcher Professor*. Biochemical engineering; cellular metabolism in bioreactors; biosensors.

Giuseppe R. Palmese, PhD *(University of Delaware) Department Head, Chemical and Biological Engineering*. Professor. Reacting polymer systems; nanostructured polymers; radiation processing of materials; composites and interfaces.

George F. Rowell, PhD *(University of Pennsylvania) Undergraduate Laboratory Supervisor*. Associate Teaching Professor. Undergraduate laboratory supervising.

Joshua D. Snyder, PhD *(Johns Hopkins University)*. Assistant Professor. Electrocatalysis (Energy Conversion/Storage) Heterogeneous Catalysis; Corrosion (Dealloying, Nanoporous Metals); Interfacial Electrochemical Phenomena in Nanostructured Materials; Colloidal Synthesis

Masoud Soroush, PhD *(University of Michigan)*. Professor. Modeling, control and optimization of solar cell, fuel cell and power storage systems Probabilistic risk assessment and mitigation; Polymerization reaction engineering; Process systems engineering; Polymer membranes; Multiscale mathematical modeling

John H. Speidel, BSHE, MCHE *(University of Delaware; Illinois Institute of Technology)*. Teaching Professor.

Maureen H. Tang, PhD *(University of California, Berkeley)*. Electrochemistry (batteries, fuel cells, electrolyzers); Catalysis and surface science.

Stephen P. Wrenn, PhD *(University of Delaware)*. Associate Professor. Biomedical engineering; biological colloids; membrane phase behavior and cholesterol transport.

# Emeritus Faculty

Charles B. Weinberger, PhD *(University of Michigan)*. Professor Emeritus. Suspension rheology; fluid mechanics of multi-phase systems.

# Courses

### CHE 201 Process Material Balances 3.0 Credits
Covers elementary principles of chemical engineering, use of stoichiometry and material balances to analyze chemical processing operations, and application to specific commercial processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** TDEC 121 [Min Grade: D] or CHEM 102 [Min Grade: D] or CHEM 162 [Min Grade: D]

### CHE 202 Process Energy Balances 3.0 Credits
Covers use of first law to analyze chemical processing operations, energy balances for non-reactive and reactive processes, chemical reaction equilibria, and application to specific commercial processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 201 [Min Grade: D]
**Corequisite:** CHE 206

### CHE 206 Basic Chemical Engineering Thermodynamics 3.0 Credits
First and second laws of thermodynamics, use of state functions to solve macroscopic problems, distinction between solving ideal gas and real fluid problems. An introduction to phase equilibrium and mixtures. Concepts of fugacity and activity as measures of nonideality.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CHE.
**Prerequisites:** CHE 201 [Min Grade: D] and MATH 200 [Min Grade: D]
**Corequisite:** CHE 202

### CHE 250 Chemical Engineering Process Principles 3.0 Credits
Applies heuristics to the art process synthesis and analysis. Identify key parameters in reaction and separation in processes. Examine common and divergent elements of major chemical processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 201 [Min Grade: D]
**Corequisite:** CHE 202

### CHE 301 Process Thermodynamics 3.0 Credits
Covers mixture thermodynamics, multi-component, multi-phase equilibrium calculations, and chemical equilibrium calculations for real fluids.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ENGR 210 [Min Grade: D] or CHE 206 [Min Grade: D]) and CHE 201 [Min Grade: D] and CHE 202 [Min Grade: D]

### CHE 302 Process Fluid Mechanics 4.0 Credits
Within the context of processes previously introduced, introduces fluid flow of gases, liquids, and particulates; momentum transport; skin friction; drag; piping networks; filtration; and fluidization.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** TDEC 221 [Min Grade: D] or MATH 210 [Min Grade: D] or MATH 262 [Min Grade: D] or ENGR 232 [Min Grade: D]

**CHE 303 Process Heat Transfer 3.0 Credits**
Covers, within the context of processes previously introduced, transfer of energy by conduction, convection, and radiation; continuation of transport phenomena; design of heat exchangers; and applications in industry and in nature.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 302 [Min Grade: D] and CHE 201 [Min Grade: D] and CHE 202 [Min Grade: D]

**CHE 304 Process Mass Transfer 4.0 Credits**
Covers, within the context of processes previously introduced, mass transfer in mixtures; diffusion, convection, and continuation of transport phenomena; component separation in continuous contractors; gas absorption; liquid-liquid extraction; and simultaneous heat and mass transfer.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 303 [Min Grade: D] and CHE 201 [Min Grade: D] and CHE 202 [Min Grade: D]

**CHE 305 Process Separations 4.0 Credits**
Covers, within the context of processes previously introduced, the application of thermodynamics and equilibrium stage concepts to the unit operations involved in chemical processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 301 [Min Grade: D] and CHE 201 [Min Grade: D] and CHE 202 [Min Grade: D]

**CHE 307 Process Modeling I 4.0 Credits**
Models simple chemical and biochemical processes such as heating, cooling, and separation systems. Covers analytical and numerical methods for solving algebraic and ordinary differential equations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 201 [Min Grade: D] and CHE 202 [Min Grade: D]

**CHE 308 Process Modeling II 4.0 Credits**
Covers mathematical modeling of chemical and biochemical processes such as chemical and biochemical reactors and heating and cooling systems, analytical methods for solving algebraic and ordinary-differential equations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 305 [Min Grade: D] and CHE 307 [Min Grade: D]
**Corequisite**: CHE 304

**CHE 310 Transport Phenomena 4.0 Credits**
Non-chemical engineering students only. Examines mass, momentum, and energy transport in processes applied to electrical and materials engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is CHE or classification is Freshman
**Prerequisites:** TDEC 202 [Min Grade: D] or MEM 210 [Min Grade: D] or ENGR 210 [Min Grade: D]

**CHE 311 Fluid Flow and Transport 3.0 Credits**
Non-chemical engineering students only. Examines fluid flow and heat and mass transfer in processes associated with civil, environmental, and materials engineering disciplines.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is CHE or classification is Freshman
**Prerequisites:** TDEC 202 [Min Grade: D] or MEM 210 [Min Grade: D]

**CHE 332 [WI] Chemical Engineering Laboratory 2.0 Credits**
Requires students to perform experiments illustrating the fundamentals of chemical engineering process analysis. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 302 [Min Grade: D] (Can be taken Concurrently)CHE 301 [Min Grade: D]

**CHE 333 [WI] Chemical Engineering Laboratory II 2.0 Credits**
Offers laboratory experiments illustrating the fundamentals of chemical engineering process analysis. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 303 [Min Grade: D] (Can be taken Concurrently)

**CHE 334 [WI] Chemical Engineering Laboratory III 2.0 Credits**
Offers laboratory experiments illustrating the fundamentals of chemical engineering process analysis. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 304 [Min Grade: D] (Can be taken Concurrently)CHE 303 [Min Grade: D]

**CHE 335 Statistics and Design of Experiments 3.0 Credits**
Provides statistical treatment of engineering data, including application of statistical techniques to process model formulation, statistical designs of engineering experiments, and analysis of probabilistic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATH 210 [Min Grade: D] or MATH 262 [Min Grade: D] or ENGR 232 [Min Grade: D]

**CHE 360 BioProcess Principles 3.0 Credits**
This course is concerned with manufacturing processes involving biological substances. Students gain detailed knowledge in the design and operation of bioreactors and learn about biomolecules produces therein. Specific topics covered include: Cells (type, organization, function and growth); Protein and Enzymes; Bioreactor Process Principles (active vs. passive immobilization, fermentation and scale-up, recovery and purification); Special consideration for animal and plant cell cultures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 250 [Min Grade: D] and BIO 214 [Min Grade: D] and BIO 215 [Min Grade: D]

**CHE 399 Special Problems in Chemical Engineering 1.0-12.0 Credit**
Covers individual research problems of a non-routine nature. Requires report.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CHE 400 Special Topics in Chemical Engineering 3.0 Credits**
Special courses offered in response to particular student and/or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CHE 420 Process Systems Engineering 3.0 Credits**
Covers the application of automatic control theory to chemical processes within the context of processes previously introduced.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 201 [Min Grade: D] and CHE 202 [Min Grade: D] and CHE 303 [Min Grade: D]

**CHE 424 Chemical Kinetics and Reactor Design 4.0 Credits**
Covers isothermal and non-isothermal reactor design, series and parallel reactions, and heterogeneous catalysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CHE 304 [Min Grade: D] and CHE 201 [Min Grade: D] and CHE 202 [Min Grade: D]

**CHE 430 Introduction to Sustainable Engineering 3.0 Credits**
This course introduces students to sustainability in an engineering context. Sustainable engineering encompasses the relationships between technology, society, the environment, and economic prosperity. A variety of systematic approaches will be used for multivariable design and analysis of the sustainability of engineering systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**CHE 431 Fundamentals of Solar Cells 3.0 Credits**
This course focuses on the fundamentals of solar cells. It will cover semiconductor materials, basic semiconductor physics, optical and electronic phenomena, and case studies of crystalline silicon, thin film, and nanostructured photovoltaics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATH 200 [Min Grade: D] and CHEM 102 [Min Grade: D] and PHYS 201 [Min Grade: D]

**CHE 450 Chemical Process Industries 3.0 Credits**
Chemical engineering juniors and seniors. Combines process heuristics and design strategies with case studies of the industrial manufacture of a variety of materials, including petrochemicals, polymers, and ammonia. Discusses operational and design problems as well as the interactions of process principles.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Pre-Junior or Sophomore

**CHE 451 Safety Engineering 3.0 Credits**
Covers selected topics such as safeguarding systems, fault trees, risk analysis, explosions, fires, and building safety.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** CHE 482 [Min Grade: D]

**CHE 452 Polymer Process Technology 3.0 Credits**
Covers chemistry of chain and stepwise polymerization, industrial reactor systems, polymer melt rheology, processing of thermoplastic resins, and plastics properties.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**CHE 460 Biochemical Engineering 3.0 Credits**
Introduces underlying biological and engineering principles in an integrate fashion for biopharmaceutical production systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is BME or major is CHE and classification is Junior or Senior.

**CHE 461 Principles of Colloid Science 3.0 Credits**
This course focuses on fundamental principles of colloid science from a biological perspective. It will cover surface active agents, thermodynamics of self-assembly of surfactants, surface chemistry and physics of monolayers and bilayers, microstructures and phase behavior, specific biological colloids (micelles, liposomes, and lipoproteins), and colloidal stability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** BIO 141 [Min Grade: C] or BIO 122 [Min Grade: C]

**CHE 481 Process Design I 3.0 Credits**
Within the context of previously introduced processes, covers economic feasibility of projects and optimization of equipment and production in the design of process plants.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CHE and classification is Senior.
**Prerequisites:** CHE 304 [Min Grade: D] and CHE 308 [Min Grade: D]
**Corequisite**: CHE 424

**CHE 482 [WI] Process Design II 3.0 Credits**
Within the context of previously introduced processes, covers execution of feasibility study and preliminary design of process plants. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** CHE 481 [Min Grade: D]

**CHE 483 [WI] Process Design III 3.0 Credits**
Within the context of previously introduced processes, covers completion of feasibility study and preliminary design of process plants. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** CHE 482 [Min Grade: D]

# Civil Engineering

*Bachelor of Science in Civil Engineering (BSCIV): 190.5 quarter credits*

## About the Program

The civil engineering major prepares students in the fundamental principles necessary to practice this profession in any of its branches, including construction management, water resources, structural, transportation, environmental, geotechnical, and public facilities engineering.

Civil engineers are active in the planning, design, construction, research and development, operation, maintenance, and rehabilitation of large engineering systems. A particular focus is the reconstruction of the nation's infrastructure through solutions that minimize the disruption of social and natural environments.

Civil engineering graduates are grounded in the fundamental principles necessary for the practice of this profession in any of its modern branches, including construction management, water resources engineering, structural engineering, geotechnical engineering, transportation engineering, and environmental engineering.

Seven of the required courses in the discipline include integral laboratories or field projects for both educational illustration and professional practice exposure.

Careful selection of the electives specified in the curriculum can lead to a wide variety of career objectives. For instance, students with an interest in water resources engineering may elect advanced courses in hydrology, ecology, and chemistry; select senior professional electives in the geotechnical and water resources areas; and choose appropriate

topics for senior design and senior seminar. Seniors, with the approval of the department head, can elect certain graduate courses.

A special feature of the major is senior design. A group of students works with a faculty advisor to develop a significant design project selected by the group. All civil engineering students participate in a design project.

## Mission Statement

The civil and architectural engineering faculty are responsible for delivering an outstanding curriculum that equips our graduates with the broad technical knowledge, design proficiency, professionalism, and communications skills required for them to make substantial contributions to society and to enjoy rewarding careers.

## Program Educational Objectives

Civil engineering graduates will become professionals who analyze, design, construct, manage or operate physical infrastructure and systems, or advance knowledge of the field.

## Student Outcomes

The department's student outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

a) an ability to apply knowledge of mathematics, science, and engineering;

b) an ability to design and conduct experiments, as well as to analyze and interpret data;

c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

d) an ability to function on multidisciplinary teams;

e) an ability to identify, formulate, and solve engineering problems;

f) an understanding of professional and ethical responsibility;

g) an ability to communicate effectively;

h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;

i) a recognition of the need for, and an ability to engage in life-long learning;

j) a knowledge of contemporary issues;

k) an ability to use the techniques, skills, and modern engineering tools necessary for civil engineering practice.

## Additional Information

The Civil Engineering program is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

For more information about this major, contact the Department of Civil, Architectural and Environmental Engineering (http://www.cae.drexel.edu) .

# Degree Requirements

**General Education/Liberal Studies Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| General Education Requirements * | | 21.0 |
| Free Electives | | 6.0 |

**Foundation Requirements**

| | | |
|---|---|---|
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| BIO 141 | Essential Biology | 4.5 |
| CS 121 | Computation Laboratory I | 1.0 |
| CS 122 | Computation Laboratory II | 1.0 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| ENGR 361 | Statistical Analysis of Engineering Systems | 3.0 |

**Major Requirements**

| | | |
|---|---|---|
| CAE 491 [WI] | Senior Design Project I | 3.0 |
| CAE 492 [WI] | Senior Design Project II | 3.0 |
| CAE 493 [WI] | Senior Design Project III | 3.0 |
| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| CAEE 211 | Measurements in Civil, Architectural and Environmental Engineering II | 4.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| CIVE 250 | Construction Materials | 4.0 |
| CIVE 310 | Soil Mechanics I | 4.0 |
| CIVE 320 | Introduction to Fluid Flow | 3.0 |
| CIVE 330 | Hydraulics | 4.0 |
| CIVE 375 | Structural Material Behavior | 3.0 |
| CIVE 410 | Foundation Engineering | 3.0 |
| CIVE 430 | Hydrology | 3.0 |

| | | |
|---|---|---|
| CIVE 477 [WI] | Seminar | 2.0 |
| CIVE 478 [WI] | Seminar | 1.0 |
| ENVE 300 | Introduction to Environmental Engineering | 3.0 |
| MEM 202 | Statics | 3.0 |
| MEM 230 | Mechanics of Materials I | 4.0 |
| Senior Professional Electives ** | | 18.0 |
| Select one of the following: | | 3.0 |
| CIVE 370 | Introduction to Structural Analysis | |
| CIVE 300 | Structural Analysis I | |
| Based on whether or not students are pursuing a structural or non-structural concentration, students select one of the following options:er: | | 4.0 |
| CIVE 301 | Structural Design I | |
| CIVE 371 & CIVE 372 | Introduction to Structural Design and Structural Laboratory | |
| **Total Credits** | | **190.5** |

\*    General Education Requirements.

\**   A sequence of three courses in a major area of study is required, with a total of six 3-credit professional electives.

# Sample Plan of Study

## BS Civil Engineering

**5 YR UG Co-op Concentration**

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| CS 121 | Computation Laboratory I | 1.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **15.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| CS 122 | Computation Laboratory II | 1.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |

| | | |
|---|---|---|
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 4** | | |
| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 5** | | |
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| MEM 202 | Statics | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 6** | | |
| CIVE 320 | Introduction to Fluid Flow | 3.0 |
| ENGR 361 | Statistical Analysis of Engineering Systems | 3.0 |
| ENVE 300 | Introduction to Environmental Engineering | 3.0 |
| MEM 230 | Mechanics of Materials I | 4.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 7** | | |
| CAEE 211 | Measurements in Civil, Architectural and Environmental Engineering II | 4.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| CIVE 250 | Construction Materials | 4.0 |
| CIVE 330 | Hydraulics | 4.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **18.0** |
| **Term 8** | | |
| CIVE 310 | Soil Mechanics I | 4.0 |
| CIVE 430 | Hydrology | 3.0 |
| CIVE 370 or 300 | Introduction to Structural Analysis Structural Analysis I | 3.0 |
| General Education Elective* | | 3.0 |
| Free Elective | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 9** | | |
| CIVE 375 | Structural Material Behavior | 3.0 |
| CIVE 410 | Foundation Engineering | 3.0 |
| General Education Electives* | | 3.0 |
| CIVE 301 | Structural Design I (Non-structural concentration takes CIVE 371 & CIVE 372) | 4.0 |
| | **Term Credits** | **13.0** |
| **Term 10** | | |
| CAE 491 [WI] | Senior Design Project I | 3.0 |

| | | |
|---|---|---|
| CIVE 477 [WI] | Seminar | 2.0 |
| Professional Electives* | | 6.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 11** | | |
| CAE 492 [WI] | Senior Design Project II | 3.0 |
| CIVE 478 [WI] | Seminar | 1.0 |
| Professional Electives* | | 6.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **13.0** |
| **Term 12** | | |
| CAE 493 [WI] | Senior Design Project III | 3.0 |
| Free Elective | | 3.0 |
| Professional Electives* | | 6.0 |
| General Education Elective* | | 3.0 |
| | **Term Credits** | **15.0** |

**Total Credit: 190.5**

* See degree requirements.

## Co-op/Career Opportunities

When students complete their co-op jobs, they are asked to write an overview of
their experiences. These brief quotes are taken from some recent student reports:

*Engineering construction inspector, state department of transportation*: Supervised daily activities involved in the roadway construction of the [interstate] bypass. Recorded daily visual inspection reports for soil sub-base and materials placed on site. Aided senior roadway engineers in approving grade prior to asphalt placement. Used various instruments to check temperature and depths for asphalt placement. Took part in on-site discussions with contractor to clear up any daily construction problems that would hinder quality of construction. ”

*Construction inspector, municipal department of public property*: "Inspected work performed by private contractors on city public works construction and rehabilitation projects for adherence to contract plans and specifications. Projects included health centers, police and fire stations, libraries, city hall, transit concourses, and prisons. Responsible for daily inspection reports and overall coordination for each respective project. Also responsible for reviewing bills and writing contract modifications and amendments. . .the variety of work was excellent. ”

*Environmental co-op, chemicals manufacturer*: "Compiled data and wrote monthly regulatory reports, in charge of hazardous waste management and small projects as needed. . . . I had my own responsibilities that had an impact on the entire company. Employer was really interested in my opinion and gave me a chance to demonstrate my abilities, but also knew when to step in. Everybody was willing to answer any questions I may have had. ”

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on co-op and post-graduate opportunities.

# Dual/Accelerated Degree

## Accelerated program

The Accelerated Program of the College of Engineering provides opportunities for highly talented and strongly motivated students to progress toward their educational goals essentially at their own pace. Primarily through advanced placement, credit by examination, flexibility of scheduling, and independent study, the program makes it possible to complete the undergraduate curriculum and initiate graduate study in less than the five years required by the standard curriculum.

## Dual Degree Bachelor's Programs

A student completing the Bachelor of Science degree program in architectural engineering may complete additional courses (specified by the department) to earn the Bachelor of Science degree in civil engineering. (The reverse is difficult because of prerequisites in the sequence of architectural studio design courses, which begins in the sophomore year. )

Civil Engineering students can also complete a dual degree with the Bachelor of Science in Environmental Engineering.

## Bachelor's/Master's Dual Degree Program

Exceptional students can also pursue a master of science degree in the same period as the bachelor of science.

For more information about this program, visit the Department's BS / MS Dual Degree Program (http://www.drexel.edu/cae/academics/ environmental-engineering/Accelerated%20and%20Dual%20Degree %20Programs%20CAEE) web page.

# Facilities

The Department is well equipped with state-of-the-art facilities:

- The department computer labs are in operation: a computer-assisted design (CAD) and computerized instructional lab; and a graduate-level lab (advanced undergraduates can become involved in graduate-level work).
- External labs are used for surveying, building diagnostics, and surface and ground-water measurements.
- A $4.5-million instruction and research lab renovation was funded by the National Science Foundation, alumni, and corporations.

# Civil, Architectural and Environmental Engineering Faculty

Abieyuwa Aghayere, PhD, P.Eng *(University of Alberta)*. Professor. Structural design - concrete, steel and wood; Structural failure analysis and retrofitting of existing structures; New structural systems and materials.

Emin A. Aktan, PhD *(University of Illinois at Urbana-Champaign) John Roebling Professor of Infrastructure Studies*. Professor. Structural engineering; infrastructure; evaluation; intelligent systems.

Ivan Bartoli, PhD *(University of California, San Diego)*. Assistant Professor. Non-destructive evaluation and structural health monitoring; dynamic identification, stress wave propagation modeling.

Robert Brehm, PhD, PE, FASCE *(Drexel University)*. Associate Teaching Professor. International infrastructure delivery; response to natural catastrophes; risk assessment and mitigation strategies; project management techniques.

S.C. Jonathan Cheng, PhD *(West Virginia University)*. Associate Professor. Soil mechanics; geosynthetics; probabilistic design; landfill containments.

Peter DeCarlo, PhD *(University of Colorado)*. Assistant Professor. Outdoor air quality, particulate matter size and composition instrumentation and measurements, source apportionment of ambient particulate matter, climate impacts of particulate matter.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute)*. Associate Professor. Soil mechanics; geoenvironmental; ground improvement; sustainability.

Patrick Gurian, PhD *(Carnegie-Mellon University)*. Associate Professor. Risk analysis of environmental and infrastructure systems, novel adsorbent materials, environmental standard setting, Bayesian statistical modeling, community outreach and environmental health.

Charles N. Haas, PhD *(University of Illinois-Urbana) L. D. Betz Professor and Department Head, Civil, Architectural and Environmental Engineering*. Professor. Control of human exposures to and risk assessment of pathogenic organisms; water and waste treatment; homeland security.

Ahmad Hamid, PhD *(McMaster University)*. Professor. Engineered masonry; building; cladding; prestressed concrete.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Polymeric and cementitioius materials; geosynthetic reliability and durability.

Joseph B. Hughes, PhD *(University of Iowa) Dean of the College of Engineering*. Distinguished Professor. Biological processes and applications of nanotechnology in environmental systems.

Roger Marino, PhD *(Drexel University)*. Associate Teaching Professor. Fluid Mechanics, Water Resources, Engineering Education, Land Development

Joseph P. Martin, PhD *(Colorado State University)*. Professor. Geoenvironmental engineering; urban environmental hydrology; transportation.

James E. Mitchell, MArch *(University of Pennsylvania)*. Associate Professor. Architectural engineering design; building systems.

Franco Montalto, PhD *(Cornell University)*. Associate Professor. Effects of built infrastructure on societal water needs, ecohydrologic patterns and processes, ecological restoration, green design, water interventions.

Franklin Moon, PhD *(Georgia Institute of Technology)*. Associate Professor. Full-scale structural testing, structural dynamics, evaluation and rehabilitation of existing structures.

Joseph V. Mullin, PhD *(Pennsylvania State University)*. Senior Lecturer. Structural material behavior, engineering economy and design.

Mira S. Olson, PhD *(University of Virginia)*. Associate Professor. Groundwater; environmental fluid mechanics; hydrology.

Anu Pradhan, PhD *(Carnegie Mellon University)*. Assistant Professor. Infrastructure management, construction engineering, transportation

engineering, sensing system, geographic information system, statistical machine learning.

Yared Shifferaw, PhD *(Johns Hopkins University)*. Assistant Professor. Computational and experimental mechanics, structural stability, optimization, health monitoring and hazard mitigation, sustainable structures, emerging materials, thin-walled structures and metallic structures.

Kurt Sjoblom, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Laboratory testing of geomaterials, geotechnical engineering, foundation engineering.

Sabrina Spatari, PhD *(University of Toronto)*. Assistant Professor. Research in industrial ecology; development and application of life cycle assessment (LCA) and material flow analysis (MFA) methods for guiding engineering and policy decisions; specific interest in biomass and bioenergy, biofuels, and urban infrastructure.

Michael Waring, PhD *(University of Texas-Austin)*. Assistant Professor. Indoor air quality and building sustainability; indoor particulate matter fate and transport; indoor chemistry and particle formation; secondary impacts of control technologies and strategies.

Jin Wen, PhD *(University of Iowa)*. Associate Professor. Architectural engineering, building control systems, indoor air quality.

Aspasia Zerva, PhD *(University of Illinois)*. Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

## Interdepartmental Faculty

Eugenia Ellis, PhD *(Virginia Polytechnic State University)*. Associate Professor. Registered architect; interior design, extended-care facilities design, research on spatial visualization, perception and imagination.

Bakhtier Farouk, PhD *(University of Delaware) Billings Professor of Mechanical Engineering*. Professor. Heat transfer; combustion; numerical methods; turbulence modeling; materials processing.

Tony H. Grubesic, PhD *(The Ohio State University) Director of the Center for Spatial Analytics and Geocomputation (CSAG)*. Professor. Geographic information science, spatial analysis, development, telecommunication policy, location modeling.

## Emeritus Faculty

Harry G. Harris, PhD *(Cornell University)*. Professor Emeritus. Structural models, dynamics of structures, plates and shells, industrialized building construction.

Robert M. Koerner, PhD *(Duke University)*. Harry Bownam Professor Emeritus. Geosynthetic engineering; soil mechanics; water resources.

Richard Weggel, PhD *(University of Illinois) Samuel S. Baxter Professor Emeritus; Civil and Environmental Engineering*. Professor Emeritus. Coastal engineering; hydraulics engineering; hydrology.

Richard Woodring, PhD *(University of Illinois) Dean of Engineering Emeritus*. Professor Emeritus. Structural engineering, reinforced concrete.

## Civil Architectural Engineering Courses

**CAE 491 [WI] Senior Design Project I 3.0 Credits**
Introduces the design process, including information retrieval, problem definition, proposal writing, patents, and design notebooks. Includes presentations on problem areas by experts from industry, government, and education. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** CIVE 330 [Min Grade: D] and (CIVE 301 [Min Grade: D] or CIVE 371 [Min Grade: D]) and (AE 391 [Min Grade: D] or CIVE 310 [Min Grade: D])

**CAE 492 [WI] Senior Design Project II 3.0 Credits**
Continues CAE 491. Requires written and oral progress reports. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CAE 491 [Min Grade: D]

**CAE 493 [WI] Senior Design Project III 3.0 Credits**
Continues CAE 492. Requires written and oral final reports, including oral presentations by each design team at a formal Design Conference open to the public and conducted in the style of a professional conference. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CAE 492 [Min Grade: D]

## Civil Engineering Courses

**CIVE 240 [WI] Engineering Economic Analysis 3.0 Credits**
Techniques for project decisions: benefit cost and present worth analysis, rate of return, capital budgeting, risk analysis, environmental impact, and depreciation. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CIVE 250 Construction Materials 4.0 Credits**
Construction Materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 202 [Min Grade: D]

**CIVE 251 Engineering Surveying 3.0 Credits**
Covers the theory and use of surveying instruments and principles of plane and topographic surveying. Introduces computer programs for surveying computations and plotting.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CIVE 261 Materials and Structural Behavior I 3.0 Credits**
Introduces the basic materials of construction (timber, masonry, steel, and concrete). Covers their behavior as ingredients of the structural system. Required for architecture and construction management students. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is AE or major is CIVE or classification is Freshman
**Prerequisites:** PHYS 182 [Min Grade: D]

**CIVE 262 Materials and Structural Behavior II 3.0 Credits**
Continues CIVE 261. Required for architecture and construction management students. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is AE or major is CIVE or classification is Freshman
**Prerequisites:** CIVE 261 [Min Grade: D]

**CIVE 263 Materials and Structural Behavior III 3.0 Credits**
Continues CIVE 262. Required for architecture and construction management students. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is AE or major is CIVE or classification is Freshman
**Prerequisites:** CIVE 262 [Min Grade: D]

**CIVE 300 Theory of Structures I 3.0 Credits**
Covers analysis of statically determinate structures: equilibrium, compatibility, boundary conditions, complimentary and virtual work, energy theorems, reactions, member forces and deflection of trusses, beams and frames, and influence lines.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CIVE 250 [Min Grade: D] and MEM 230 [Min Grade: C]

**CIVE 301 Theory of Structures II 4.0 Credits**
Covers analysis of statically indeterminate structures: force methods for trusses, beams and frames, slope-deflection and equilibrium methods, moment distribution, stiffness matrices of truss and beam elements, and stiffness matrix method of analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CIVE 300 [Min Grade: D]

**CIVE 310 Soil Mechanics I 4.0 Credits**
Gives an overview of types of problems encountered in geotechnical engineering: index, mechanical, hydraulic and environmental properties of soils; earth mass stability, deformation, and groundwater seepage; laboratory measurements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** (EGEO 220 [Min Grade: D] or CAEE 211 [Min Grade: D]) and CIVE 250 [Min Grade: D]

**CIVE 320 Introduction to Fluid Flow 3.0 Credits**
Covers fundamentals of fluid flow, fluid properties, hydrostatic forces, kinematics of flow, the Bernoulli equation, linear momentum, dimensional analysis, Froude and Reynolds similarity and hydraulic models and an introduction to pipe flows and friction.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D]

**CIVE 330 Hydraulics 4.0 Credits**
Covers pipe flow, friction losses, multiple pipe systems, water demand and distribution network design, pumps and pumping systems, air flow in ducts and fans, open channel flows, hydraulic jumps and energy dissipation, gravity pipe networks and the design of storm and sanitary sewer systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 320 [Min Grade: D]

**CIVE 341 Municipal Water Facilities 3.0 Credits**
Covers analysis and design of municipal water supply systems, including collection, transmission and distribution facilities; public health considerations in water supply; and maintenance of water supply infrastructure.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CIVE 330 [Min Grade: D] and CIVE 430 [Min Grade: D]

**CIVE 370 Introduction to Structural Analysis 3.0 Credits**
Covers equilibrium, virtual work, reactions, and member forces in trusses, beams, and frames. Introduces analysis of statically indeterminate structures and the stiffness matrix method of analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 230 [Min Grade: D] and CIVE 250 [Min Grade: D]

**CIVE 371 Introduction to Structural Design 3.0 Credits**
Covers the design process, with topics including structural systems, loads and load path, structural safety, and design methods. Offers introduction to steel, reinforced concrete, wood, and masonry design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CIVE 370 [Min Grade: D]

**CIVE 372 Structural Laboratory 1.0 Credit**
Course use of structural analysis computer programs to construct analytical models of various structural systems. Calculate reactions and deflections of statically determinate and determinate structures and check reliability of results.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Sophomore
**Corequisite**: CIVE 371

**CIVE 375 Structural Material Behavior 3.0 Credits**
Study of deformation, fracture and fatigue of structural materials used in infrastructure. Includes basic failure modes, yielding and plasticity, and fracture mechanics. Emphasis on analytical and predictive methods that designers use to avoid failure. Metals, ceramic and composites are considered, as is time-dependent behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 230 [Min Grade: D] and CIVE 250 [Min Grade: D] and (MATH 201 [Min Grade: D] or MATH 261 [Min Grade: D] or ENGR 231 [Min Grade: D])

**CIVE 380 Special Topics in Civil Engineering 12.0 Credits**
Covers selected topics in civil engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CIVE 399 Independent Study in Civil Engineering 12.0 Credits**
Independent study on a topic selected by the student. Independent study is supervised by a faculty member and guided by a plan of study.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 400 Structural Design I 3.0 Credits**
Covers principles of design of structural members and systems, including loads on structures, structural safety, and structural members and their behavior. Introduces elastic and limit design procedures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** CIVE 301 [Min Grade: D]

**CIVE 401 Structural Design II 3.0 Credits**
Covers principles of design of reinforced concrete structural systems, including beams, slabs, columns, and footings.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CIVE 400 [Min Grade: D]

**CIVE 402 Structural Design III 3.0 Credits**
Covers elastic and plastic design of structural steel members, including beams, columns, tension members, beam columns, and plate girders; design of welded and high-strength bolted connections; and design of steel trusses, bridges, and buildings.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CIVE 401 [Min Grade: D]

**CIVE 410 Foundation Engineering 3.0 Credits**
Covers shear strength, bearing capacity, and lateral earth pressure; design of shallow foundations (footings, mats) and deep foundations (piles, drilled shafts); and excavation and slope stability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 310 [Min Grade: D]

**CIVE 420 Water and Waste Treatment I 3.0 Credits**
Covers water supply chemistry, including corrosion in water distribution systems, microbiology of water and wastes, biodegradation of toxic materials, and growth and metabolism in wastewater treatment processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** CIVE 330 [Min Grade: D] and CIVE 340 [Min Grade: D]

**CIVE 430 Hydrology 3.0 Credits**
Covers the relationship between precipitation and runoff, unit hydrographs, flood routing, and water supply principles and applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CAEE 211 [Min Grade: D]

**CIVE 431 Hydrology-Ground Water 3.0 Credits**
Covers geologic and hydrologic occurrence of groundwater, underground flow, and groundwater supply. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CIVE 330 [Min Grade: D]

**CIVE 432 Water Resources Design 3.0 Credits**
Covers planning and design of basin and developments for requirements of various water use purposes. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CIVE 430 [Min Grade: D]

**CIVE 477 [WI] Seminar 2.0 Credits**
Covers professional development and ethics. Requires preparation of a technical paper. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**CIVE 478 [WI] Seminar 1.0 Credit**
Requires preparation and presentation of a technical paper. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

## Civil, Architectural Environmental Engr Courses

**CAEE 201 Introduction to Infrastructure Engineering 3.0 Credits**
This course presents case studies to introduce the design, construction, operation and maintenance of infrastructure projects. Key engineering elements within civil, architectural and environmental engineering are presented. The concept of an "infrastructure system" along with interrelationships among three disciplines are illustrated using specific case studies which changes annually as various local infrastructure projects move from design through construction. On or two field trips are part of the course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CAEE 210 Measurements in Civil, Architectural and Environmental Engineering I 3.0 Credits**
This course introduces student to various technical specialties within Civil, Architectural and Environmental engineering through hands-on experience of conducting field and laboratory measurements that are typical to three engineering fields. The course emphasizes graphical presentation of data using EXCEL, SKETCHUP and other software. Students collect data from lab or field sites.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CAEE 201 [Min Grade: D]

**CAEE 211 Measurements in Civil, Architectural and Environmental Engineering II 4.0 Credits**
This course is a continuation of CAEE 210. There are two main modules in the course: fundamental geological principles and relationships to engineering properties and fundamental surveying principles and measurements using modern surveying equipment including GPS.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CAEE 210 [Min Grade: D]

# Computer Engineering

*Bachelor of Science in Computer Engineering (BSCE): 192.0 quarter credits*

## About the Program

The major provides a broad focus on digital circuit design, computer hardware and organization, programming and computer software, algorithms, and networks.

Computer engineers design smaller, faster, and more reliable computers and digital systems, embed microprocessors in larger systems (e.g., anti-lock brake systems), work in theoretical issues in computing, use object-oriented programming languages, and design large-scale software systems and computer networks. Computer engineers may work in positions that apply computers in control systems, digital signal processing, telecommunications, and power systems, and may design very large-scale integration (VLSI) integrated circuits and systems.

The computer engineering degree program is designed to provide our students with breadth in engineering, the sciences, mathematics, and the humanities, as well as depth in both software and hardware disciplines appropriate for a computer engineer. It embodies the philosophy and style of the Drexel Engineering Curriculum, and will develop the student's design and analytical skills. In combination with the co-op experience, it opens to the student opportunities in engineering practice, advanced training in engineering or in other professions, and an entry to business and administration.

The computer engineering program's courses in ECE are supplemented with courses from the departments of Mathematics and Computer Science. Students gain the depth of knowledge of computer hardware and software essential for the computer engineer.

## Mission Statement

The ECE Department at Drexel University serves the public and the university community by providing superior career-integrated education in electrical and computer engineering; by conducting research in these fields, to generate new knowledge and technologies; and by promoting among all its constituents professionalism, social responsibility, civic engagement and leadership.

## Program Educational Objectives

The Electrical and Computer Engineering Program Educational Objectives are such that its alumni, in their early years after graduation can:

1. Secure positions and continue as valued, creative, dependable, and proficient employees in a wide variety of fields and industries, in particular as electrical and computer engineers;

2. Succeed in graduate and professional studies, such as engineering, science, law, medicine and business;

3. Pursue professional development through lifelong learning opportunities for a successful and rewarding career;

4. Provide leadership in their profession, in their communities, and in the global society;

5. Contribute to their professional disciplines body of knowledge;

6. Function as responsible members of society with an awareness of the social and ethical ramifications of their work.

## Student Outcomes

The department's student outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

a) an ability to apply knowledge of mathematics, science, and engineering;

b) an ability to design and conduct experiments, as well as to analyze and interpret data;

c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

d) an ability to function on multidisciplinary teams;

e) an ability to identify, formulate, and solve engineering problems;

f) an understanding of professional and ethical responsibility;

g) an ability to communicate effectively;

h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;

i) a recognition of the need for, and an ability to engage in life-long learning;

j) a knowledge of contemporary issues;

k) an ability to use the techniques, skills, and modern engineering tools necessary for computer engineering practice.

## Additional Information

The Computer Engineering program is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

Additional information about the major is available on the ECE Department website (http://www.ece.drexel.edu/Undergraduate_Programs2.html) .

Timothy P. Kurzweg, PhD

Associate Professor

Associate Department Head for Undergraduate Studies

Department of Electrical and Computer Engineering

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To make an appointment, please call 215.895.2241
Drop-in hours: Mon - Fri 1:30 - 2:30.

## Degree Requirements

**General Education/Liberal Studies Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| General Education Requirements [*] | | 18.0 |
| **Foundation Requirements** | | |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| BIO 141 | Essential Biology | 4.5 |

| | | |
|---|---|---|
| ENGR 121 | Computation Lab I | 2.0 |
| ENGR 122 | Computation Lab II | 1.0 |
| ECE 200 | Digital Logic Design | 3.0 |
| ECE 201 | Foundations of Electric Circuits | 3.0 |
| ECE 203 | Programming for Engineers | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| **Professional Requirements** | | |
| CS 260 | Data Structures | 3.0 |
| CS 265 | Advanced Programming Tools and Techniques | 3.0 |
| ECE 391 | Introduction to Engineering Design Methods | 1.0 |
| ECE 491 [WI] | Senior Design Project I | 2.0 |
| ECE 492 [WI] | Senior Design Project II | 2.0 |
| ECE 493 | Senior Design Project III | 4.0 |
| ECEC 301 | Advanced Programming for Engineers | 3.0 |
| ECEC 302 | Digital Systems Projects | 4.0 |
| ECEC 304 | Design with Microcontrollers | 4.0 |
| ECEC 353 | Systems Programming | 3.0 |
| ECEC 355 | Computer Organization & Architecture | 4.0 |
| ECEC 356 | Embedded Systems | 4.0 |
| ECEC 357 | Introduction to Computer Networks | 4.0 |
| ECEL 301 [WI] | Electrical Engineering Laboratory | 2.0 |
| ECEL 302 | ECE Laboratory II | 2.0 |
| ECEL 303 | ECE Laboratory III | 2.0 |
| ECEL 304 | ECE Laboratory IV | 2.0 |
| MATH 221 | Discrete Mathematics | 3.0 |
| ECES 301 | Transform Methods and Filtering | 4.0 |
| ECE 361 | Probability for Engineers | 3.0 |
| or ECE 362 | Engineering Statistics | |
| or ENGR 361 | Statistical Analysis of Engineering Systems | |
| **Six Computer Engineering Courses** | | 18.0 |
| **Free Electives** | | 11.5 |
| **Total Credits** | | **192.0** |

[*]      General Education Requirements.

## Sample Plan of Study

### 5 YR Ug Co-op Concentration

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |

| ENGR 101 | Engineering Design Laboratory I | 2.0 |
|---|---|---|
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| ENGR 121 | Computation Lab I | 2.0 |
| | **Term Credits** | **16.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 122 | Computation Lab II | 1.0 |
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **18.0** |
| **Term 4** | | |
| ECE 200 | Digital Logic Design | 3.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 5** | | |
| ECE 201 | Foundations of Electric Circuits | 3.0 |
| ECE 203 | Programming for Engineers | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| MATH 221 | Discrete Mathematics | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 6** | | |
| ECEC 301 | Advanced Programming for Engineers | 3.0 |
| ECEC 302 | Digital Systems Projects | 4.0 |
| ECEL 301 [WI] | Electrical Engineering Laboratory | 2.0 |
| ECES 301 | Transform Methods and Filtering | 4.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 7** | | |
| ECEC 304 | Design with Microcontrollers | 4.0 |
| ECEC 355 | Computer Organization & Architecture | 4.0 |
| ECEL 302 | ECE Laboratory II | 2.0 |
| PHIL 315 | Engineering Ethics | 3.0 |

| Free elective | | 3.0 |
|---|---|---|
| | **Term Credits** | **16.0** |
| **Term 8** | | |
| CS 265 | Advanced Programming Tools and Techniques | 3.0 |
| ECEC 357 | Introduction to Computer Networks | 4.0 |
| ECEL 303 | ECE Laboratory III | 2.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **12.0** |
| **Term 9** | | |
| CS 260 | Data Structures | 3.0 |
| ECE 391 | Introduction to Engineering Design Methods (Also offered spring term.) | 1.0 |
| ECEC 356 | Embedded Systems | 4.0 |
| ECEC 353 | Systems Programming | 3.0 |
| ECEL 304 | ECE Laboratory IV | 2.0 |
| ECE 361, 362, or ENGR 361 | Probability for Engineers Engineering Statistics Statistical Analysis of Engineering Systems | 3.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **19.0** |
| **Term 10** | | |
| ECE 491 [WI] | Senior Design Project I | 2.0 |
| Two Computer Engineering electives | | 6.0 |
| General Education elective[*] | | 3.0 |
| Free Elective | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 11** | | |
| ECE 492 [WI] | Senior Design Project II | 2.0 |
| Two Computer Engineering electives | | 6.0 |
| General Education elective[*] | | 3.0 |
| Free elective | | 3.5 |
| | **Term Credits** | **14.5** |
| **Term 12** | | |
| ECE 493 | Senior Design Project III | 4.0 |
| Two Computer Engineering electives | | 6.0 |
| General Education elective[*] | | 2.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **15.0** |

**Total Credit: 192.0**

[*]    See degree requirements.

# Co-op/Career Opportunities

Drexel University's co-op program has an 80 year history and is one of the oldest and largest co-op programs in the world. Students graduate with 6-18 months of full time employment experience, depending on their choice of a 4-year or 5-year program. The majority of Computer Engineering students in ECE choose the 5-year program and graduate with 18 months of full-time work experience, and often receive a job offer from their third co-op employer or from a connection made from one of their co-op experiences.

Computer engineers work for computer and microprocessor manufacturers; manufacturers of digital devices for telecommunications, peripherals, electronics, control, and robotics; software engineering; the computer network industry; and related fields. A degree in computer engineering can also serve as an excellent foundation to pursue graduate professional careers in medicine, law, business, and government.

Graduates are also pursuing advanced studies in electrical and computer engineering, aerospace engineering, and mechanical engineering at such schools as MIT, Stanford, Princeton, Georgia Institute of Technology, University of California at Berkeley, University of Pennsylvania, and University of Maryland.

The Steinbright Career Development Center had a co-op placement rate of approximately 99% for electrical and computer engineering majors.

Co-op employers for computer engineering majors include:

- Comcast Corporation
- Independence Blue Cross
- Lockheed Martin
- Micron Technology, Inc
- National Board of Medical Examiners
- PJM Interconnection, LLC
- SAP America
- Susquehanna International Group LLC
- UNISYS Corporation
- Woodward McCoach, Inc.
- Amazon, Inc.
- Microsoft's Explore Internship Program
- South Korea KAIST Hubo lab

For more information about the co-op process, please contact the Steinbright Career Development Center (http://drexel.edu/scdc).

# Dual/Accelerated Degree

## Accelerated Program

The accelerated programs of the College of Engineering provide opportunities for highly talented and strongly motivated students to progress toward their educational goals essentially at their own pace. These options include opportunities for accelerated studies, dual degrees, and combined bachelor's/master's programs.

Primarily through advanced placement, credit by examination, flexibility of scheduling, and independent study, the "fast track" makes it possible to complete the undergraduate curriculum and initiate graduate study in less than the five years required by the standard curriculum.

## Dual Degree Bachelor's Programs

With careful planning, students can complete both a Computer Engineering and an Electrical Engineering degree in the time usually required to complete one degree. For detailed information the student should contact the ECE advisor (http://drexel.edu/ece/academics/undergrad/advising) .

# Bachelor's/Master's Dual Degree Program

Exceptional students can also pursue a master of science degree in the same period as the bachelor of science.

For more information on these and other options, visit the Department of Electrical and Computer Engineering BS/MS (http://drexel.edu/ece/academics/undergrad/bs-ms) page.

# Minor in Computer Engineering

The computer engineering minor is designed to provide students from other computer-intensive majors—such as computer science or other engineering majors—with a foundation of knowledge in the hardware portion of computer systems. The minor consists of a minimum of seven ECE courses. There are four required courses and an additional 12.0 credits of elective courses. Students majoring in Electrical Engineering and minoring in Computer Engineering may only choose CE minor electives from the ECEC courses.

## Prerequisites

The minor assumes that students will have a background in mathematics, physics, and computer programming equivalent to that covered in the first two years of engineering.

Calculus prerequisites should include MATH 121, MATH 122, and MATH 200. Physics requirements are PHYS 101, PHYS 102 and PHYS 201. Programming experience must include CS 121/CS 122/ CS 123 or ENGR 121/ENGR 122 or CS 171 at the minimum. CS 172, CS 260 and CS 265 are also recommended, and are required for some upper level ECEC courses. Courses taken to meet these requirements will not count toward the minor.

**Required Courses**

| | | |
|---|---|---|
| ECE 200 | Digital Logic Design | 3.0 |
| ECEC 302 | Digital Systems Projects | 4.0 |
| ECEC 355 | Computer Organization & Architecture | 4.0 |
| ECEL 304 | ECE Laboratory IV (prerequisite waived for minor) | 2.0 |
| **Electives** [*] | | 12.0 |
| **Total Credits** | | **25.0** |

[*] Students should choose an additional 12 credits from 300- and/or 400-level Computer Engineering (ECEC) courses. All prerequisites must be satisfied.

## Additional Information

Additional information about this minor is available on the ECE Department website (http://www.ece.drexel.edu/Undergraduate_Programs2.html) .

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To make an appointment, please call 215.895.2241
Drop-in hours: Mon - Fri 1:30 - 2:30

# Facilities

Drexel University and the Electrical and Computer Engineering Department are nationally recognized for a strong history of developing innovative research. Research programs in the ECE Department prepare students for careers in research and development, and aim to endow graduates with the ability to identify, analyze, and address new technical and scientific challenges. The ECE Department is well equipped with state-of-the-art facilities in each of the following ECE Research laboratories:

## Research Laboratories at the ECE Department

### Adaptive Signal Processing and Information Theory Research Group

The Adaptive Signal Processing and Information Theory Research Group (http://www.ece.drexel.edu/walsh/aspitrg/home.html) conducts research in the area of signal processing and information theory. Our main interests are belief/expectation propagation, turbo decoding and composite adaptive system theory. We are currently doing projects on the following topics:
i) Delay mitigating codes for network coded systems,
ii) Distributed estimation in sensor networks via expectation propagation,
iii) Turbo speaker identification,
iv) Performance and convergence of expectation propagation,
v) Investigating bounds for SINR performance of autocorrelation based channel shorteners.

### Applied Networking Research Lab

Applied Networking Research Lab (ANRL) projects focus on modeling and simulation as well as experimentation in wired, wireless and sensor networks. ANRL is the home of MuTANT, a Multi-Protocol Label Switched Traffic Engineering and Analysis Testbed composed of 10 high-end Cisco routers and several PC-routers, also used to study other protocols in data networks as well as automated network configuration and management. The lab also houses a sensor network testbed.

#### Bioimage Laboratory

Uses computer gaming hardware for enhanced and affordable 3-D visualization, along with techniques from information theory and machine learning to combine the exquisite capabilities of the human visual system with computational sensing techniques for analyzing vast quantities of image sequence data.

### Data Fusion Laboratory

The Data Fusion Laboratory investigates problems in multisensory detection and estimation, with applications in robotics, digital communications, radar, and target tracking. Among the projects in progress: computationally efficient parallel distributed detection architectures, data fusion for robot navigation, modulation recognition and RF scene analysis in time-varying environments, pattern recognition in biological data sequences and large arrays, and hardware realizations of data fusion architectures for target detection and target tracking.

### Drexel Network Modeling Laboratory

The Drexel Network Modeling Laboratory investigates problems in the mathematical modeling of communication networks, with specific focus on wireless ad hoc networks, wireless sensor networks, and supporting guaranteed delivery service models on best effort and multipath routed networks. Typical methodologies employed in our research include mathematical modeling, computer simulation, and performance optimization, often with the end goal of obtaining meaningful insights into network design principles and fundamental performance tradeoffs.

### Drexel Power-Aware Computing Laboratory

The Power-Aware Computing Lab (http://dpac.ece.drexel.edu) investigates methods to increase energy efficiency across the boundaries of circuits, architecture, and systems. Our recent accomplishments include the Sigil profiling tool, scalable modeling infrastructure for accelerator implementations, microarchitecture-aware VDD gating algorithms, an accelerator architecture for ultrasound imaging, evaluation of hardware reference counting, hardware and operating system support for power-agile computing, and memory systems for accelerator-based architectures.

### Drexel University Nuclear Engineering Education Laboratory

The field of nuclear engineering encompasses a wide spectrum of occupations, including nuclear reactor design, medical imaging, homeland security, and oil exploration. The Drexel University Nuclear Engineering Education Laboratory (DUNEEL) provides fundamental hands on understanding for power plant design and radiation detection and analysis. Software based study for power plant design, as well as physical laboratory equipment for radiation detection, strengthen the underlying concepts used in nuclear engineering such that the student will comprehend and appreciate the basic concepts and terminology used in various nuclear engineering professions. Additionally, students use the laboratory to develop methods for delivering remote, live time radiation detection and analysis. The goal of DUNEEL is to prepare students for potential employment in the nuclear engineering arena.

### Drexel VLSI Laboratory

The Drexel VLSI Laboratory (http://ece.drexel.edu/faculty/taskin/wiki/vlsilab/index.php/Main_Page) investigates problems in the design, analysis, optimization and manufacturing of high performance (low power, high throughput) integrated circuits in contemporary CMOS and emerging technologies. Suited with industrial design tools for integrated circuits, simulation tools and measurement beds, the VLSI group is involved with digital and mixed-signal circuit design to verify the functionality of the discovered novel circuit and physical design principles. The Drexel VLSI laboratory develops design methodologies and automation tools in these areas, particularly in novel clocking techniques, featuring resonant clocking, and interconnects, featuring wireless interconnects.

## Drexel Wireless Systems Laboratory

The Drexel Wireless Systems Laboratory (DWSL) contains an extensive suite of equipment for constructing, debugging, and testing prototype wireless communications systems. Major equipment within DWSL includes:

- three software defined radio network testbeds (HYDRA, USRP, and WARP) for rapidly prototyping radio, optical and ultrasonic communications systems,
- a TDK RF anechoic chamber and EMSCAN desktop antenna pattern measurement system,
- a materials printer and printed circuit board milling machine for fabricating conformal antennas and
- wireless protocol conformance testing equipment from Aeroflex.

The lab is also equipped with network analyzers, high speed signal generators, oscilloscopes, and spectrum analyzers as well as several Zigbee development platforms for rapidly prototyping sensor networks.

DWSL personnel also collaborate to create wearable, fabric based transceivers through collaboration with the Shima Seiki Haute Laboratory in the Drexel ExCITe Center. The knitting equipment at Drexel includes sixteen SDS-ONE APEX3 workstations and four state-of-the-art knitting machines. The workstations accurately simulate fabric construction and provide researchers and designers the opportunity to program, create and simulate textile prototypes, import CAD specifications of final products, and produce made-to-measure or mass-produced pieces on Shima Seiki knitting machines. For testing smart textiles for biomedical, DWSL personnel also have collaborators in the Center for Interdisciplinary Clinical Simulation and Practice (CICSP) in the Drexel College of Medicine which provides access to medical mannequin simulators.

## Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (EESI) (http://www.ece.drexel.edu/gailr/EESI) seeks to solve problems in high-throughput genomics and engineer better solutions for biochemical applications. The lab's primary thrust is to enhance the use of high-throughput DNA sequencing technologies with pattern recognition and signal processing techniques. Applications include assessing the organism content of an environmental sample, recognizing/classifying potential and functional genes, inferring environmental factors and inter-species relationships, and inferring microbial evolutionary relationships from short-read DNA/RNA fragments. The lab also investigates higher-level biological systems such as modeling and controlling chemotaxis, the movement of cells.

## Electric Power Engineering Center

This newly established facility makes possible state-of-the-art research in a wide variety of areas, ranging from detailed theoretical model study to experimental investigation in its high voltage laboratories. The mission is to advance and apply scientific and engineering knowledge associated with the generation, transmission, distribution, use, and conservation of electric power. In pursuing these goals, this center works with electric utilities, state and federal agencies, private industries, nonprofit organizations and other universities on a wide spectrum of projects. Research efforts, both theoretical and experimental, focus on the solution of those problems currently faced by the electric power industry. Advanced concepts for electric power generation are also under investigation to ensure that electric power needs will be met at the present and in the future.

## Electronic Design Automation Facility

Industrial-grade electronic design automation software suite and intergrated design environment for digital, analog and mixed-signal systems development. Field Programmable Gate Array (FPGA) development hardware. Most up-to-date FPGA/embedded system development hardware kits. Printed circuit board production facility. Also see Drexel VLSI Laboratory.

## Microwave-Photonics Device Laboratories

The laboratory is equipped with test and measurement equipment for high-speed analog and digital electronics and fiber optic systems. The test equipment includes network analyzers from Agilent (100kHz- 1.3 GHz and 45 Mhz-40 GHz), and Anritsu (45 MHz-6 GHz); spectrum analyzers from Tektronix, HP, and Agilent with measurement capability of DC to 40 GHz and up to 90 GHz using external mixers; signal generators and communication channel modulators from HP, Rhode-Schwartz, Systron Donner, and Agilent; microwave power meter and sensor heads, assortment of passive and active microwave components up to 40 GHz ; data pattern generator and BER tester up to 3Gb/s; optical spectrum analyzer from Anritsu and power meters from HP; single and multimode fiber optic based optical transmitter and receiver boards covering ITU channels at data rates up to 10Gb/s; passive optical components such as isolator, filter, couplers, optical connectors and fusion splicer; LPKF milling machine for fabrication of printed circuit boards; wire-bonding and Cascade probe stations; Intercontinental test fixtures for testing of MMIC circuits and solid-state transistors; state-of-the-art microwave and electromagnetic CAD packages such as Agilent ADS, ANSYS HFSS, and COMSOL multi-physics module.

## Music and Entertainment Technology Laboratory

The Music and Entertainment Technology Laboratory (MET-lab) is devoted to research in digital media technologies that will shape the future of entertainment, especially in the areas of sound and music. We employ digital signal processing and machine learning to pursue novel applications in music information retrieval, music production and processing technology, and new music interfaces. The MET-lab is also heavily involved in outreach programs for K-12 students and hosts the Summer Music Technology program, a one-week learning experience for high school students. Lab facilities include a sound isolation booth for audio and music recording, a digital audio workstation running ProTools, two large multi-touch display interfaces of our own design, and a small computing cluster for distributed processing.

## NanoPhotonics+ Lab
http://drexelnanophotonics.com)

Our research is primarily in the area of nanophotonics with a focus on the nanoscale interaction of light with matter. Interests include: liquid crystal/polymer composites for gratings, lenses and HOEs; liquid crystal interactions with surfaces and in confined nanospaces; alternative energy generation through novel photon interactions; ink-jet printed conducting materials for RF and photonic applications; and the creation and development of smart textiles technologies including soft interconnects, sensors, and wireless implementations.

## Opto-Electro-Mechanical Laboratory

This lab concentrates on the system integration on optics, electronics, and mechanical components and systems, for applications in imaging, communication, and biomedical research. Research areas include:

Programmable Imaging with Optical Micro-electrical-mechanical systems (MEMS), in which microscopic mirrors are used to image light into a single photodetector; Pre-Cancerous Detection using White Light Spectroscopy, which performs a cellular size analysis of nuclei in tissue; Free-space Optical Communication using Space Time Coding, which consists of diffused light for computer-to-computer communications, and also tiny lasers and detectors for chip-to-chip communication; Magnetic Particle Locomotion, which showed that particles could swim in a uniform field; and Transparent Antennas using Polymer, which enables antennas to be printed through an ink-jet printer.

## Plasma and Magnetics Laboratory

Research is focused on applications of electrical and magnetic technologies to biology and medicine. This includes the subjects of non-thermal atmospheric pressure plasma for medicine, magnetic manipulation of particles for drug delivery and bio-separation, development of miniature NMR sensors for cellular imaging and carbon nanotube cellular probes.

## Power Electronics Research Laboratory

The Power Electronics Research Laboratory (PERL) is involved in circuit and design simulation, device modeling and simulation, and experimental testing and fabrication of power electronic circuits. The research and development activities include electrical terminations, power quality, solar photovoltaic systems, GTO modeling, protection and relay coordination, and solid-state circuit breakers. The analysis tools include EMPT, SPICE, and others, which have been modified to incorporate models of such controllable solid-state switches as SCRs, GTOs, and MOSFETs. These programs have a wide variety and range of modeling capabilities used to model electromagnetics and electromechanical transients ranging from microseconds to seconds in duration. The PERL is a fully equipped laboratory with 42 kVA AC and 70 kVA DC power sources and data acquisition systems, which have the ability to display and store data for detailed analysis. Some of the equipment available is a distribution and HV transformer and three phase rectifiers for power sources and digital oscilloscopes for data measuring and experimental analysis. Some of the recent studies performed by the PERL include static VAR compensators, power quality of motor controllers, solid-state circuit breakers, and power device modeling which have been supported by PECO, GE, Gould, and EPRI.

## RE Touch Lab

The RE Touch Lab is investigating the perceptual and mechanical basis of active touch perception, or haptics, and the development of new technologies for stimulating the sense of touch, allowing people to touch, feel, and interact with digital content as seamlessly as we do with objects in the real world. We study the scientific foundations of haptic perception and action, and the neuroscientific and biomechanical basis of touch, with a long-term goal of uncovering the fundamental perceptual and mechanical computations that enable haptic interaction. We also create new technologies for rendering artificial touch sensations that simulate those that are experienced when interacting with real objects, inspired by new findings on haptic perception.

## Testbed for Power-Performance Management of Enterprise Computing Systems

This computing testbed is used to validate techniques and algorithms aimed at managing the performance and power consumption of enterprise computing systems. The testbed comprises a rack of Dell 2950 and Dell 1950 PowerEdge servers, as well as assorted desktop machines, networked via a gigabit switch. Virtualization of this cluster is enabled by VMWare's ESX Server running the Linux RedHat kernel. It also comprises of a rack of ten Apple Xserve machines networked via a gigabit switch. These servers run the OS X Leopard operating systems and have access to a RAID with TBs of total disk capacity.

# Electrical and Computer Engineering Faculty

Suryadevara Basavaiah, PhD *(University of Pennsylvania).* Teaching Professor. Computer engineering; computer engineering education; custom circuit design; VLSI technology; process and silicon fabrication.

Tom Chmielewski, PhD *(Drexel University).* Assistant Teaching Professor. Modeling and simulation of electro-mechanical systems; Optimal, Adaptive and Non-Linear Control; DC Motor Control; System Identification; Kalman Filters (Smoothing Algorithms, tracking); image processing, Robot design; Biometric technology and design of embedded systems for control applications utilizing MATLAB and SIMULINK

Fernand Cohen, PhD *(Brown University).* Professor. Surface modeling; tissue characterization and modeling; face modeling; recognition and tracking.

Andrew Cohen, PhD *(Rensselaer Polytechnic Institute).* Associate Professor. Image processing; multi-target tracking; statistical pattern recognition and machine learning; algorithmic information theory; 5-D visualization.

Kapil Dandekar, PhD *(University of Texas-Austin) Director of the Drexel Wireless Systems Laboratory (DWSL); Associate Dean of Research, College of Engineering.* Professor. Cellular/mobile communications and wireless LAN; smart antenna/MIMO for wireless communications; applied computational electromagnetics; microwave antenna and receiver development; free space optical communication; ultrasonic communication; sensor networks for homeland security; ultrawideband communication.

Afshin Daryoush, PhD *(Drexel University).* Professor. Microwave photonics systems; nonlinear microwave circuits; RFIC and wireless communications; antennas and radiating systems; electromagnetic interaction with biological systems.

Bruce A. Eisenstein, PhD *(University of Pennsylvania) Arthur J. Rowland Professor of Electrical and Computer Engineering; Vice Dean, College of Engineering.* Professor. Pattern recognition; estimation; decision theory; digital signal processing.

Adam K. Fontecchio, PhD *(Brown University) Associate Dean for Undergraduate Affairs; Associate Director, Expressive and Creative Interactive Technologies (EXCITE) Center.* Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park).* Professor. Biological and biomedical applications of nanoscale magnetic systems.

Eli Fromm, PhD *(Jefferson Medical College) Roy A. Brothers University Professor / Director for Center of Educational Research.* Professor. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania) Assistant EDE Department Head; Liason for Evening Programs.* Professor. Computerized instruments and measurements; undergraduate engineering education.

Allon Guez, PhD *(University of Florida)*. Professor. Intelligent control systems; robotics, biomedical, automation and manufacturing; business systems engineering.

Mark Hempstead, PhD *(Harvard University) Junior Colehower Chair*. Assistant Professor. Computer engineering; power-aware computing; computer architecture; low power VLSI Design; wireless sensor networks.

Peter R. Herczfeld, PhD *(University of Minnesota) Lester A. Kraus Professor/Director, Center for Microwave/Lightwave Engineering*. Professor. Lightwave technology; microwaves; millimeter waves; fiberoptic and integrated optic devices.

Leonid Hrebien, PhD *(Drexel University)*. Professor. Tissue excitability; acceleration effects on physiology; bioinformatics.

Paul R. Kalata, PhD *(Illinois Institute of Technology)*. Associate Professor. Stochastic and adaptive control theory; identification and decision theory; Kalman filters.

Nagarajan Kandasamy, PhD *(University of Michigan)*. Associate Professor. Embedded systems, self-managing systems, reliable and fault-tolerant computing, distributed systems, computer architecture, and testing and verification of digital systems.

Bruce Katz, PhD *(University of Illinois)*. Adjunct Professor. Neural networks; the study of aesthetics; artificial intelligence; music perception.

Youngmoo Kim, PhD *(Massachusetts Institutie of Technology) Director, Expressive and Creative Interaction Technologies (EXCITE) Center*. Associate Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Timothy P. Kurzweg, PhD *(University of Pittsburgh) Associate Department Head for Undergraduate Studies and Director of the BSE Program*. Associate Professor. Optical MEM modeling and simulation; system-level simulation; computer architecture.

Mohammad Madihian, PhD *(Shizuoka University)*. Adjunct Professor. Solid-state device-circuit interaction; microwave and millimeter-wave monolithic circuit design and evaluation technology; solid-state power generation/amplification/mixing technology; single/multi-mode wireless RF/IF transceiver technology

Karen Miu, PhD *(Cornell University)*. Professor. Power systems; distribution networks; distribution automation; optimization; system analysis.

Bahram Nabet, PhD *(University of Washington)*. Professor. Optoelectronics; fabrication and modeling; fiber optic devices; nanoelectronics; nanowires.

Prawat Nagvajara, Ph.D. *(Boston University)*. Associate Professor. System on a chip; embedded systems; power grid computation; testing of computer hardware; fault-tolerant computing; VLSI systems; error control coding.

Vasileios Nasis, PhD *(Drexel University)*. Associate Teaching Professor. Imaging with MOEMS, Projection systems using MEMS/MOEMS, Wireless communications, Remote monitoring, sensor networks.

Dagmar Niebur, PhD *(Swiss Federal Institute of Technology)*. Associate Professor. Intelligent systems; dynamical systems; power system monitoring and control.

Chika Nwankpa, PhD *(Illinois Institute of Technology) Interum Department Head*. Professor. Power system dynamics; power electronic switching systems; optically controlled high power switches.

Christopher Peters, PhD *(University of Michigan, Ann Arbor)*. Teaching Professor. Nuclear reactor design; ionizing radiation detection; nuclear forensics; power plant reliability and risk analysis; naval/marine power and propulsion; directed energy/high power microwaves; nonstationary signal processing; radar; electronic survivability/susceptibility to harsh environments; electronic warfare.

Karkal S. Prahbu, PhD *(Harvard University)*. Teaching Professor. Computer and software engineering; advanced microprocessors and distributed operating systems.

Gail L. Rosen, PhD *(Georgia Institute of Technology)*. Associate Professor. Signal processing, signal processing for biological analysis and modeling, bio-inspired designs, source localization and tracking.

Ioannis Savidis, PhD *(University of Rochester) Director of the Integrated Circuits and Electronics (ICE) Design and Analysis Laboratory*. Assistant Professor. Analysis, modeling, and design methodologies for high performance digital and mixed-signal integrated circuits; Emerging integrated circuit technologies; Electrical and thermal modeling and characterization, signal and power integrity, and power and clock delivery for 3-D IC technologies.

Kevin J. Scoles, PhD *(Dartmouth College)*. Associate Professor. Microelectronics; electric vehicles; solar energy; biomedical electronics.

Harish Sethu, PhD *(Lehigh University)*. Associate Professor. Protocols, architectures and algorithms in computer networks; computer security; mobile ad hoc networks; large-scale complex adaptive networks and systems.

James Shackleford, PhD *(Drexel University)*. Assistant Professor. Medical image processing, high performance computing, embedded systems, computer vision, machine learning.

P. Mohana Shankar, PhD *(Indian Institute of Technology) Allen Rothwarf Professor of Electrical and Computer Engineering*. Professor. Wireless communications; biomedical ultrasonics; fiberoptic bio-sensors.

Matthew Stamm, PhD *(University of Maryland, College Park) Head, Multimedia and Information Security Laboratory (MSL)*. Assistant Professor. Information Security; Multimedia Forensics and Anti-Forensics; Information Verification; Adversarial Dynamics; Signal Processing.

Baris Taskin, PhD *(University of Pittsburgh)*. Associate Professor. Electronic design automation (EDA) of integrated circuits, high-performance VLSI circuits and systems, sequential circuit timing and synchronization, system-on-chip (SOC) design, operational research, VLSI computer-aided design.

Lazar Trachtenberg, DSc *(Israel Institute of Technology)*. Professor. Fault tolerance; multi-level logic synthesis; signal processing; suboptimal filtering.

Yon Visell, PhD *(McGill University)*. Assistant Professor. Haptic display engineering, material and biomechanical contact physics, neuroscientific and physical basis of human tactile sensation/perception, haptic human-machine interaction, sensorimotor learning, interaction in virtual reality

John Walsh, PhD *(Cornell University)*. Associate Professor. Performance and convergence of belief/expectation propagation and turbo decoding/

equalization/synchronization, permeation models for ion channels, composite adaptive systems theory.

Steven Weber, PhD *(University of Texas-Austin) Assistant Department Head for Graduate Affairs, Electrical and Computer Engineering.* Associate Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice Cavalcante de Oliveira, PhD *(Georgia Institute of Technology).* Associate Professor. Next generation Internet; quality of service in computer communication networks; wireless networks.

## Interdepartmental Faculty

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine.* Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Jeremy R. Johnson, PhD *(Ohio State University).* Professor. Computer algebra; parallel computations; algebraic algorithms; scientific computing.

John Lacontora, PhD *(New Jersey Institute of Technology).* Associate Research Professor. Service engineering; industrial engineering.

Ryszard Lec, PhD *(University of Warsaw Engineering College).* Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Spiros Mancoridis, PhD *(University of Toronto) Sr. Associate Dean for Computing and CCI Academic Affairs.* Professor. Software engineering; software security; code analysis; evolutionary computation.

Karen Moxon, PhD *(University of Colorado).* Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Paul Y. Oh, PhD *(Columbia University).* Adjunct Professor. Smart sensors servomechanisms; machine vision and embedded microcomputers for robotics and mechatronics.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems.* Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University).* Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

William C. Regli, PhD *(University of Maryland-College Park).* Professor. Artificial intelligence; computer graphics; engineering design and Internet computing.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering.* Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering.* Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces; scanning probe microscopy; laser spectroscopy, including Raman scattering.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems.* Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Aspasia Zerva, PhD *(University of Illinois).* Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

## Emeritus Faculty

Robert Fischl, PhD *(University of Michigan) John Jarem Professor Emeritus / Founder of the Center for Electric Power Engineering.* Professor Emeritus. Power: systems, networks, controls, computer-aided design, power systems, solar energy.

Vernon L. Newhouse, PhD *(University of Leeds) Disque Professor Emeritus.* Professor Emeritus. Biomedical and electrophysics: ultrasonic flow measurement, imaging and texture analysis in medicine, ultrasonic nondestructive testing and robot sensing, clinical engineering.

Hun H. Sun, PhD *(Cornell University) Ernest O. Lange Professor Emeritus.* Professor Emeritus. Systems and signals in biomedical control systems.

Oleh Tretiak, ScD *(MIT).* Professor Emeritus. Image processing; tomography; image registration; pattern recognition.

## Elec Comp Engr-Computers Courses

**ECEC 301 Advanced Programming for Engineers 3.0 Credits**
An advanced introduction to classes and objects; inheritance and polymorphism; abstract classes and interfaces; exception handling; files and streams; garbage collection and dynamic memory allocation; recursion; using linked lists, stacks, queues, and trees; search and sorting algorithms; generic methods and classes; a comparative introduction to dominant programming languages; engineering examples.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 203 [Min Grade: D] or CS 203 [Min Grade: D]

**ECEC 302 Digital Systems Projects 4.0 Credits**
Offers hands-on experiences in digital system design with automation tools. Uses field programmable gate arrays in the projects. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CS 171 [Min Grade: D] (Can be taken Concurrently) or ECE 203 [Min Grade: D] or CS 203 [Min Grade: D]) and ECE 200 [Min Grade: D]

**ECEC 304 Design with Microcontrollers 4.0 Credits**
Offers hands-on experience in the design of controllers that incorporate microcontrollers as an embedded component in a larger system. The microcomputer topics to be studied will include architecture, software, programming and interfaces.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECE 200 [Min Grade: D] and (CS 171 [Min Grade: D] or ECE 203 [Min Grade: D] or CS 203 [Min Grade: D])

**ECEC 352 Secure Computer Systems: Design Concepts 4.0 Credits**
Covers concepts of secure computation, including economics vs. faults, errors, and hidden messages; mathematical foundations of secure computing; design issues in fault-tolerant computing; and testability and cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEC 302 [Min Grade: D] and MATH 221 [Min Grade: D]

**ECEC 353 Systems Programming 3.0 Credits**
This course introduces computer systems, including interaction of hardware and software through the operating system, from the programmer's perspective. Three fundamental abstractions are emphasized: processes, virtual memory, and files. These abstractions provide programmers a common interface to a wide variety of hardware devices. Topics covered include linking, system level I/O, concurrent programming, and network programming.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CS 265 [Min Grade: D]

**ECEC 355 Computer Organization & Architecture 4.0 Credits**
This course will cover the principles of designing microprocessors using solid engineering fundamentals and quantitative cost/performance trade-offs. Topics will cover instruction set architectures, arithmetic for computers, assessing and understanding processor performance, processor datapath and control, pipelining, cache design, and virtual-memory design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECE 200 [Min Grade: D] or CS 270 [Min Grade: D]) and ECEC 302 [Min Grade: D]

**ECEC 356 Embedded Systems 4.0 Credits**
Lectures will cover theoretical concepts of embedded and cyber#physical systems including discrete and continuous dynamics, hybrid systems, state machines, concurrent computation, embedded systems architecture and scheduling. Lab involves programming embedded applications for the decentralized software services architecture using C# and the Microsoft Robotics Software Development Kit (SDK) together with the hardware image processing and tracking capabilities of the Kinect sensor.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 304 [Min Grade: D]

**ECEC 357 Introduction to Computer Networks 4.0 Credits**
History of the Internet; introduction to packet switching, circuit switching and virtual circuit switching; statistical multiplexing; protocol layering; metrics of network performance including bandwidth, delay and loss; medium access protocols and Ethernet; routing algorithms; end-to-end issues; flow and congestion control; an overview of application layer protocols.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 203 [Min Grade: D] or CS 171 [Min Grade: D]

**ECEC 390 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 411 Computer Hardware 3.0 Credits**
Covers the design and performance of computer hardware devices, including direct memory access, priority arbitration, double buffering, and bus standards. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECEC 355 [Min Grade: D]

**ECEC 412 Modern Processor Design 3.0 Credits**
This course introduces modern processor design in a systematic manner. It discusses dynamically scheduled superscalar techniques including multi-issue, dynamic instruction scheduling, speculative execution, and branch prediction; advanced cache designs, and new techniques including SMT and VLIW. The course provides a comprehensive coverage of modern processor architectures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D] or CS 281 [Min Grade: D]

**ECEC 413 Introduction to Parallel Computer Architecture 3.0 Credits**
This course provides an introduction to the fundamental principles and engineering trade-offs involved in designing modern parallel computers (multi-processors). Topics covered include, but are not limited to, shared-memory and message-passing programming, cache-coherence, synchronization, scalable distributed memory multi-processors, and interconnection techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D] or CS 281 [Min Grade: D]

**ECEC 414 High Performance Computing 3.0 Credits**
This course is an introduction to high performance computing, including both concepts and applications. Course contents will include discussions of different types of high performance computer architectures (multi-core/multi-threaded processors, parallel computers, etc.), the design, implementation, optimization and analysis of efficient algorithms for uni-processors, multi-threaded processors, and parallel computers, and high performance programming.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D] or (CS 281 [Min Grade: D] and CS 282 [Min Grade: D])

**ECEC 421 Introduction to Operating Systems I 3.0 Credits**
Covers basic concepts of computer operating systems, including multiprocessing and multiprogramming systems, lock operations, synchronization, and file structures. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECEC 355 [Min Grade: D] and CS 260 [Min Grade: D]

**ECEC 422 Introduction to Operating Systems I 3.0 Credits**
Further develops the topics of ECEC 421. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEC 421 [Min Grade: D]

**ECEC 431 Introduction to Computer Networks 3.0 Credits**
Covers topics in computer and telecommunications network design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECE 200 [Min Grade: D] and CS 260 [Min Grade: D]

**ECEC 432 Internet Architecture and Protocols 3.0 Credits**
Covers architecture, protocols, and services of the Internet with an
analytical approach focused on design principles; Internet architecture
and topology; architecture of web and mail servers; router architectures;
routing protocols; multicasting; multimedia over IP and associated
protocols; Quality-of-Service issues in the Internet.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 357 [Min Grade: D] or CS 472 [Min Grade: D]

**ECEC 433 Network Programming 3.0 Credits**
Covers application layer protocol and how applications use the transport
layer; principles and practice of network programming; the client-server
model; concurrent processing; introduction to sockets and related
functions client and server software design with examples; principles,
issues and challenges in e-mail and web application protocols; security
protocols; and network life system concepts.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 357 [Min Grade: D]

**ECEC 441 Robotic Computer Interface & Control I 3.0 Credits**
Covers fundamentals of robotics systems, including mechanics, actuators,
sensors, kinematics, and inverse kinematics. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECES 356 [Min Grade: D]

**ECEC 442 Robotic Computer Interface & Control II 3.0 Credits**
Covers robot dynamics, Lagrangian and Newton Euler methods, linear
control of robots, path planning, and computer implementation. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEC 441 [Min Grade: D]

**ECEC 443 Robotic Computer Interface & Control III 3.0 Credits**
Covers robot-computer interface methods, including redundancy,
optimal control, robustness, nonlinear control, adaptive control, and
multiprocessor control. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEC 442 [Min Grade: D]

**ECEC 451 Computer Arithmetic 3.0 Credits**
This course provides an introduction to number representations used in
computer arithmetic, issues of complexity in arithmetic operations, fixed
point arithmetic, floating point arithmetic, and residue number systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 200 [Min Grade: D] and ECEC 355 [Min Grade: D]

**ECEC 453 Image Processing Architecture 3.0 Credits**
This course covers applications of computing techniques and hardware
in image (still and video) processing. Methods of compression (lossless,
lossy), video compression, JPEG standards, MPEG standards,
processing requirements, and implementations for multimedia.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 200 [Min Grade: D] and ECES 301 [Min Grade: D]
and ECES 303 [Min Grade: D]

**ECEC 455 Intelligent System Architectures 3.0 Credits**
This course outlines the principles of designing the architectures for
intelligent systems. Methods of knowledge representation are compared
for a variety of engineering problems. Methods of sensing and behavior
generation are demonstrated for applications in large engineering and
information systems including autonomous robots. Principles of goal-
oriented computers are discussed, and modules of intelligent systems
architectures are described. Theoretical fundamentals and practical
techniques for learning are also covered.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** MATH 221 [Min Grade: D] and ECEC 355 [Min Grade: D]

**ECEC 457 Security in Computing 3.0 Credits**
The course introduces ideas from Cryptography and Fault Tolerant
Computing. Cryptography studies how to artificially create distortions that
being interwoven with computations mask them from eavesdropping.
Fault Tolerance studies techniques of suppressing effects of natural
noises that operate in computation channels. The course deals with both
some introductory issues in Public Key Cryptography and some important
aspects of designing Fault Tolerant Systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D]

**ECEC 459 Testing of Hardware 3.0 Credits**
Testing has become the largest expense item in the semiconductor
industry. There is rapidly being developed new techniques in testing,
design for test and built-in self-test because no existing set of techniques
can satisfy the existing and future needs. The course reviews, in a unified
way, important issues in testing and diagnosis of hardware. Together with
the "Security in Computing" course, it brings a design engineer student to
the state of the art level in the field.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D]

**ECEC 471 Introduction to VLSI Design 3.0 Credits**
This is an introductory course where systematic understanding, design and analysis of digital VLSI integrated circuits will be covered. The course will begin with a review of CMOS transistor operation and semiconductor processes. Logic design with CMOS transistor and circuit families will be described. Specifically, layout, design rules, and circuit simulation will be addressed. Performance metrics will be analyzed in design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECE 200 [Min Grade: D] or CS 270 [Min Grade: D]) and (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D])

**ECEC 472 VLSI Design & Automation 3.0 Credits**
Design and analysis of VLSI integrated circuits will be covered from circuits and systems design perspectives. First, system timing and arithmetic building blocks will be presented. Then, design automation will be presented by hierarchical design examples using hardware description languages (HDL) and physical design with VLSI CAD tools.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D] and (ECE 200 [Min Grade: D] or CS 270 [Min Grade: D])

**ECEC 473 Modern VLSI IC Design 3.0 Credits**
This is a project-oriented course where a high-complexity VLSI design project will be assigned to student teams. Team-work, task assignment and team communication will be mediated in an industry setting. Design tasks will cover the entire IC design flow range, from system specification to TRL description to timing and power analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 472 [Min Grade: D]

**ECEC 474 ASIC Design I 3.0 Credits**
This course will focus exclusively on digital CMOS Application Specific Integrated Circuit (ASIC) systems design and automation. The ASIC physical design flow, including logic synthesis, floorplanning, placement, clock tree synthesis, routing and verification will be presented. These back-end physical design flow steps will also be covered through hands-on practice using industrial VLSI CAD tools. Contemporary design practices will be reviewed and presented in experiments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 200 [Min Grade: D] and ECEC 355 [Min Grade: D]

**ECEC 475 ASIC Design II 3.0 Credits**
Design and analysis of Application Specific Integrated Circuits (ASICs) will be covered from a systems design perspective. System timing, arithmetic building block and memory block design processes will be presented. Design tasks in a quarter-long, small-complexity processor design project will cover the back-end of the IC design flow range, from RTL synthesis to timing and power analysis. Projects will be performed in a hierarchical group, similar to an industrial setting, with other graduate and undergraduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 474 [Min Grade: D]

**ECEC 490 Special Topics in Computer Engineering 12.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEC 497 Research In Computer Engineering 0.5-12.0 Credits**
Computer engineering students only. Requires independent research in a field approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is CE.

**ECEC 499 Independent Study in Computer Engineering 0.5-12.0 Credits**
Computer engineering students only. Requires independent study or research in a field approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is CE.
Cannot enroll if classification is Freshman or Sophomore

# Elec Computer Engr-Electroph Courses

**ECEE 302 Electronic Devices 4.0 Credits**
Covers principles of operation of semiconductor devices, including PN diodes, bipolar transistors, and field effect transistors (JFET, MOSFET, MESFET). Applications of PN junctions, including solar cells, led, laser diodes. Laboratories reinforce lecture material by allowing students to build, measure and analyze data from simple devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** TDEC 211 [Min Grade: D] or ENGR 220 [Min Grade: D]

**ECEE 304 Electromagnetic Fields & Waves 4.0 Credits**
Covers vector calculus, Coulomb's Law, Gauss' Law, Ampere's Law, Maxwell's equations, Electromagnetic (EM) fields in devices, EM fields in circuits, EM fields in machinery, EM waves, biological effects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATH 291 [Min Grade: D]

**ECEE 352 Analog Electronics 4.0 Credits**
Teaches the fundamentals of electronic circuit analysis and design by means of practical projects, such as a dc power supply and an audio amplifier. Covers design with discrete components as well as integrated circuit design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D] and ECES 301 [Min Grade: D]

**ECEE 354 Wireless and Optical Electronics 4.0 Credits**
Covers propagation of waves in various media as it relates to wireless communications: reflection, transmission, polarization, wave packets, dispersion, radiation and antennas, microwave electronic devices, optical wave guides, and fiber optics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D] and ECEE 304 [Min Grade: D]

**ECEE 390 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 421 Advanced Electronics I 4.0 Credits**
Application-and design-focused course. Analyzes feedback in electronic circuits such as operational amplifiers. Covers design and applications of active filters and other typical electronic circuitry. Includes experiments in the design of multistage transistor circuits, feedback loops, operational amplifiers, and active filters.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 352 [Min Grade: D]

**ECEE 422 Advanced Electronic Circuits I 3.0 Credits**
Application-and design-focused course. Covers analysis and design of communication circuits and non-linear active circuits; oscillators, mixers, IF and RF amplifiers; and AM and FM modulators.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 421 [Min Grade: D]

**ECEE 423 Advanced Electronics Circuits II 3.0 Credits**
Application-and design-focused course. Covers non-linear circuits; function and wave form generators; log-amp, multipliers, dividers, power amp, and phase-lock loops; and design of electronics needed to implement different logic circuit families.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 421 [Min Grade: D]

**ECEE 434 Digital Electronics 4.0 Credits**
Covers basic digital integrated circuit building blocks (inverters, nor and nand logic), CMOS logic gates (dc and transient behavior), drivers, and digital circuits and systems (PLA, gate array, memory). Experiments in semiconductor material characterization, device characterization, circuit and device simulations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D]

**ECEE 441 Lightwave Engineering I 3.0 Credits**
Covers fundamentals of wave propagation, including propagation in various fiber wave guides and field distributions, diffraction, attenuation, dispersion, information capacity, and other analytic and design considerations in fiber systems. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 304 [Min Grade: D]

**ECEE 442 Lightwave Engineering II 3.0 Credits**
Covers operating principles, construction, and characteristics of sources, couplers, and detectors used in optical systems. Includes equivalent circuit models and principles of generation, transmission, and reception. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 441 [Min Grade: D]

**ECEE 443 Lightwave Engineering III 3.0 Credits**
Covers applications of devices and systems in such areas as data, voice, and image trans-mission; industrial automation; process control; medicine; and computers. Includes basic measurement systems. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 442 [Min Grade: D]

**ECEE 451 Electroacoustics 3.0 Credits**
Applications-oriented course. Covers fundamentals of vibrating systems; equations of motion; acoustical, electrical, and mechanical analogs; properties of waves in fluids; acoustic impedance and plane wave transmission; application to design of transducers; and application of acoustic waves in medical imaging, non-destructive testing, and the biomedical field.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Junior or Pre-Junior or Sophomore

**ECEE 471 RF Components and Techniques 4.0 Credits**
This course covers microwave networks (Z, Y, S, T ABCD Parameters), signal flowgraph, impedance matching techniques (lumped and distributed, quarter wave transformers), circulators and isolators, directional couplers (branch line, Wilkinson, Lange, slot waveguide), and filters (lowpass, bandpass, bandstop, highpass). CAD laboratory and design projects are an integral part of this course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 354 [Min Grade: D]

**ECEE 472 RF Electronics 4.0 Credits**
This course covers static and dynamic characteristics of transistors, unipolar (MOSFET, MESFET, HEMT), bipolar (BJT, HBT), LNA design and realization, power amplifiers, distributed amplifiers, switches, limiters, phase shifters, detectors, mixers, oscillators (Colpitts, YIG turned, reflection, transmission, DRO). CAD laboratory and design projects are an integral part of this course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 471 [Min Grade: D]

**ECEE 473 Antennas and Radiating Systems 4.0 Credits**
This course covers short and magnetic dipole, radiation pattern, radiation resistance, directivity and gain, line antennas (dipoles, monopoles, V and inverted V antennas), helix, Yagi-Uda, log-periodic, aperture antennas (slot, horn and reflector), printed circuit antennas (patch and spiral), and phased antennas. CAD laboratory and design projects are an integral part of this course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 471 [Min Grade: D]

**ECEE 490 Special Topics in Electrophysics 12.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEE 497 Research in Electrophysics 0.5-12.0 Credits**
Requires independent research in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 499 Independent Study In Electrophysics 0.5-12.0 Credits**
Requires independent study in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

# Elec Computer Engr-Power Eng Courses

**ECEP 352 Electric Motor Control Principles 4.0 Credits**
Introduces machinery principles, magnetic circuits, three-phase circuits, the electrical and economic structure of the power industry, ac and dc machine fundamentals, and power electronic converters and their interfaces with electric motors. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D] (Can be taken Concurrently) (ECE 201 [Min Grade: D] or ECES 211 [Min Grade: D])

**ECEP 354 Energy Management Principles 4.0 Credits**
Covers principles of power engineering, including the electrical and economic structure of the power industry (distribution, subtransmission, and bulk transmission levels; environmental issues; the electrical system analysis; the thermal system analysis; links between electromechanics and thermodynamics; and safety issues). Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D] (Can be taken Concurrently) (ECE 201 [Min Grade: D] or ECES 211 [Min Grade: D])

**ECEP 371 Introduction to Nuclear Engineering 2.0 Credits**
This course introduces the student to the fundamental topic of nuclear engineering. This course should be the first course for students interested in the nuclear engineering minor, as all of the topics will be discussed in greater detail in other courses. Topics include atomic and nuclear structure, binding energy, reaction kinetics and energetics, and radioactive decay.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 201 [Min Grade: C] and (ENGR 210 [Min Grade: C] or CHE 206 [Min Grade: C])

**ECEP 372 Radiation Detection and Measurement 3.0 Credits**
Introduces students to the fundamentals of radiation detection, and applications of radiation detection equipment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 371 [Min Grade: D] or ECEP 404 [Min Grade: D] or MEM 371 [Min Grade: D]

**ECEP 380 Introduction to Renewable Energy 3.0 Credits**
Introduction to Renewable Energy is an undergraduate survey course for engineers, scientists and others interested in energy systems and applications. The course introduces students to the mix of current major electric power sources and the pressures that are forcing a transition to renewable sources. Wind and solar energy will be studied in detail, with others as time allows. Course culminates with an integrating off-grid energy system design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATH 122 [Min Grade: D] and (PHYS 102 [Min Grade: D] or PHYS 115 [Min Grade: D] or PHYS 154 [Min Grade: D])

**ECEP 390 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 402 Theory of Nuclear Reactors 4.0 Credits**
Introduces students to atomic and nuclear physics, radiation interaction with matter, components of nuclear reactors, neutron diffusion and moderation, nuclear reactor theory, and heat removal from nuclear reactors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENGR 210 [Min Grade: D]

**ECEP 403 Nuclear Power Plant Design & Operation 3.0 Credits**
Introduces students to the design of nuclear power plants. Topics covered include electrical transmission, non-nuclear related equipment, fluid flow, heat transfer, thermodynamics, heat exchangers, pump, valves, piping and nuclear reactor design. Course includes a final project which is the design of a nuclear power plant.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 404 Introduction to Nuclear Engineering 2.0 Credits**
Introduces the fundamental scientific, technical, social and ethical issues in nuclear engineering; nuclear reactions and readiation, radiation protection and control, nuclear energy production and utilization, nuclear fuel cycle, nuclear fuel cycle, nuclear materials, controlled fusion and thermonuclear plasma systems, basics of plasma physics and plasma chemistry, nuclear waste management, nuclear reactor safety, analysis of severe nuclear accidents, risk assessment and related issues of engineering ethics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 201 [Min Grade: D] and (ENGR 210 [Min Grade: D] or CHE 206 [Min Grade: D])

**ECEP 406 Introduction to Radiation Health Principles 3.0 Credits**
This course is intended to impart radiation safety knowledge to the nuclear engineering student. A fundamental knowledge of radiation safety is critical for all nuclear engineers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 371 [Min Grade: D] or ECEP 404 [Min Grade: D]

**ECEP 411 Power Systems I 3.0 Credits**
Covers steady state generator, transformer and transmission line modeling used for balanced steady state power system analysis including three-phase to single-phase model conversion, per-unit analysis, generator and line loadability, transformer and transmission line voltage regulation and reactive compensation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 352 [Min Grade: D]

**ECEP 412 Power Systems II 4.0 Credits**
Covers y-bus based analysis of power systems including steady-state power-flow models and algorithms, economic dispatch of power generation, load-frequency control and introduction to transient stability analysis including time-domain simulation and equal area criterion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 411 [Min Grade: D]

**ECEP 413 Power Systems III 3.0 Credits**
Covers Z-bus-based analysis of power systems including symmetrical component networks of generators, transformers, transmission lines and loads, symmetrical and unbalanced three-phase bus and line faults, and an introduction to power system protection.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 412 [Min Grade: D]

**ECEP 421 Modeling and Analysis of Electric Power Distribution Systems 3.0 Credits**
Introduction to power distribution systems; balanced and unbalanced systems, component and load modeling, radial and weekly meshed topologies; algorithms for unbalanced power studies including radial and general structure solver.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Corequisite**: ECEP 411

**ECEP 422 Power Distribution Automation and Control 3.0 Credits**
Focuses on distribution management systems and their application: including optimizing network operation - capacitor placement and control, network reconfiguration, service restoration. Modern solution technologies are addressed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 421 [Min Grade: C]

**ECEP 423 Service and Power Quality Distribution Systems 3.0 Credits**
Focus on power distribution systems: service and power quality assessment including stat estimation, voltage quality, trouble call analysis, service restoration, component and system reliability assessment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 422 [Min Grade: C]

**ECEP 431 Advanced Electromagnetic Energy Conversion I 4.0 Credits**
Covers theory and operation of alternating current machinery, with emphasis on design alternatives and the effects of design on performance. Includes construction of machine models from laboratory measurements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 352 [Min Grade: D]

**ECEP 432 Advanced Electromagnetic Energy Conversion II 4.0 Credits**
Covers dynamic behavior and transient phenomena of rotating machines and the mathematical models used to describe them, generalized machine theory, measurement of parameters for the mathematical models, and measurement of dynamic and transient behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 431 [Min Grade: D]

**ECEP 441 Protective Relaying 3.0 Credits**
Covers operating principles of electromechanical and static relays, fault clearance, and protection of individual parts of a power system. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 411 [Min Grade: D] (Can be taken Concurrently)ECEP 352 [Min Grade: D]

**ECEP 451 Power Electronic Converter Fundamentals 3.0 Credits**
Fundamentals of power electronics that include waveforms, basic power switch properties and magnetic circuits. Introduction to basic power electronic converter circuits: diode and phase-controlled rectifies and inverters; switch-mode converters. Applications to DC and AC power supply systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 352 [Min Grade: D]

**ECEP 452 Experimental Study of Power Electronic Converters 3.0 Credits**
Experimental study of common power electronic converters: diode rectifiers, phase-controlled rectifies, switch-mode inverters. Both hardware and software studies. Additional lectures on: Study of DC-DC switch-mode converters.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 451 [Min Grade: D]

**ECEP 453 Applications of Power Electronic Converters 3.0 Credits**
Provides a first look at various power electronic applications in residential, commercial and industrial sites. Examples include utility application such as static var compensators (SVC), thyristor switch capacitors (TSC), high voltage direct-current (HVDC) transmission systems among others. In addition, fundamentals of motor drives and their controls are covered. Examples include induction, DC synchronous and specialized motors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 451 [Min Grade: D]

**ECEP 461 High Voltage Laboratory 1.0 Credit**
Requires students to perform four basic experiments to become familiar with high-voltage techniques and then do a high-voltage design project of their own choosing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 352 [Min Grade: D]

**ECEP 471 Power Seminar I 0.5 Credits**
Discusses current developments in power system operation and research, concentrating on current and future energy sources.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEP 472 Power Seminar II 0.5 Credits**
Discusses current developments in power system operation and research, concentrating on generating stations, transmission lines, and substations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEP 473 Power Seminar III 0.5 Credits**
Discusses current developments in power system operation and research, concentrating on distribution, security, and economics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEP 480 Solar Energy Engineering 3.0 Credits**
Covers design of grid-connected and battery backup grid-connected photovoltaic systems. Both electrical and mechanical aspects are included. Topics include system components (solar cells, charge controllers, maximum power point trackers, inverters, etc.), system economics, computer and web-based design aids, electrical codes and standards, externalities of PV systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D] or ECEE 352 [Min Grade: D] or CHE 431 [Min Grade: D] or ECEP 380 [Min Grade: D]

**ECEP 490 Special Topics in Power Engineering 12.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEP 497 Research in Power Systems 0.5-12.0 Credits**
Requires independent study in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 499 Independent Study In Power Engineering 0.5-12.0 Credits**
Requires independent study in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

# Elec Computer Engr-Systems Courses

**ECES 201 Introduction to Audio-Visual Signals 4.0 Credits**
This introductory engineering course will focus on the digital signal representations commonly used in prevailing entertainment media: audio, images, and video. It will explore how each medium is represented digitally and convey the signal processing concepts used in storing, manipulating, transmitting, and rendering such content. The goal of the course is to provide non-engineering students with a fundamental understanding of core digital signal processing methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATH 122 [Min Grade: D]

**ECES 301 Transform Methods and Filtering 4.0 Credits**
This course covers the engineering related concepts of signals and systems, their modeling and analysis. We discuss the problem of formulation of physical systems, plus mathematical solution of models (equations). Continuous-time signals and systems, discrete-time signals and systems, linear time-invariant systems, convolution integrals and sums, Fourier series, Fourier, Laplace and Z-transforms, and system functions will be studied.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D] or MATH 262 [Min Grade: D] or MATH 210 [Min Grade: D]) and ECE 201 [Min Grade: D]

**ECES 302 Transform Methods and Filtering 4.0 Credits**
Covers the Fourier series and the Fourier transform, sinusoidal steady-state analysis and filtering, discrete-time systems and the Z-transform, discrete Fourier transform, network functions and stability, magnitude, phase, poles and zeroes, Nyquist criterion, the Nyquist plot and root loci, stability of one-ports, sensitivity, worst-case design and failure-tolerance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D] or MATH 262 [Min Grade: D] or MATH 210 [Min Grade: D]) and ECE 201 [Min Grade: D]

**ECES 303 Transform Methods II 3.0 Credits**
This course covers the engineering related concepts of signals and systems, their modeling and analysis. We discuss the problem of formulation of physical systems, plus mathematical solution of models (equations). Continuous-time signals and systems, discrete-time signals and systems, linear time-invariant systems, convolution integrals and sums, Fourier series, Fourier, Laplace and Z-transforms, and system functions will be studied.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 301 [Min Grade: D]

**ECES 304 Dynamic Systems and Stability 4.0 Credits**
Covers linear time-invariant circuits and systems; two-and multi-terminal resistors, operational-amplifier circuits, first-order circuits, linear and nonlinear second-order systems, state equation and state variables, eigenvalues and eigenvectors, zero-input response, qualitative behavior of x'=Ax (stability and equilibria), qualitative behavior of x'=f(x), phase portraits, equilibrium states.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D]

**ECES 306 Analog & Digital Communication 4.0 Credits**
Covers signal sampling and reconstruction; modulation, angle modulation; digital communications systems, digital transmission.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D]

**ECES 352 Introduction to Digital Signal Process 4.0 Credits**
Covers discrete-time signals, analog-digital conversion, time and frequency domain analysis of discrete-time systems, analysis using Z-transform, introduction to digital filters, discrete-time Fourier transform, Discrete Fourier Transform (DFT), and Fast Fourier Transform (FFT).
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D]

**ECES 354 Wireless, Mobile & Cellular Communications 4.0 Credits**
Covers concepts of wireless systems; propagation effects, including loss, dispersion, fading, transmission, and reception; mobile systems, including design of base units and mobile units; micro cells and pico cells; cell division, including frequency use and reuse; concepts of FDMA, TDMA, and CDMA; error rates and outage probability; and circuits and components for wireless and mobile systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 306 [Min Grade: D]

**ECES 356 Theory of Control 4.0 Credits**
Covers the foundations of control theory. Includes experiments and demonstrations during lectures and labs that may be jointly held, taking advantage of multimedia and computer-controlled apparatus.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 304 [Min Grade: D]

**ECES 358 Computer Control Systems 4.0 Credits**
Reviews principles of applications of computer control systems to a variety of industries and technologies, including manufacturing processes, robotic cells, machine cells, chemical processes, network control, investment portfolio control, and real-time expert and learning systems for diagnostics and quality control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 356 [Min Grade: D]

**ECES 390 Special Topics 4.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 411 Convex Optimization in Engineering Systems 3.0 Credits**
Covers fundamental of convex optimization including convex sets, convex functions, linear and nonlinear constraints, complementary slackness, Lagrange multipliers, Lagrangian duality, and quadralic programming. Focuses on applications (e.g., signal processing, communications, computer networking, and portfolio management). Focuses on use of Matlab or equivalent software.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D] and (ENGR 361 [Min Grade: D] or ECE 361 [Min Grade: D])

**ECES 412 Simulation of Stochastic Engineering Systems 3.0 Credits**
Covers algorithms for generation of pseudo-random numbers, generation of random variates using the inverse transform, acceptance rejection techniques, Monte Carlo simulation, basics of point and interval estimation and hypothesis testing. Coverage of Markov chains, Markov chain Monte Carlo, Metropolis algorithm, simulated annealing, as time permits. Applications include computer networks, statistical physics, derivative pricing. Focus on use of Matlab or equivalent software.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D] and (ENGR 361 [Min Grade: D] or ECE 361 [Min Grade: D])

**ECES 413 Strategies for Repeated Games 3.0 Credits**
Covers the gambler's ruin problem, optimality of bold play for subfair games, the Martingale betting system, Kelly betting and the maximum growth rate in superfair games, the multi-armed bandit and it generalizations, Parrondo's paradox for coupled subfair games, basics of auction theory. Focus on use of Matlab or equivalent software.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D] and (ENGR 361 [Min Grade: D] or ECE 361 [Min Grade: D])

**ECES 421 Communications I 3.0 Credits**
Covers analog communications, including linear modulation methods (AM, DSB, SSB), exponential modulation (FM, PM), and noise effects on analog communication systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 306 [Min Grade: D]

**ECES 422 Communications II 3.0 Credits**
Covers analog (PAM, PPM) and digital (PCM, DM) pulse modulation systems, entropy, source coding, and channel coding.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 421 [Min Grade: D]

**ECES 423 Communications III 3.0 Credits**
Covers digital transmission systems, baseband and passband, spread-spectrum communications, and basics of wireless and mobile systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 422 [Min Grade: D]

**ECES 434 Applied Digital Signal Processing 4.0 Credits**
This course explores digital signal processing (DSP) concepts through the context of current applications, which range from video encoding to human genome analysis. Topics such as sampling, aliasing, and quantization, are considered in terms of the constraints of particular applications. Discrete-time linear systems, frequency-domain analysis, and digital filtering using Discrete Fourier Transform are examined in-depth and realized through application-specific lab projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 352 [Min Grade: D]

**ECES 435 Recent Advances in Digital Signal Processing 4.0 Credits**
Digital signal processing algorithms once thought to be impractical are now implemented in devices, such as household appliances & mobile phones. This course explores the computationally-intensive DSP methods including short-time linear prediction, cepstral analysis, and complex phase reconstruction as well as alternative signal representations and transforms, including the Hilbert, Chirp, and Discrete Cosine Transforms. Laboratory projects will focus on the implementation of these methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 352 [Min Grade: D]

**ECES 436 Multi-disciplinary Digital Signal Processing 4.0 Credits**
The applications of digital signal processing (DSP) span a wide range of problem domains and disciplines. This course explores the multi-disciplinary aspects of DSP by focusing on a core set of common methods applicable to problems in many fields, such as periodicity detection, signal and power spectrum estimation, and data modeling. Laboratory projects will utilize experiments drawn from a diversity of fields, including medicine, music analysis, image processing,voice/data communications and robotics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 352 [Min Grade: D]

**ECES 444 Systems and Control I 4.0 Credits**
This course reviews classical control: analysis and design, state space approach to systems analysis and control; Eigenvalue/Eigenvector analysis, model decomposition, state space solutions and Cayley-Hamilton technique and applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 356 [Min Grade: D]

**ECES 445 Systems and Control II 4.0 Credits**
This course covers Eigenvector single-value decomposition and modal decomposition; controllability, observability and Kalman canonical forms; state controllers and observers and the separation principle.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 444 [Min Grade: D]

**ECES 446 Systems and Control III 4.0 Credits**
This course covers linear quadratic control, non-linear stability and analysis. Current topics in control include Robust, H-infinity, and Fuzzy Control concepts.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 445 [Min Grade: D]

**ECES 462 Medical Robotics II 3.0 Credits**
This course will review the emerging, multidisciplinary field of Medical Robotics. The course includes multiple site/field visits to observe Medical Robot systems demonstrations and interaction with the medical team and system manufacturers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 461 [Min Grade: D]

**ECES 490 Special Topics in Systems Engineering 12.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECES 497 Research in Systems Engineering 0.5-12.0 Credits**
Electrical engineering students only. Requires independent research in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECES 499 Supervised Study in Systems Engineering 0.5-20.0 Credits**
Requires independent study in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

# Electrical Computer Engr Courses

**ECE 101 Electrical and Computer Engineering in the Real World 1.0 Credit**
This seminar introduces students to highly visible and compelling applications of ECE through the use of familiar real-world applications. The course will highlight some of the high-impact advances of ECE and the importance of ECE in our daily lives. Fundamental concepts, such as electricity, light, computing, networking, and signal processing will be introduced in this context and explained at an introductory level. This course is intended to inspire students to pursue ECE and will lead them directly into ECE 102.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 102 Applications of Electrical and Computer Engineering 2.0 Credits**
Introduces the basic fundamentals of ECE through the use of real-world applications. The course will introduce Signals and Systems, Analog electronic basics, as well as Digital numbers and systems. The course will introduce students to basic ECE material, preparing the students for ECE 200 and ECE 201.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 121 Introduction to Entertainment Engineering 3.0 Credits**
This introductory survey course will focus on the four prevailing entertainment media: music, images, video, and games. We will explore how each medium is represented digitally and reveal the technologies used to capture, manipulate and display such content. Technical standards used in everyday entertainment devices (mp3, H.264, JPEG 1080p, HDMI) will be explained in layman's terms. The goal is to provide students with technical literacy for using digital media.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 190 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECE 200 Digital Logic Design 3.0 Credits**
Number systems and representation, two's complement arithmetic, digital logic devices, switching algebra, truth tables, minimization of Boolean functions, combinational logic design and analysis, sequential circuit analysis and design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CS 170 [Min Grade: D] or TDEC 132 [Min Grade: D] or CS 171 [Min Grade: D] or ENGR 103 [Min Grade: D] or ENGR 104 [Min Grade: D]

**ECE 201 Foundations of Electric Circuits 3.0 Credits**
Covers basic electric circuit concepts and laws; circuit theorems; mesh and node methods; analysis of first-and second-order electric circuits; force and natural response; sinusoidal steady state analysis; complex frequency.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is CAE or classification is Freshman
**Prerequisites:** PHYS 211 [Min Grade: D] or TDEC 115 [Min Grade: D] or PHYS 281 [Min Grade: D] or PHYS 102 [Min Grade: D]

**ECE 203 Programming for Engineers 3.0 Credits**
Fundamentals of computer organization; rudiments of programming including data types, arithmetic and logical expressions, conditional statements, control structures; problem solving techniques for engineers using programming; object-oriented programming; arrays; simulation of engineering systems; principles of good programming practice.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECE 211 Electrical Engineering Principles 3.0 Credits**
Not open to electrical or mechanical engineering students. Covers basic techniques of electric circuit analysis, electronic devices, amplifiers, operational amplifier, and fundamentals of instrumentation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is EE or major is MECH or classification is Freshman
**Prerequisites:** (MATH 201 [Min Grade: D] or ENGR 231 [Min Grade: D] or MATH 261 [Min Grade: D]) and (PHYS 211 [Min Grade: D] or PHYS 281 [Min Grade: D] or PHYS 102 [Min Grade: D])
**Corequisite**: ECE 212

**ECE 212 Electrical Engineering Principles Laboratory 1.0 Credit**
Not open to electrical or mechanical engineering students. Includes experiments involving concepts discussed in ECE 211.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is EE or major is MECH or classification is Freshman
**Corequisite**: ECE 211

**ECE 290 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECE 361 Probability for Engineers 3.0 Credits**
This course will cover topics related to probability and statistics. Probability topics include sample space and probability, discrete and continuous random variables, expectation, variance, covariance, correlation, conditional expectation, conditional variance, the weak and strong law of large numbers and the central limit theorem. Statistics topics include properties of a random sample, principles of data reduction, and point estimation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENGR 202 [Min Grade: D] and (ENGR 231 [Min Grade: D] or MATH 261 [Min Grade: D])

**ECE 362 Engineering Statistics 3.0 Credits**
This course will cover topics related to statistics and probability. Probability topics include sample space and probability; discrete and continuous random variables, expectation, variance, the law of large numbers and the central limit theorem. Statistics topics include properties of a random sample, principles of data reduction, point estimation, hypothesis testing, interval estimation, and linear regression.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ENGR 202 [Min Grade: D] and ENGR 231 [Min Grade: D]) or (ENGR 202 [Min Grade: D] and MATH 261 [Min Grade: D])

**ECE 390 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECE 391 Introduction to Engineering Design Methods 1.0 Credit**
Introduces the design process, including information retrieval, problem definition, proposal writing, patents, and design notebooks. Includes presentations on problem areas by experts from industry, government, and education.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**ECE 491 [WI] Senior Design Project I 2.0 Credits**
Introduces the design process, including information retrieval, problem definition, proposal writing, patents, and design notebooks. Includes presentations on problem areas by experts from industry, government, and education. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**ECE 492 [WI] Senior Design Project II 2.0 Credits**
Continues ECE 491. Requires written and oral progress reports. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECE 491 [Min Grade: D]

**ECE 493 Senior Design Project III 4.0 Credits**
Continues ECE 492. Requires written and oral final reports, including oral presentations by each design team at a formal Design Conference open to the public and conducted in the style of a professional conference.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECE 492 [Min Grade: D]

# Electrical Engineering Lab Courses

**ECEL 301 [WI] Electrical Engineering Laboratory 2.0 Credits**
Offers laboratory experiences in each of the five ECE tracks: computers, controls/robotics, electronics, power and energy, and telecommunications. Each lab consists of a stand-alone module containing: lecture material providing basic theory, references, and laboratory experiments. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECE 200 [Min Grade: D] and ECE 201 [Min Grade: D] and (TDEC 132 [Min Grade: D] or TDEC 133 [Min Grade: D] or ENGR 104 [Min Grade: D] or ENGR 103 [Min Grade: D])

**ECEL 302 ECE Laboratory II 2.0 Credits**
Offers laboratory experiences in each of the five ECE tracks: computers, controls/robotics, electronics, power and energy, and telecommunications. Each lab consists of a stand-alone module containing: lecture material providing basic theory, references, and laboratory experiments. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D] (Can be taken Concurrently)ECEL 301 [Min Grade: D]

**ECEL 303 ECE Laboratory III 2.0 Credits**
Covers basic digital signal processing concepts, an introduction to analog-to-digital and digital-to-analog converters, and power supply design using analog IC devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEL 302 [Min Grade: D]

**ECEL 304 ECE Laboratory IV 2.0 Credits**
This course offers laboratory experience, using both modeling software and digital and analog hardware relevant to both electrical and computer engineers. Multi-week design projects and design teams are used to prepare students for Senior Design work.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEL 303 [Min Grade: D]

**ECEL 311 ECE Laboratory Methods I 3.0 Credits**
Introduces students to MATLAB and PSpice, industry standard CAD software for electronics (analog and digital) and systems engineers. Solve DC bias, DC sweep, AC sweep, and transient problems in PSpice and MATLAB. Build and design simple digital circuits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 200 [Min Grade: D] and ECE 201 [Min Grade: D] and ENGR 103 [Min Grade: D]

**ECEL 312 ECE Laboratory Methods II 3.0 Credits**
Covers introduction to transistor circuits, PSpice simulations of active devices, transfer function analysis, Bode analysis, active filter analysis and design. Programming and use of Microprocessors and/or FPGA. Perform measurements on devices and circuits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEL 301 [Min Grade: D] or ECEL 311 [Min Grade: D]

**ECEL 401 Lightwave Engineering Laboratory 3.0 Credits**
Teaches fundamentals of interaction of light with matter. Waves and photons. nterference and diffraction. Optical fibers and free-space optics. Introduces students to optical communication and imaging.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D] and ECEE 302 [Min Grade: D]) or (ECEL 311 [Min Grade: D] and ECEL 312 [Min Grade: D] and ECEE 304 [Min Grade: D])

**ECEL 402 Nano-Photonics Laboratory 3.0 Credits**
Teaches a fundamental knowledge of nanophotonic materials, devices, and applications in a hands-on laboratory setting. Introduces students to photonic bandgaps, photonic crystals, optical sensing methods, holography methods and materials, concepts of surface plasmons and Plasmon resonance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D] and ECEE 304 [Min Grade: D]) or (ECEL 311 [Min Grade: D] and ECEL 312 [Min Grade: D] and ECEE 304 [Min Grade: D])

**ECEL 403 Bio-Photonics Laboratory 3.0 Credits**
Teaches the fundamentals of the interaction of light with matter. Introduces students to different types of optical detection for biomedical applications,Quantized states of matter, Energy levels of atoms and molecules, Absorption, Scattering, Fluorescence, Imaging of cells and molecules, Spectroscopy, and Cancer precursors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D] and ECEE 304 [Min Grade: D]) or (ECEL 311 [Min Grade: D] or ECEL 312 [Min Grade: D] or ECEE 304 [Min Grade: D])

**ECEL 404 Software Defined Radio Laboratory 3.0 Credits**
This course introduces students to the concept of software defined radio using the USRP hardware platform and GNU Radio software. Functional blocks of wireless communications systems will be discussed, programmed in Python, and tested on hardware.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D] and ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D]) or (ECEL 311 [Min Grade: D] and ECEL 312 [Min Grade: D] and ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D])

**ECEL 405 Digital Systems Laboratory 3.0 Credits**
Students will gain practical knowledge of digital systems and signal processing by designing, simulating, constructing, testing and refining a digital audio recording system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D] and ECES 301 [Min Grade: D]) or (ECEL 311 [Min Grade: D] and ECEL 312 [Min Grade: D] and ECES 301 [Min Grade: D])

**ECEL 407 General Purpose GPU Programming 3.0 Credits**
This course will teach students how to develop parallel algorithms for the GPU and implement them using the CUDA progamming interface.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D] and ECEC 301 [Min Grade: D] and ECEC 355 [Min Grade: D]) or (ECEL 311 [Min Grade: D] and ECEL 312 [Min Grade: D] and ECEC 301 [Min Grade: D] and ECEC 355 [Min Grade: D])

**ECEL 490 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Construction Management

*Bachelor of Science Degree: 184.5 quarter credits*

## About the Program

Construction management is a dynamic profession that is a combination of art and science. While an understanding of the technical aspects of construction is extremely important, it is also essential that construction professionals have knowledge of the business and management aspects of the profession. While construction has traditionally been a very conservative industry, the increasing rate of technological development and competition in the industry serves to accelerate the development of new construction methods, equipment, materials, and management techniques. As a result of these forces, there is an increasing need for innovative and professionally competent construction professionals.

The Construction Management major prepares students for all phases of operation and management of the construction organization including cost estimating, project scheduling, and planning. Students are able to choose from a wide range of subjects in the social sciences and humanities to satisfy electives in the liberal arts and free elective requirements. Pursuing part-time, degree completion on average takes six years.

Students in Drexel's Construction Management program receive broad academic, technical, business, and construction management courses that are designed to produce well-rounded construction professionals. Students interested in extending their construction management studies into real estate development should consider the concentration in real estate. This concentration in real estate is designed for students to attain the knowledge and skills required to create and maintain built environments for living, working and entertainment purposes, as well as to explore issues in the real estate development process and the industry as a whole.

## Program Delivery Options

Program delivery options for the Construction Management program include:

- A traditional 5-year with co-op
- A part-time study option
- The Drexel University and Burlington County College (BCC) option (Available for currently enrolled, full-time Drexel at BCC Construction Management Students):
  Drexel University and Burlington County College (BCC) joined together to create a unique educational opportunity: Drexel at BCC. This partnership enabled BCC students to earn a bachelor's degree from Drexel University while remaining on BCC's Mount Laurel campus. Drexel University has elected to phase out its Drexel at BCC on-site program and will no longer be accepting students.

## Additional Information

For additional information, visit the Construction Management (http://drexel.edu/engmgmt/cmgt) website or contact:

James Tsafos, PhD

215.895.6024
tsafosjm@drexel.edu

## Degree Requirements

**English/Communication**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| COM 230 | Techniques of Speaking | 3.0 |
| COM 270 [WI] | Business Communication | 3.0 |
| COM 310 [WI] | Technical Communication | 3.0 |
| COM 330 | Professional Presentations | 3.0 |

**Mathematics**

| | | |
|---|---|---|
| MATH 110 | Precalculus | 3.0 |
| MATH 121 | Calculus I | 4.0 |

**Science**

| | | |
|---|---|---|
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| ENVS 260 | Environmental Science and Society | 3.0 |
| ENVS 272 | Physical Geology | 4.0 |
| PHYS 182 | Applied Physics I | 3.0 |

**Business**

| | | |
|---|---|---|
| ACCT 115 | Financial Accounting Foundations | 4.0 |
| BLAW 201 | Business Law I | 4.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| ECON 202 | Principles of Macroeconomics | 4.0 |
| FIN 301 | Introduction to Finance | 4.0 |
| HRMT 323 | Principles of Human Resource Administration | 4.0 |
| ORGB 300 [WI] | Organizational Behavior | 4.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |

**Humanities and Social Science**

| | | |
|---|---|---|
| PHIL 301 | Business Ethics | 3.0 |
| Three Humanities and Social Science Electives | | 9.0 |

**Professional Core - Construction Science**

| | | |
|---|---|---|
| CMGT 161 | Building Materials and Construction Methods I | 3.0 |
| CMGT 162 | Building Materials and Construction Methods II | 3.0 |
| CMGT 163 | Building Materials and Construction Methods III | 3.0 |
| CMGT 251 | Construction Surveying | 3.0 |
| CMGT 263 | Understanding Construction Drawings | 3.0 |
| CMGT 266 | Building Systems I | 3.0 |
| CMGT 267 | Building Systems II | 3.0 |
| CMGT 365 | Soil Mechanics in Construction | 4.0 |
| CMGT 371 | Structural Aspects in Construction I | 3.0 |
| CMGT 372 | Structural Aspects in Construction II | 3.0 |

**Professional Core - Construction**

| | | |
|---|---|---|
| CMGT 101 | Introduction to Construction Management | 3.0 |
| CMGT 240 | Economic Planning for Construction | 3.0 |
| CMGT 261 | Construction Safety | 3.0 |
| CMGT 262 | Building Codes | 3.0 |
| CMGT 361 | Contracts And Specifications I | 3.0 |

| | | |
|---|---|---|
| CMGT 362 | Contracts and Specifications II | 3.0 |
| CMGT 363 | Estimating I | 3.0 |
| CMGT 364 | Estimating II | 3.0 |
| CMGT 450 | Construction Management of Field Operations | 3.0 |
| CMGT 461 | Construction Management | 3.0 |
| CMGT 463 | Value Engineering | 3.0 |
| CMGT 467 | Techniques of Project Control | 4.0 |
| **Construction Electives** | | |
| Select four of the following: | | 12.0 |
| CMGT 265 | Information Technologies in Construction | |
| CMGT 355 | Introduction to Sustainability in Construction | |
| CMGT 451 | Heavy Construction Principles & Practices | |
| CMGT 465 | Marketing Construction Services | |
| CMGT 468 | Real Estate | |
| CMGT 469 | Construction Seminar: Contemporary Issues | |
| CMGT 470 | Productivity in Construction | |
| Other Approved CMGT Elective * | | |
| **Construction Capstone** | | |
| CMGT 499 | Construction Management Independent Study Project | 3.0 |
| **University Requirements** | | |
| UNIV G101 | The Drexel Experience | 2.0 |
| **Free Electives** | | 12.0 |
| **Total Credits** | | **184.5** |

\*   Students may choose another construction elective but the permission of the Program is required.

# Sample Plan of Study

| Term 1 | | Credits |
|---|---|---|
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| CMGT 101 | Introduction to Construction Management | 3.0 |
| CMGT 161 | Building Materials and Construction Methods I | 3.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| MATH 110 | Precalculus | 3.0 |
| UNIV G101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **18.5** |
| **Term 2** | | |
| ACCT 115 | Financial Accounting Foundations | 4.0 |
| CMGT 162 | Building Materials and Construction Methods II | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV G101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **15.0** |
| **Term 3** | | |
| CMGT 163 | Building Materials and Construction Methods III | 3.0 |
| CMGT 263 | Understanding Construction Drawings | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |

| | | |
|---|---|---|
| PHYS 182 | Applied Physics I | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 4** | | |
| CMGT 261 | Construction Safety | 3.0 |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 202 | Principles of Macroeconomics | 4.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **13.0** |
| **Term 5** | | |
| CMGT 262 | Building Codes | 3.0 |
| COM 270 [WI] | Business Communication | 3.0 |
| ENVS 272 | Physical Geology | 4.0 |
| PHIL 301 | Business Ethics | 3.0 |
| Humanities/Social science elective | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 6** | | |
| CMGT 240 | Economic Planning for Construction | 3.0 |
| CMGT 266 | Building Systems I | 3.0 |
| CMGT 371 | Structural Aspects in Construction I | 3.0 |
| COM 310 [WI] | Technical Communication | 3.0 |
| ORGB 300 [WI] | Organizational Behavior | 4.0 |
| | **Term Credits** | **16.0** |
| **Term 7** | | |
| BLAW 201 | Business Law I | 4.0 |
| CMGT 267 | Building Systems II | 3.0 |
| CMGT 371 | Structural Aspects in Construction I | 3.0 |
| COM 330 | Professional Presentations | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 8** | | |
| CMGT 251 | Construction Surveying | 3.0 |
| CMGT 361 | Contracts And Specifications I | 3.0 |
| CMGT 363 | Estimating I | 3.0 |
| ENVS 260 | Environmental Science and Society | 3.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |
| | **Term Credits** | **16.0** |
| **Term 9** | | |
| CMGT 362 | Contracts and Specifications II | 3.0 |
| CMGT 364 | Estimating II | 3.0 |
| HRMT 323 | Principles of Human Resource Administration | 4.0 |
| Construction Management elective* | | 3.0 |
| Humanities/Social science elective | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 10** | | |
| CMGT 365 | Soil Mechanics in Construction | 4.0 |
| CMGT 450 | Construction Management of Field Operations | 3.0 |
| CMGT 467 | Techniques of Project Control | 4.0 |
| FIN 301 | Introduction to Finance | 4.0 |
| | **Term Credits** | **15.0** |

**Term 11**

| CMGT 461 | Construction Management | 3.0 |
|---|---|---|
| Two Construction Management electives[*] | | 6.0 |
| Humanities/Social science elective | | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **15.0** |

**Term 12**

| CMGT 463 | Value Engineering | 3.0 |
|---|---|---|
| CMGT 499 | Construction Management Independent Study Project | 3.0 |
| Construction Management elective[*] | | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **12.0** |

**Total Credit: 184.5**

[*]  See degree requirements.

# Real Estate Concentration

The concentration in real estate provides students with training in issues such as project finance, real estate as investment, design and construction, operations, development law, environmental remediation, public policy, market analysis, and architecture. For this specialization, students take the same Construction Management (CMGT) core requirements, replacing some electives with the concentration-specific courses.

**English/Communication**

| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
|---|---|---|
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| COM 230 | Techniques of Speaking | 3.0 |
| COM 270 [WI] | Business Communication | 3.0 |
| COM 310 [WI] | Technical Communication | 3.0 |
| COM 330 | Professional Presentations | 3.0 |

**Mathematics**

| MATH 110 | Precalculus | 3.0 |
|---|---|---|
| MATH 121 | Calculus I | 4.0 |

**Science**

| ENVS 260 | Environmental Science and Society | 3.0 |
|---|---|---|
| ENVS 272 | Physical Geology | 4.0 |
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| PHYS 182 | Applied Physics I | 3.0 |

**Business**

| ACCT 115 | Financial Accounting Foundations | 4.0 |
|---|---|---|
| BLAW 201 | Business Law I | 4.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| ECON 202 | Principles of Macroeconomics | 4.0 |
| FIN 301 | Introduction to Finance | 4.0 |
| HRMT 323 | Principles of Human Resource Administration | 4.0 |
| ORGB 300 [WI] | Organizational Behavior | 4.0 |

| STAT 201 | Introduction to Business Statistics | 4.0 |
|---|---|---|

**Humanities and Social Science**

| PHIL 301 | Business Ethics | 3.0 |
|---|---|---|
| Three Humanities and Social Science Electives | | 9.0 |

**Professional Core - Construction Science**

| CMGT 161 | Building Materials and Construction Methods I | 3.0 |
|---|---|---|
| CMGT 162 | Building Materials and Construction Methods II | 3.0 |
| CMGT 163 | Building Materials and Construction Methods III | 3.0 |
| CMGT 251 | Construction Surveying | 3.0 |
| CMGT 263 | Understanding Construction Drawings | 3.0 |
| CMGT 266 | Building Systems I | 3.0 |
| CMGT 267 | Building Systems II | 3.0 |
| CMGT 365 | Soil Mechanics in Construction | 4.0 |
| CMGT 371 | Structural Aspects in Construction I | 3.0 |
| CMGT 372 | Structural Aspects in Construction II | 3.0 |

**Professional Core - Construction**

| CMGT 240 | Economic Planning for Construction | 3.0 |
|---|---|---|
| CMGT 101 | Introduction to Construction Management | 3.0 |
| CMGT 261 | Construction Safety | 3.0 |
| CMGT 262 | Building Codes | 3.0 |
| CMGT 361 | Contracts And Specifications I | 3.0 |
| CMGT 362 | Contracts and Specifications II | 3.0 |
| CMGT 363 | Estimating I | 3.0 |
| CMGT 364 | Estimating II | 3.0 |
| CMGT 450 | Construction Management of Field Operations | 3.0 |
| CMGT 461 | Construction Management | 3.0 |
| CMGT 463 | Value Engineering | 3.0 |
| CMGT 467 | Techniques of Project Control | 4.0 |

**Concentration in Real Estate**

| ARCH 432 | The Development Process | 3.0 |
|---|---|---|
| CMGT 468 | Real Estate | 3.0 |
| REAL 310 | Introduction to Real Estate | 3.0 |
| REAL 320 | Real Estate Law - Principle & Practice | 3.0 |
| REAL 330 | Facilities & Property Management | 3.0 |
| REAL 470 | Real Estate Investments - Market & Feasibility Analysis | 3.0 |

**University Requirements**

| UNIV 101 | The Drexel Experience | 2.0 |
|---|---|---|
| **Free Electives** | | 9.0 |
| **Total Credits** | | **184.5** |

# Career Opportunities

The graduates of the construction management program have secured positions as project managers, estimators, schedulers, and field superintendents for general contractors, subcontractors, and construction managers. Many are employed as owner representatives working for architectural firms, consulting engineering firms, commercial companies and institutions that have needs for building or other construction projects. Some have risen to executive positions within companies while others own their own firms. Graduates have also returned to the program after obtaining positions in the field to teach and share expertise.

The College of Engineering offers a Bachelor of Science in Construction Management as well as a Certificate Program in Construction Management. Depending on student goals, each option provides a strong educational foundation for successful performance and/or entrance into the construction industry.

**Employers**

Some of the companies that have hired Drexel students as co-op or full-time employees:

- Gilbane Building Company
- L.F. Driscoll Construction Company
- American Infrastructure
- Pennoni Associates
- Brandywine Realty Trust
- Turner Construction Company
- Intech Construction Managers
- Urban Engineers, Inc.

**Potential Careers**

*Construction Manager*: Coordinates a venture from its initial development through final construction. Develops a schedule and ensures the project is completed on time and within budget. Obtains necessary licenses and permits and oversees the progress of the project.

*Cost Estimator*: Prepares information about costs that are necessary for a business to bid on a contract or to determine the profitability of a proposed product. Assembles information about factors that can influence costs such as materials, labor, location, and special machinery requirements, including computer hardware and software.

*Project Manager*: Develops requirements, budgets, and timetables for a firm's construction plans to ensure that the projects are successful. Determines the tasks to complete, assigns responsibilities to team members, and sees the project through from conception to completion.

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more information on career opportunities.

# Minor in Construction Management

Students in civil engineering, architectural engineering and architecture may select to pursue construction management as a minor area of study. Because construction is inherently related to design in these disciplines, the construction management minor can be a natural extension of each field of study.

The requirements for the minor include:

- Completion of a minimum of 24.0 credits.
- Courses used to fulfill general education requirements may not be counted toward an academic minor.
- Up to nine credits earned within the student's major may be counted toward the minor with minor department approval.
- Prerequisite courses may be counted toward the minor if recommended by the minor department.

**Required Courses**

| | | |
|---|---|---|
| CMGT 161 | Building Materials and Construction Methods I | 3.0 |
| CMGT 162 | Building Materials and Construction Methods II | 3.0 |
| CMGT 361 | Contracts And Specifications I | 3.0 |

| | | |
|---|---|---|
| CMGT 362 | Contracts and Specifications II | 3.0 |
| CMGT 363 | Estimating I | 3.0 |
| CMGT 467 | Techniques of Project Control | 4.0 |
| Select two of the following: * | | 6.0 |
| CMGT 261 | Construction Safety | |
| CMGT 263 | Understanding Construction Drawings | |
| CMGT 364 | Estimating II | |
| CMGT 461 | Construction Management | |
| CMGT 463 | Value Engineering | |
| CMGT 465 | Marketing Construction Services | |

\*   Choice of electives must be approved by the department based on the student's major field and prior experience.

Certain courses within the student's major may also be used to meet the minor requirements. These include:

| | | |
|---|---|---|
| ARCH 261 | Environmental Systems I | 3.0 |
| ARCH 262 | Environmental Systems II | 3.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| ARCH 161 | Architectural Construction * | 3.0 |
| **Total Credits** | | **12.0** |

\*   ARCH 161 can be substituted for CMGT 161 for Architects. An elective may be substituted for CMGT 162.

# Construction Management Faculty

Jeffrey Beard, PHD, MGTPRO *(Georgia Institute of Technology)*. Associate Clinical Professor. Project delivery methodologies; Systems decomposition for civil and industrial projects; Service Life Predictors for the Built Environment and its Components; Design and Construction Entrepreneurship; History of Urban Engineering and ConstructionHistory of Urban Engineering and Construction.

Douglas Carney, MBA, AIA, LEED, AP *(Eastern University)*. Assistant Clinical Professor. Architecture; Contract management; Master planning; Site analysis; Feasibility and zoning studies; Space needs and program development.

Charles Cook, PhD *(New York University)*. Assistant Clinical Professor. Construction management; project management; leadership and teambuilding; oral and written communication.

Edward Keeter, PhD *(Texas A&M University)*. Associate Clinical Professor. Integrated project management; Construction risk management; Construction management; Management of field operations.

Robert Muir, PhD, PE *(Drexel University) Program Director*. Associate Clinical Professor. Construction management; value engineering; management of field operations; planning and scheduling; project management; heavy and industrial construction.

Richard Sievert, PhD, PMP, CFM *(Northwestern University)*. Assistant Clinical Professor. Project management and construction management; value engineering; cost reduction and waste minimization; facilities planning and management; marketing and selling professional

services; quality management, engineering and construction business administration.

# Courses

**CMGT 101 Introduction to Construction Management 3.0 Credits**
This course will introduce the basic history and management concepts of the construction industry to students with the expectation that upon completion students will have an overview of the industry. Career choices, industry firms, and key players in the Construction Management process will be explored.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Junior or Senior

**CMGT 161 Building Materials and Construction Methods I 3.0 Credits**
This course is designed to explore the range of building materials in use today and their interrelationships in a construction project. Topics will include a study of the major components of construction materials, the selection process, specification, alternatives, procurement, placement and quality management for the building systems covered. Foundations, excavations, wood framing and steel construction and the role these materials play in the success of a project once chosen will be considered and evaluated.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is AE or major is CIVE

**CMGT 162 Building Materials and Construction Methods II 3.0 Credits**
Continues CMGT 161. Covers concrete, reinforced concrete, site cast and pre-cast concrete, brick and concrete masonry, reinforced masonry, and properties of these materials and construction methods associated with them.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is AE or major is CIVE
**Prerequisites:** CMGT 161 [Min Grade: D]

**CMGT 163 Building Materials and Construction Methods III 3.0 Credits**
Continues CMGT 162. Covers roofing systems, glass, glazing, windows, doors, cladding systems, interior finishes, the properties of these materials and construction methods associated with each of them.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is AE or major is CIVE
**Prerequisites:** CMGT 162 [Min Grade: D]

**CMGT 240 Economic Planning for Construction 3.0 Credits**
Covers techniques for economic decision making for building and infrastructure construction topics. Topics include cash flow, present worth analysis, equivalent annual worth, rate of return, risk analysis, and benefit/ cost analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is AE
**Prerequisites:** MATH 121 [Min Grade: D]

**CMGT 251 Construction Surveying 3.0 Credits**
Covers the theory and use of surveying instruments and principles of plane and topographic surveying. Introduces satellite positioning, geomatics, and other modern surveying techniques related to construction.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is AE
**Prerequisites:** MATH 121 [Min Grade: D]

**CMGT 261 Construction Safety 3.0 Credits**
Covers OSHA liability, general safety, hazard communication, fire, material handling, tools, welding, electricity, scaffolding, fall protection, cranes, heavy equipment, excavation, concrete, ladders and stairways, confined space entry, personal protective equipment, and health hazards. Course approved by the osha Training Institute.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is ARCH or major is CIVE or major is CMGT or major is EE.
Cannot enroll if classification is Freshman

**CMGT 262 Building Codes 3.0 Credits**
Familiarizes students with the content of the boca International Building Code (emphasizing the non-structural provisions), the purpose and intent of code requirements, and how to apply the code to structures and occupancies. Examines how the code is used as a tool in design and construction and prepares students for the advent of a single model building code planned for the nation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is ARCH or major is CIVE or major is CMGT or major is EE.
Cannot enroll if classification is Freshman

**CMGT 263 Understanding Construction Drawings 3.0 Credits**
This course examines a variety of construction documents, including drawings, details, graphic standards, sections, and quantities for competitive bidding and execution of projects. Both residential and commercial construction documents will be examined.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CMGT 161 [Min Grade: D] and CMGT 162 [Min Grade: D]

**CMGT 264 Construction Management of Field Operations 3.0 Credits**
This course is intended to equip students with the requisite knowledge and skills required to successfully manage and support construction field operations. Knowledge areas include contract administration, project engineering, site superintendence, and other topics critical to field operations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CMGT 101 [Min Grade: D] and CMGT 163 [Min Grade: D] and CMGT 263 [Min Grade: D]

**CMGT 265 Information Technologies in Construction 3.0 Credits**
The objective of this course is to expose students to a large variety of information technologies in construction and will discuss the impact of these technologies on work environments, processes, and work quality. Students will investigate a variety of issues surrounding IT in construction including implementation, standards, integration, knowledge management and the underlying technology.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CMGT 266 Building Systems I 3.0 Credits**
This course covers construction management and design concepts relating to heating, ventilation, and air conditioning systems and the integration of these systems into the building design and construction process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** PHYS 182 [Min Grade: D]

**CMGT 267 Building Systems II 3.0 Credits**
Continues CMGT 266. This course covers construction management concepts relating to electrical systems, wiring, lighting, signal and data systems, and transportation systems and the integration of these into the building design and construction process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CMGT 266 [Min Grade: D]

**CMGT 355 Introduction to Sustainability in Construction 3.0 Credits**
An overview of the design and construction of high performance buildings. Students will gain topical familiarity with the wide range of issues related to sustainable design and construction. The USGBC's green building certification program will be covered in detail. Both historical and contemporary case studies will be utilized.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 361 Contracts And Specifications I 3.0 Credits**
Analyzes construction contracts, specifications, and practices with regard to business law and liability. Required for construction management students. Elective for others. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CMGT 362 Contracts and Specifications II 3.0 Credits**
Continues CMGT 361. Examines contractor, architect, and engineer responsibilities through case studies and class discussions. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CMGT 361 [Min Grade: D]

**CMGT 363 Estimating I 3.0 Credits**
Covers discussion of the estimating function and review and applications of material quantity survey techniques used in estimating costs of construction projects. Includes types of approximate and precise methods of estimating and their uses, and computer applications. Required for construction management students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATH 110 [Min Grade: D] and CMGT 263 [Min Grade: D]

**CMGT 364 Estimating II 3.0 Credits**
Covers pricing and bidding of construction work including cost factors, labor and equipment, productivity factors, prices databases, job direct and indirect costs, methods of estimating time, materials, equipment, subcontractors' work, general expenses, and profit, bid preparations and submission, and computer applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CMGT 363 [Min Grade: D]

**CMGT 365 Soil Mechanics in Construction 4.0 Credits**
Gives an overview of the types of problems encountered in geotechnical construction. Subjects covered will be composition, groundwater fundamentals, settlement and consolidation, stability of earth slopes, types of foundations and behavior of difficult soils.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** CMGT 161 [Min Grade: D] and MATH 102 [Min Grade: D] and PHYS 182 [Min Grade: D]

**CMGT 366 Construction Accounting and Financial Management 3.0 Credits**
This course brings together all of the key principles from general business accounting, financial management, and engineering economics needed by construction managers vis-a-vis the unique characteristics of the construction industry, and addresses how these principles are specifically applied in the construction industry, and how they should interact effectively to ensure the efficient and profitable management of construction projects and companies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ACCT 116 [Min Grade: D] and CMGT 364 [Min Grade: D] and CIVE 240 [Min Grade: D]

**CMGT 371 Structural Aspects in Construction I 3.0 Credits**
The first of two course series designed specifically for construction management majors. The sequence addresses the interactions of different kinds of loads with common structural elements and design considerations for typical construction materials. This course places emphasis on the design of wood framed construction.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** CMGT 161 [Min Grade: D] and MATH 102 [Min Grade: D] and PHYS 182 [Min Grade: D]

**CMGT 372 Structural Aspects in Construction II 3.0 Credits**
The second part in a two-course sequence for Construction Management majors. The course places emphasis on the design and analysis of concrete and steel frame construction.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CMGT 371 [Min Grade: D]

**CMGT 380 Special Topics in Construction Management 12.0 Credits**
Examines a variety of topics in the construction industry. Past topics have included real estate.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CMGT 450 Construction Management of Field Operations 3.0 Credits**
This course is intended to equip students with knowledge and skills required to successfully manage and support construction field operations. Knowledge areas include contract administration, project engineering, site superintendence, and other topics critical to field operations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
**Prerequisites:** CMGT 101 [Min Grade: D] and CMGT 163 [Min Grade: D] and CMGT 263 [Min Grade: D]

**CMGT 451 Heavy Construction Principles & Practices 3.0 Credits**
This course is intended to provide students an introduction to the principles and practices employed in heavy construction. The course content is presented from a practical perspective focusing on actual field applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Sophomore

**CMGT 461 Construction Management 3.0 Credits**
Covers construction management concepts and practices, the management system, construction planning and programming, project control, environmental management, total quality management, and ethics in construction management. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is ARCH or major is CIVE or major is CMGT or major is INTR and classification is Junior or Pre-Junior or Senior.

**CMGT 463 Value Engineering 3.0 Credits**
Covers the value concept, value engineering job plan, and techniques of project selection.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CMGT 465 Marketing Construction Services 3.0 Credits**
Applies marketing principles to the construction industry. Includes understanding the roles of market research, business development planning, and networking techniques. Students will acquire the skills and techniques to prepare a winning presentation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Sophomore

**CMGT 467 Techniques of Project Control 4.0 Credits**
This course covers construction planning, scheduling, network systems, and communications required for project control, diagram logic, and claims prevention.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
**Prerequisites:** CMGT 163 [Min Grade: D] and CMGT 263 [Min Grade: D]

**CMGT 468 Real Estate 3.0 Credits**
Overview of the development process including site selection, residential densities, market analysis and cash flow analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**CMGT 469 Construction Seminar: Contemporary Issues 3.0 Credits**
This course is intended to prepare students for professional practice through a survey of the current and future state of the industry.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Junior or Pre-Junior or Sophomore

**CMGT 470 Productivity in Construction 3.0 Credits**
Explores the evaluation of construction management's effectiveness. Overview of techniques required for improvement of construction field efficiency including quality management, productivity measurements, method improvement, human factors, and communications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 499 Construction Management Independent Study Project 0.5-4.0 Credits**
This course is a capstone course intended to be a culminating experience in the Construction Management Program.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 2 times for 8 credits
**Restrictions:** Can enroll if classification is Senior.

# Electrical Engineering

*Bachelor of Science in Electrical Engineering (BSEE): 192.0 quarter credits*

## About the Program

The electrical engineering major emphasizes the fundamentals of electrical engineering, hands-on learning, and flexibility in course selection

to satisfy diverse career goals. Students choose one or more areas of study beginning in their pre-junior year.

State-of-the-art interdisciplinary courses have been developed to prepare the Drexel engineer for the technical challenges and the business atmosphere of the 21st century. Strong emphasis is given to the role of the engineer in the global competitive economy, and to the need to work closely with experts and practitioners in many fields.

Students can choose courses in various areas of study, including telecommunications, digital signal processing, electronics, power and systems and control.

## Mission Statement

The ECE Department at Drexel University serves the public and the university community by providing superior career-integrated education in electrical and computer engineering; by conducting research in these fields, to generate new knowledge and technologies; and by promoting among all its constituents professionalism, social responsibility, civic engagement and leadership.

## Program Educational Objectives

The Electrical and Computer Engineering Program Educational Objectives are that its alumni in their early years after graduation:

1. Secure positions and continue as valued, creative, dependable, and proficient employees in a wide variety of fields and industries, in particular as electrical and computer engineers;

2. Succeed in graduate and professional studies, such as engineering, science, law, medicine and business;

3. Pursue professional development through lifelong learning opportunities for a successful and rewarding career;

4. Provide leadership in their profession, in their communities, and in the global society;

5. Contribute to their professional disciplines body of knowledge;

6. Function as responsible members of society with an awareness of the social and ethical ramifications of their work.

## Student Outcomes

The department's student outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

a) an ability to apply knowledge of mathematics, science, and engineering;

b) an ability to design and conduct experiments, as well as to analyze and interpret data;

c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

d) an ability to function on multidisciplinary teams;

e) ability to identify, formulate, and solve engineering problems;

f) an understanding of professional and ethical responsibility;

g) an ability to communicate effectively;

h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;

i) a recognition of the need for, and an ability to engage in life-long learning;

j) a knowledge of contemporary issues;

k) an ability to use the techniques, skills, and modern engineering tools necessary for electrical engineering practice.

## Areas of Study

### Telecommunications and Digital Signal Processing (DSP)

Telecommunications and digital signal processing (DSP) are two of the fastest-growing fields of electrical engineering. The telecommunications and DSP areas of study prepare students for mastery of fundamental and applied knowledge in the theory and the technology of the transmission and processing of information-bearing signals such as voice, audio, data, images, and video. The curriculum includes core courses in electromagnetic propagation, communication devices and media, signal processing, analog and digital communication. Complementary electives can be taken in computers, electronics, control systems, and electric power systems.

Career opportunities include design and development of digital communications systems and telephony, speech recognition systems, fiber-optic networks, digital radio, medical diagnostic image processing, high-definition television, cellular and wireless communications, satellite communications, networked multimedia communications, and personal communication systems.

### Electronics

The electronics area of study constitutes the study of electronic and optical semiconductor devices; analog and digital electronic circuits; and generation, transmission, and reception of information both in optical and microwave frequency ranges and guided or free-space conditions.

Career opportunities include jobs in telecommunications (optical, wireless, wired, satellite, and radar), VLSI (analog and digital), aerospace, remote sensing and instrumentation, computer circuitry interface, biomedical instrumentation, semiconductor device fabrication, and transportation.

### Power and Systems/Control

Power and Systems/Control has at its core the areas of controls engineering and electric power engineering, the classic core of electrical engineering, and exploits the synergies between these two areas. These areas of study explores subjects such as modeling, analysis and control of dynamic systems including power systems, planning and optimization, electromechanical energy conversion, motor operation and control, transformers, power electronics, sensors and actuators, and the electrical and economic structure of the power industry. These areas of study offer access to two state-of-the-art laboratories. In the Interconnected Power System Laboratory, students can operate and control a small power system through the fusing of computer software and hardware technology with high-voltage, high-power technology. The Ortlip Systems Laboratory houses various experiments in sensing, feedback, and control. Both laboratories stress the use of modeling software, especially MATLAB, and the integrated use of computers and hardware.

Career opportunities include options ranging from manufacturing, the power industry (generation, transmission, distribution, marketing, and consumption), robotics, and transportation to Wall Street.

## Additional Information

The Electrical Engineering program is accredited by the Engineering Accreditation Commission of ABET. (http://www.abet.org)

Additional information about the major is available on the ECE Department website (http://www.ece.drexel.edu/Undergraduate_Programs2.html) .

For advising questions, please e-mail advising@ece.drexel.edu.

To make an appointment, please call 215.895.2241
Drop-in hours: Please e-mail advising@ece.drexel.edu for up-to-date drop-in availability.

## Degree Requirements

In addition to completing 192.0 credits, students majoring in electrical engineering student must have a 2.0 cumulative overall GPA and a 2.0 cumulative GPA in their Electrical Engineering courses.

**General Education/Liberal Studies Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| General Education Courses [*] | | 18.0 |
| **Foundation Requirements** | | |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| BIO 141 | Essential Biology | 4.5 |
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| ENGR 121 | Computation Lab I | 2.0 |
| ENGR 122 | Computation Lab II | 1.0 |
| ECE 200 | Digital Logic Design | 3.0 |
| ECE 201 | Foundations of Electric Circuits | 3.0 |
| ECE 203 | Programming for Engineers | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |

| | | |
|---|---|---|
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| **Sophomore Engineering Elective Options** | | |
| Select one of the following: | | 3.0-4.0 |
| ENGR 210 | Introduction to Thermodynamics | |
| MATH 221 | Discrete Mathematics | |
| PHYS 202 | Fundamentals of Physics IV | |
| **Professional Requirements** | | |
| ECEL 301 [WI] | Electrical Engineering Laboratory | 2.0 |
| ECEL 302 | ECE Laboratory II | 2.0 |
| ECEL 303 | ECE Laboratory III | 2.0 |
| ECEL 304 | ECE Laboratory IV | 2.0 |
| ECE 361 | Probability for Engineers | 3.0 |
| or ECE 362 | Engineering Statistics | |
| or ENGR 361 | Statistical Analysis of Engineering Systems | |
| ECES 301 | Transform Methods and Filtering | 4.0 |
| ECES 303 | Transform Methods II | 3.0 |
| ECE 391 | Introduction to Engineering Design Methods | 1.0 |
| ECE 491 [WI] | Senior Design Project I | 2.0 |
| ECE 492 [WI] | Senior Design Project II | 2.0 |
| ECE 493 | Senior Design Project III | 4.0 |
| 13 ECE Electives | | 42.0 |
| **Math Elective** [**] | | 3.0 |
| **Free Electives** | | 13.5 |
| **Total Credits** | | **192.0-193.0** |

[*]    General Education Courses.

[**]    The math elective is a 3.0-4.5 credit course from MATH at a 200-level or higher. MATH 291 (Complex & Vector Analysis) is encouraged for EE majors.

[†]    ECE Electives (ECEX electives) are at least 42 credits of ECE courses (ECEC, ECEP, ECES, ECEE). At least 9 credits must be in the major at the 400-level or higher. Up to 12 credits may be taken from other College of Engineering or School of Biomedical Engineering, Science and Health System majors.
Note: ECE 101 and ECE 102 in combination can count as 1 ECE Elective.

## Sample Plan of Study

### 5 YR UG Co-op Concentration

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| ENGR 121 | Computation Lab I | 2.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **16.5** |

**Term 2**

| | | |
|---|---|---|
| CHEM 102 | General Chemistry II | 4.5 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGR 122 | Computation Lab II | 1.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |

**Term 3**

| | | |
|---|---|---|
| BIO 141 | Essential Biology | 4.5 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **18.0** |

**Term 4**

| | | |
|---|---|---|
| ECE 200 | Digital Logic Design | 3.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |

**Term 5**

| | | |
|---|---|---|
| ECE 201 | Foundations of Electric Circuits | 3.0 |
| ECE 203 | Programming for Engineers | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| Sophomore Engineering elective[*] | | 3.0 |
| | **Term Credits** | **15.0** |

**Term 6**

| | | |
|---|---|---|
| ECEL 301 [WI] | Electrical Engineering Laboratory | 2.0 |
| ECES 301 | Transform Methods and Filtering | 4.0 |
| Two ECE Electives[*] | | 6.0 |
| Math elective | | 3.0 |
| | **Term Credits** | **15.0** |

**Term 7**

| | | |
|---|---|---|
| ECE 361, 362, or ENGR 361 | Probability for Engineers Engineering Statistics Statistical Analysis of Engineering Systems | 3.0 |
| ECEL 302 | ECE Laboratory II | 2.0 |
| ECES 303 | Transform Methods II | 3.0 |
| One ECE Elective[*] | | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **17.0** |

**Term 8**

| | | |
|---|---|---|
| Two ECE Electives[*] | | 6.0 |
| ECEL 303 | ECE Laboratory III | 2.0 |
| General Education elective[*] | | 3.0 |
| Free elective | | 4.0 |
| | **Term Credits** | **15.0** |

**Term 9**

| | | |
|---|---|---|
| ECE 391 | Introduction to Engineering Design Methods (Also offered spring term.) | 1.0 |
| ECEL 304 | ECE Laboratory IV | 2.0 |
| Two ECE Electives[*] | | 6.0 |
| General Education elective[*] | | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **15.0** |

**Term 10**

| | | |
|---|---|---|
| ECE 491 [WI] | Senior Design Project I | 2.0 |
| Two ECE Electives[*] | | 6.0 |
| Two General Education electives[*] | | 6.0 |
| | **Term Credits** | **14.0** |

**Term 11**

| | | |
|---|---|---|
| ECE 492 [WI] | Senior Design Project II | 2.0 |
| Two ECE Electives[*] | | 7.0 |
| General Education elective[*] | | 3.0 |
| Free elective | | 4.5 |
| | **Term Credits** | **16.5** |

**Term 12**

| | | |
|---|---|---|
| ECE 493 | Senior Design Project III | 4.0 |
| Two ECE Electives[*] | | 7.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **14.0** |

**Total Credit: 192.0**

[*] See degree requirements.

# Co-op/Career Opportunities

Top co-op employers for electrical engineering majors include:

- AT&T Mobility
- Central Intelligence Agency
- Comcast Corporation
- EwingCole
- Exelon Corporation (PECO)
- Lockheed Martin
- NAVSEA
- PJM Interconnection LLC
- Schweitzer Engineering Laboratories Inc
- U.S. Federal Aviation Administration
- Singapore as a Apple iPhone App Developer
- Vietnam as a Game Developer for Glass Egg

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) for more detailed information on co-op and post-graduate opportunities.

Drexel University's co-op program has a 80 year history and is one of the oldest and largest co-op programs in the world. Students graduate

with 6-18 months of full time employment experience, depending on their choice of a 4-year or 5-year program. The majority of Computer Engineering students in ECE choose the 5-year program and graduate with 18 months of full-time work experience, and often receive a job offer from their third co-op employer or from a connection made from one of their co-op experiences.

Electrical engineers are employed in corporations, government agencies, and other organizations. In their work, these engineers are developers of electrical equipment for digital communications (such as satellite communication, fiber-optic networks, and coding and cryptography), mobile radio, radar and surveillance, process control, robotics, speech processing, aerospace circuitry, power generation and distribution, computer hardware and software, computer networks, sensor technology, counter-crime measures, electronic compatibility, consumer electronics, and related fields.

Graduates are also pursuing advanced studies in electrical and computer engineering, aerospace engineering, and mechanical engineering at such schools as MIT, Stanford, Princeton, Georgia Institute of Technology, University of California at Berkeley, University of Pennsylvania, and University of Maryland.

The Steinbright Career Development Center had a co-op placement rate of approximately 99% for electrical and computer engineering majors.

A degree in electrical engineering can also serve as an excellent foundation to pursue graduate professional careers in medicine, law, business, and government.

# Dual/Accelerated Degree

## Accelerated Program

The accelerated programs of the College of Engineering provide opportunities for highly talented and strongly motivated students to progress toward their educational goals essentially at their own pace. These options include opportunities for accelerated studies, dual degrees, and combined bachelor's/master's programs.

Primarily through advanced placement, credit by examination, flexibility of scheduling, and independent study, the "fast track" makes it possible to complete the undergraduate curriculum and initiate graduate study in less than the five years required by the standard curriculum.

## Dual Degree Bachelor's Programs

With careful planning, students can complete both an Electrical Engineering degree and a Computer Engineering degree in the time usually required to complete one degree. For detailed information the student should contact the ECE advisor (http://drexel.edu/ece/academics/undergrad/advising) .

## Bachelor's/Master's Dual Degree Program

Exceptional students can also pursue a master of science degree in the same period as the bachelor of science.

For more information on these and other options, visit the Department of Electrical and Computer Engineering BS/MS (http://drexel.edu/ece/academics/undergrad/bs-ms) page.

# Minor in Electrical Engineering

This minor is designed to provide other engineering majors or students from other disciplines an introduction to the wide-ranging content of the electrical engineering major. The minor consists of a minimum of nine ECE courses resulting in 26.0 credits. There are six required courses and an additional 9 credits of elective courses.

## Prerequisites

The minor assumes that students will have a background in mathematics and physics equivalent to that covered in the first two years of the engineering curriculum. In mathematics, this would cover calculus and differential equations. Knowledge of linear algebra is also recommended. Courses taken to meet these requirements will not count toward the minor.

**Required Courses**

| | | |
|---|---|---|
| ECE 200 | Digital Logic Design | 3.0 |
| ECE 201 | Foundations of Electric Circuits | 3.0 |
| ECEL 301 [WI] | Electrical Engineering Laboratory | 2.0 |
| ECEL 302 | ECE Laboratory II | 2.0 |
| ECES 301 | Transform Methods and Filtering | 4.0 |
| ECES 303 | Transform Methods II | 3.0 |
| Electives [*] | | 9.0 |
| **Total Credits** | | **26.0** |

\* Students should choose 9 credits from the 300- and/or 400-level ECE courses. These courses can come from the Computer (ECEC), Electrophysics (ECEE), Electric Power (ECEP), or Systems (ECES) groups. All prerequisites must be satisfied. Students majoring in Computer Engineering and minoring in Electrical Engineering may *only* choose elective courses from the ECEE, ECEP, and ECES course groups.

## Additional information

Additional information about this minor is available on the ECE Department website (http://www.drexel.edu/ece/academics/undergrad/minors) .

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Drop-in hours: Mon - Fri 1:30 - 2:30

## Facilities

Drexel University and the Electrical and Computer Engineering Department are nationally recognized for a strong history of developing innovative research. Research programs in the ECE Department prepare students for careers in research and development, and aim to endow graduates with the ability to identify, analyze, and address new technical and scientific challenges. The ECE Department is well equipped

with state-of-the-art facilities in each of the following ECE Research laboratories:

# Research Laboratories at the ECE Department

## Adaptive Signal Processing and Information Theory Research Group

The Adaptive Signal Processing and Information Theory Research Group (http://www.ece.drexel.edu/walsh/aspitrg/home.html) conducts research in the area of signal processing and information theory. Our main interests are belief/expectation propagation, turbo decoding and composite adaptive system theory. We are currently doing projects on the following topics:

i) Delay mitigating codes for network coded systems,
ii) Distributed estimation in sensor networks via expectation propagation,
iii) Turbo speaker identification,
iv) Performance and convergence of expectation propagation,
v) Investigating bounds for SINR performance of autocorrelation based channel shorteners.

## Applied Networking Research Lab

Applied Networking Research Lab (ANRL) projects focus on modeling and simulation as well as experimentation in wired, wireless and sensor networks. ANRL is the home of MuTANT, a Multi-Protocol Label Switched Traffic Engineering and Analysis Testbed composed of 10 high-end Cisco routers and several PC-routers, also used to study other protocols in data networks as well as automated network configuration and management. The lab also houses a sensor network testbed.

### Bioimage Laboratory

Uses computer gaming hardware for enhanced and affordable 3-D visualization, along with techniques from information theory and machine learning to combine the exquisite capabilities of the human visual system with computational sensing techniques for analyzing vast quantities of image sequence data.

## Data Fusion Laboratory

The Data Fusion Laboratory investigates problems in multisensory detection and estimation, with applications in robotics, digital communications, radar, and target tracking. Among the projects in progress: computationally efficient parallel distributed detection architectures, data fusion for robot navigation, modulation recognition and RF scene analysis in time-varying environments, pattern recognition in biological data sequences and large arrays, and hardware realizations of data fusion architectures for target detection and target tracking.

## Drexel Network Modeling Laboratory

The Drexel Network Modeling Laboratory investigates problems in the mathematical modeling of communication networks, with specific focus on wireless ad hoc networks, wireless sensor networks, and supporting guaranteed delivery service models on best effort and multipath routed networks. Typical methodologies employed in our research include mathematical modeling, computer simulation, and performance optimization, often with the end goal of obtaining meaningful insights into network design principles and fundamental performance tradeoffs.

## Drexel Power-Aware Computing Laboratory

The Power-Aware Computing Lab (http://dpac.ece.drexel.edu) investigates methods to increase energy efficiency across the boundaries of circuits, architecture, and systems. Our recent accomplishments include the Sigil profiling tool, scalable modeling infrastructure for accelerator implementations, microarchitecture-aware VDD gating algorithms, an accelerator architecture for ultrasound imaging, evaluation of hardware reference counting, hardware and operating system support for power-agile computing, and memory systems for accelerator-based architectures.

## Drexel University Nuclear Engineering Education Laboratory

The field of nuclear engineering encompasses a wide spectrum of occupations, including nuclear reactor design, medical imaging, homeland security, and oil exploration. The Drexel University Nuclear Engineering Education Laboratory (DUNEEL) provides fundamental hands on understanding for power plant design and radiation detection and analysis. Software based study for power plant design, as well as physical laboratory equipment for radiation detection, strengthen the underlying concepts used in nuclear engineering such that the student will comprehend and appreciate the basic concepts and terminology used in various nuclear engineering professions. Additionally, students use the laboratory to develop methods for delivering remote, live time radiation detection and analysis. The goal of DUNEEL is to prepare students for potential employment in the nuclear engineering arena.

## Drexel VLSI Laboratory

The Drexel VLSI Laboratory (http://ece.drexel.edu/faculty/taskin/wiki/vlsilab/index.php/Main_Page) investigates problems in the design, analysis, optimization and manufacturing of high performance (low power, high throughput) integrated circuits in contemporary CMOS and emerging technologies. Suited with industrial design tools for integrated circuits, simulation tools and measurement beds, the VLSI group is involved with digital and mixed-signal circuit design to verify the functionality of the discovered novel circuit and physical design principles. The Drexel VLSI laboratory develops design methodologies and automation tools in these areas, particularly in novel clocking techniques, featuring resonant clocking, and interconnects, featuring wireless interconnects.

## Drexel Wireless Systems Laboratory

The Drexel Wireless Systems Laboratory (DWSL) contains an extensive suite of equipment for constructing, debugging, and testing prototype wireless communications systems. Major equipment within DWSL includes:

- three software defined radio network testbeds (HYDRA, USRP, and WARP) for rapidly prototyping radio, optical and ultrasonic communications systems,
- a TDK RF anechoic chamber and EMSCAN desktop antenna pattern measurement system,
- a materials printer and printed circuit board milling machine for fabricating conformal antennas and
- wireless protocol conformance testing equipment from Aeroflex.

The lab is also equipped with network analyzers, high speed signal generators, oscilloscopes, and spectrum analyzers as well as several Zigbee development platforms for rapidly prototyping sensor networks.

DWSL personnel also collaborate to create wearable, fabric based transceivers through collaboration with the Shima Seiki Haute Laboratory

in the Drexel ExCITe Center. The knitting equipment at Drexel includes sixteen SDS-ONE APEX3 workstations and four state-of-the-art knitting machines. The workstations accurately simulate fabric construction and provide researchers and designers the opportunity to program, create and simulate textile prototypes, import CAD specifications of final products, and produce made-to-measure or mass-produced pieces on Shima Seiki knitting machines. For testing smart textiles for biomedical, DWSL personnel also have collaborators in the Center for Interdisciplinary Clinical Simulation and Practice (CICSP) in the Drexel College of Medicine which provides access to medical mannequin simulators.

## Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (EESI) (http://www.ece.drexel.edu/gailr/EESI) seeks to solve problems in high-throughput genomics and engineer better solutions for biochemical applications. The lab's primary thrust is to enhance the use of high-throughput DNA sequencing technologies with pattern recognition and signal processing techniques. Applications include assessing the organism content of an environmental sample, recognizing/classifying potential and functional genes, inferring environmental factors and inter-species relationships, and inferring microbial evolutionary relationships from short-read DNA/RNA fragments. The lab also investigates higher-level biological systems such as modeling and controlling chemotaxis, the movement of cells.

## Electric Power Engineering Center

This newly established facility makes possible state-of-the-art research in a wide variety of areas, ranging from detailed theoretical model study to experimental investigation in its high voltage laboratories. The mission is to advance and apply scientific and engineering knowledge associated with the generation, transmission, distribution, use, and conservation of electric power. In pursuing these goals, this center works with electric utilities, state and federal agencies, private industries, nonprofit organizations and other universities on a wide spectrum of projects. Research efforts, both theoretical and experimental, focus on the solution of those problems currently faced by the electric power industry. Advanced concepts for electric power generation are also under investigation to ensure that electric power needs will be met at the present and in the future.

## Electronic Design Automation Facility

Industrial-grade electronic design automation software suite and intergrated design environment for digital, analog and mixed-signal systems development. Field Programmable Gate Array (FPGA) development hardware. Most up-to-date FPGA/embedded system development hardware kits. Printed circuit board production facility. Also see Drexel VLSI Laboratory.

## Microwave-Photonics Device Laboratories

The laboratory is equipped with test and measurement equipment for high-speed analog and digital electronics and fiber optic systems. The test equipment includes network analyzers from Agilent (100kHz- 1.3 GHz and 45 Mhz-40 GHz), and Anritsu (45 MHz-6 GHz); spectrum analyzers from Tektronix, HP, and Agilent with measurement capability of DC to 40 GHz and up to 90 GHz using external mixers; signal generators and communication channel modulators from HP, Rhode-Schwartz, Systron Donner, and Agilent; microwave power meter and sensor heads, assortment of passive and active microwave components up to 40 GHz ; data pattern generator and BER tester up to 3Gb/s; optical spectrum analyzer from Anritsu and power meters from HP; single and multimode

fiber optic based optical transmitter and receiver boards covering ITU channels at data rates up to 10Gb/s; passive optical components such as isolator, filter, couplers, optical connectors and fusion splicer; LPKF milling machine for fabrication of printed circuit boards; wire-bonding and Cascade probe stations; Intercontinental test fixtures for testing of MMIC circuits and solid-state transistors; state-of-the-art microwave and electromagnetic CAD packages such as Agilent ADS, ANSYS HFSS, and COMSOL multi-physics module.

## Music and Entertainment Technology Laboratory

The Music and Entertainment Technology Laboratory (MET-lab) is devoted to research in digital media technologies that will shape the future of entertainment, especially in the areas of sound and music. We employ digital signal processing and machine learning to pursue novel applications in music information retrieval, music production and processing technology, and new music interfaces. The MET-lab is also heavily involved in outreach programs for K-12 students and hosts the Summer Music Technology program, a one-week learning experience for high school students. Lab facilities include a sound isolation booth for audio and music recording, a digital audio workstation running ProTools, two large multi-touch display interfaces of our own design, and a small computing cluster for distributed processing.

## NanoPhotonics+ Lab (http://drexelnanophotonics.com)

Our research is primarily in the area of nanophotonics with a focus on the nanoscale interaction of light with matter. Interests include: liquid crystal/polymer composites for gratings, lenses and HOEs; liquid crystal interactions with surfaces and in confined nanospaces; alternative energy generation through novel photon interactions; ink-jet printed conducting materials for RF and photonic applications; and the creation and development of smart textiles technologies including soft interconnects, sensors, and wireless implementations.

## Opto-Electro-Mechanical Laboratory

This lab concentrates on the system integration on optics, electronics, and mechanical components and systems, for applications in imaging, communication, and biomedical research. Research areas include: Programmable Imaging with Optical Micro-electrical-mechanical systems (MEMS), in which microscopic mirrors are used to image light into a single photodetector; Pre-Cancerous Detection using White Light Spectroscopy, which performs a cellular size analysis of nuclei in tissue; Free-space Optical Communication using Space Time Coding, which consists of diffused light for computer-to-computer communications, and also tiny lasers and detectors for chip-to-chip communication; Magnetic Particle Locomotion, which showed that particles could swim in a uniform field; and Transparent Antennas using Polymer, which enables antennas to be printed through an ink-jet printer.

## Plasma and Magnetics Laboratory

Research is focused on applications of electrical and magnetic technologies to biology and medicine. This includes the subjects of non-thermal atmospheric pressure plasma for medicine, magnetic manipulation of particles for drug delivery and bio-separation, development of miniature NMR sensors for cellular imaging and carbon nanotube cellular probes.

## Power Electronics Research Laboratory

The Power Electronics Research Laboratory (PERL) is involved in circuit and design simulation, device modeling and simulation, and experimental testing and fabrication of power electronic circuits. The research and

development activities include electrical terminations, power quality, solar photovoltaic systems, GTO modeling, protection and relay coordination, and solid-state circuit breakers. The analysis tools include EMPT, SPICE, and others, which have been modified to incorporate models of such controllable solid-state switches as SCRs, GTOs, and MOSFETs. These programs have a wide variety and range of modeling capabilities used to model electromagnetics and electromechanical transients ranging from microseconds to seconds in duration. The PERL is a fully equipped laboratory with 42 kVA AC and 70 kVA DC power sources and data acquisition systems, which have the ability to display and store data for detailed analysis. Some of the equipment available is a distribution and HV transformer and three phase rectifiers for power sources and digital oscilloscopes for data measuring and experimental analysis. Some of the recent studies performed by the PERL include static VAR compensators, power quality of motor controllers, solid-state circuit breakers, and power device modeling which have been supported by PECO, GE, Gould, and EPRI.

## RE Touch Lab

The RE Touch Lab is investigating the perceptual and mechanical basis of active touch perception, or haptics, and the development of new technologies for stimulating the sense of touch, allowing people to touch, feel, and interact with digital content as seamlessly as we do with objects in the real world. We study the scientific foundations of haptic perception and action, and the neuroscientific and biomechanical basis of touch, with a long-term goal of uncovering the fundamental perceptual and mechanical computations that enable haptic interaction. We also create new technologies for rendering artificial touch sensations that simulate those that are experienced when interacting with real objects, inspired by new findings on haptic perception.

## Testbed for Power-Performance Management of Enterprise Computing Systems

This computing testbed is used to validate techniques and algorithms aimed at managing the performance and power consumption of enterprise computing systems. The testbed comprises a rack of Dell 2950 and Dell 1950 PowerEdge servers, as well as assorted desktop machines, networked via a gigabit switch. Virtualization of this cluster is enabled by VMWare's ESX Server running the Linux RedHat kernel. It also comprises of a rack of ten Apple Xserve machines networked via a gigabit switch. These servers run the OS X Leopard operating systems and have access to a RAID with TBs of total disk capacity.

# Electrical and Computer Engineering Faculty

Suryadevara Basavaiah, PhD *(University of Pennsylvania)*. Teaching Professor. Computer engineering; computer engineering education; custom circuit design; VLSI technology; process and silicon fabrication.

Tom Chmielewski, PhD *(Drexel University)*. Assistant Teaching Professor. Modeling and simulation of electro-mechanical systems; Optimal, Adaptive and Non-Linear Control; DC Motor Control; System Identification; Kalman Filters (Smoothing Algorithms, tracking); image processing, Robot design; Biometric technology and design of embedded systems for control applications utilizing MATLAB and SIMULINK

Fernand Cohen, PhD *(Brown University)*. Professor. Surface modeling; tissue characterization and modeling; face modeling; recognition and tracking.

Andrew Cohen, PhD *(Rensselaer Polytechnic Institute)*. Associate Professor. Image processing; multi-target tracking; statistical pattern recognition and machine learning; algorithmic information theory; 5-D visualization.

Kapil Dandekar, PhD *(University of Texas-Austin) Director of the Drexel Wireless Systems Laboratory (DWSL); Associate Dean of Research, College of Engineering*. Professor. Cellular/mobile communications and wireless LAN; smart antenna/MIMO for wireless communications; applied computational electromagnetics; microwave antenna and receiver development; free space optical communication; ultrasonic communication; sensor networks for homeland security; ultrawideband communication.

Afshin Daryoush, PhD *(Drexel University)*. Professor. Microwave photonics systems; nonlinear microwave circuits; RFIC and wireless communications; antennas and radiating systems; electromagnetic interaction with biological systems.

Bruce A. Eisenstein, PhD *(University of Pennsylvania) Arthur J. Rowland Professor of Electrical and Computer Engineering; Vice Dean, College of Engineering*. Professor. Pattern recognition; estimation; decision theory; digital signal processing.

Adam K. Fontecchio, PhD *(Brown University) Associate Dean for Undergraduate Affairs; Associate Director, Expressive and Creative Interactive Technologies (EXCITE) Center*. Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park)*. Professor. Biological and biomedical applications of nanoscale magnetic systems.

Eli Fromm, PhD *(Jefferson Medical College) Roy A. Brothers University Professor / Director for Center of Educational Research*. Professor. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania) Assistant EDE Department Head; Liason for Evening Programs*. Professor. Computerized instruments and measurements; undergraduate engineering education.

Allon Guez, PhD *(University of Florida)*. Professor. Intelligent control systems; robotics, biomedical, automation and manufacturing; business systems engineering.

Mark Hempstead, PhD *(Harvard University) Junior Colehower Chair*. Assistant Professor. Computer engineering; power-aware computing; computer architecture; low power VLSI Design; wireless sensor networks.

Peter R. Herczfeld, PhD *(University of Minnesota) Lester A. Kraus Professor/Director, Center for Microwave/Lightwave Engineering*. Professor. Lightwave technology; microwaves; millimeter waves; fiberoptic and integrated optic devices.

Leonid Hrebien, PhD *(Drexel University)*. Professor. Tissue excitability; acceleration effects on physiology; bioinformatics.

Paul R. Kalata, PhD *(Illinois Institute of Technology)*. Associate Professor. Stochastic and adaptive control theory; identification and decision theory; Kalman filters.

Nagarajan Kandasamy, PhD *(University of Michigan)*. Associate Professor. Embedded systems, self-managing systems, reliable and

fault-tolerant computing, distributed systems, computer architecture, and testing and verification of digital systems.

Bruce Katz, PhD *(University of Illinois)*. Adjunct Professor. Neural networks; the study of aesthetics; artificial intelligence; music perception.

Youngmoo Kim, PhD *(Massachusetts Institutie of Technology) Director, Expressive and Creative Interaction Technologies (EXCITE) Center*. Associate Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Timothy P. Kurzweg, PhD *(University of Pittsburgh) Associate Department Head for Undergraduate Studies and Director of the BSE Program*. Associate Professor. Optical MEM modeling and simulation; system-level simulation; computer architecture.

Mohammad Madihian, PhD *(Shizuoka University)*. Adjunct Professor. Solid-state device-circuit interaction; microwave and millimeter-wave monolithic circuit design and evaluation technology; solid-state power generation/amplification/mixing technology; single/multi-mode wireless RF/IF transceiver technology

Karen Miu, PhD *(Cornell University)*. Professor. Power systems; distribution networks; distribution automation; optimization; system analysis.

Bahram Nabet, PhD *(University of Washington)*. Professor. Optoelectronics; fabrication and modeling; fiber optic devices; nanoelectronics; nanowires.

Prawat Nagvajara, Ph.D. *(Boston University)*. Associate Professor. System on a chip; embedded systems; power grid computation; testing of computer hardware; fault-tolerant computing; VLSI systems; error control coding.

Vasileios Nasis, PhD *(Drexel University)*. Associate Teaching Professor. Imaging with MOEMS, Projection systems using MEMS/MOEMS, Wireless communications, Remote monitoring, sensor networks.

Dagmar Niebur, PhD *(Swiss Federal Institute of Technology)*. Associate Professor. Intelligent systems; dynamical systems; power system monitoring and control.

Chika Nwankpa, PhD *(Illinois Institute of Technology) Interum Department Head*. Professor. Power system dynamics; power electronic switching systems; optically controlled high power switches.

Christopher Peters, PhD *(University of Michigan, Ann Arbor)*. Teaching Professor. Nuclear reactor design; ionizing radiation detection; nuclear forensics; power plant reliability and risk analysis; naval/marine power and propulsion; directed energy/high power microwaves; nonstationary signal processing; radar; electronic survivability/susceptibility to harsh environments; electronic warfare.

Karkal S. Prahbu, PhD *(Harvard University)*. Teaching Professor. Computer and software engineering; advanced microprocessors and distributed operating systems.

Gail L. Rosen, PhD *(Georgia Institute of Technology)*. Associate Professor. Signal processing, signal processing for biological analysis and modeling, bio-inspired designs, source localization and tracking.

Ioannis Savidis, PhD *(University of Rochester) Director of the Integrated Circuits and Electronics (ICE) Design and Analysis Laboratory*. Assistant Professor. Analysis, modeling, and design methodologies for high performance digital and mixed-signal integrated circuits; Emerging integrated circuit technologies; Electrical and thermal modeling and characterization, signal and power integrity, and power and clock delivery for 3-D IC technologies.

Kevin J. Scoles, PhD *(Dartmouth College)*. Associate Professor. Microelectronics; electric vehicles; solar energy; biomedical electronics.

Harish Sethu, PhD *(Lehigh University)*. Associate Professor. Protocols, architectures and algorithms in computer networks; computer security; mobile ad hoc networks; large-scale complex adaptive networks and systems.

James Shackleford, PhD *(Drexel University)*. Assistant Professor. Medical image processing, high performance computing, embedded systems, computer vision, machine learning.

P. Mohana Shankar, PhD *(Indian Institute of Technology) Allen Rothwarf Professor of Electrical and Computer Engineering*. Professor. Wireless communications; biomedical ultrasonics; fiberoptic bio-sensors.

Matthew Stamm, PhD *(University of Maryland, College Park) Head, Multimedia and Information Security Laboratory (MSL)*. Assistant Professor. Information Security; Multimedia Forensics and Anti-Forensics; Information Verification; Adversarial Dynamics; Signal Processing.

Baris Taskin, PhD *(University of Pittsburgh)*. Associate Professor. Electronic design automation (EDA) of integrated circuits, high-performance VLSI circuits and systems, sequential circuit timing and synchronization, system-on-chip (SOC) design, operational research, VLSI computer-aided design.

Lazar Trachtenberg, DSc *(Israel Institute of Technology)*. Professor. Fault tolerance; multi-level logic synthesis; signal processing; suboptimal filtering.

Yon Visell, PhD *(McGill University)*. Assistant Professor. Haptic display engineering, material and biomechanical contact physics, neuroscientific and physical basis of human tactile sensation/perception, haptic human-machine interaction, sensorimotor learning, interaction in virtual reality

John Walsh, PhD *(Cornell University)*. Associate Professor. Performance and convergence of belief/expectation propagation and turbo decoding/equalization/synchronization, permeation models for ion channels, composite adaptive systems theory.

Steven Weber, PhD *(University of Texas-Austin) Assistant Department Head for Graduate Affairs, Electrical and Computer Engineering*. Associate Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice Cavalcante de Oliveira, PhD *(Georgia Institute of Technology)*. Associate Professor. Next generation Internet; quality of service in computer communication networks; wireless networks.

## Interdepartmental Faculty

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Jeremy R. Johnson, PhD *(Ohio State University)*. Professor. Computer algebra; parallel computations; algebraic algorithms; scientific computing.

John Lacontora, PhD *(New Jersey Institute of Technology)*. Associate Research Professor. Service engineering; industrial engineering.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Spiros Mancoridis, PhD *(University of Toronto) Sr. Associate Dean for Computing and CCI Academic Affairs*. Professor. Software engineering; software security; code analysis; evolutionary computation.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Paul Y. Oh, PhD *(Columbia University)*. Adjunct Professor. Smart sensors servomechanisms; machine vision and embedded microcomputers for robotics and mechatronics.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

William C. Regli, PhD *(University of Maryland-College Park)*. Professor. Artificial intelligence; computer graphics; engineering design and Internet computing.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering*. Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces; scanning probe microscopy; laser spectroscopy, including Raman scattering.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Aspasia Zerva, PhD *(University of Illinois)*. Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

# Emeritus Faculty

Robert Fischl, PhD *(University of Michigan) John Jarem Professor Emeritus / Founder of the Center for Electric Power Engineering*. Professor Emeritus. Power: systems, networks, controls, computer-aided design, power systems, solar energy.

Vernon L. Newhouse, PhD *(University of Leeds) Disque Professor Emeritus*. Professor Emeritus. Biomedical and electrophysics: ultrasonic flow measurement, imaging and texture analysis in medicine, ultrasonic nondestructive testing and robot sensing, clinical engineering.

Hun H. Sun, PhD *(Cornell University) Ernest O. Lange Professor Emeritus*. Professor Emeritus. Systems and signals in biomedical control systems.

Oleh Tretiak, ScD *(MIT)*. Professor Emeritus. Image processing; tomography; image registration; pattern recognition.

# Elec Comp Engr-Computers Courses

**ECEC 301 Advanced Programming for Engineers 3.0 Credits**
An advanced introduction to classes and objects; inheritance and polymorphism; abstract classes and interfaces; exception handling; files and streams; garbage collection and dynamic memory allocation; recursion; using linked lists, stacks, queues, and trees; search and sorting algorithms; generic methods and classes; a comparative introduction to dominant programming languages; engineering examples.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 203 [Min Grade: D] or CS 203 [Min Grade: D]

**ECEC 302 Digital Systems Projects 4.0 Credits**
Offers hands-on experiences in digital system design with automation tools. Uses field programmable gate arrays in the projects. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CS 171 [Min Grade: D] (Can be taken Concurrently) or ECE 203 [Min Grade: D] or CS 203 [Min Grade: D]) and ECE 200 [Min Grade: D]

**ECEC 304 Design with Microcontrollers 4.0 Credits**
Offers hands-on experience in the design of controllers that incorporate microcontrollers as an embedded component in a larger system. The microcomputer topics to be studied will include architecture, software, programming and interfaces.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECE 200 [Min Grade: D] and (CS 171 [Min Grade: D] or ECE 203 [Min Grade: D] or CS 203 [Min Grade: D])

**ECEC 352 Secure Computer Systems: Design Concepts 4.0 Credits**
Covers concepts of secure computation, including economics vs. faults, errors, and hidden messages; mathematical foundations of secure computing; design issues in fault-tolerant computing; and testability and cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEC 302 [Min Grade: D] and MATH 221 [Min Grade: D]

**ECEC 353 Systems Programming 3.0 Credits**
This course introduces computer systems, including interaction of hardware and software through the operating system, from the programmer's perspective. Three fundamental abstractions are emphasized: processes, virtual memory, and files. These abstractions provide programmers a common interface to a wide variety of hardware devices. Topics covered include linking, system level I/O, concurrent programming, and network programming.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CS 265 [Min Grade: D]

**ECEC 355 Computer Organization & Architecture 4.0 Credits**
This course will cover the principles of designing microprocessors using solid engineering fundamentals and quantitative cost/performance trade-offs. Topics will cover instruction set architectures, arithmetic for computers, assessing and understanding processor performance, processor datapath and control, pipelining, cache design, and virtual-memory design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECE 200 [Min Grade: D] or CS 270 [Min Grade: D]) and ECEC 302 [Min Grade: D]

**ECEC 356 Embedded Systems 4.0 Credits**
Lectures will cover theoretical concepts of embedded and cyber#physical systems including discrete and continuous dynamics, hybrid systems, state machines, concurrent computation, embedded systems architecture and scheduling. Lab involves programming embedded applications for the decentralized software services architecture using C# and the Microsoft Robotics Software Development Kit (SDK) together with the hardware image processing and tracking capabilities of the Kinect sensor.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 304 [Min Grade: D]

**ECEC 357 Introduction to Computer Networks 4.0 Credits**
History of the Internet; introduction to packet switching, circuit switching and virtual circuit switching; statistical multiplexing; protocol layering; metrics of network performance including bandwidth, delay and loss; medium access protocols and Ethernet; routing algorithms; end-to-end issues; flow and congestion control; an overview of application layer protocols.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 203 [Min Grade: D] or CS 171 [Min Grade: D]

**ECEC 390 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 411 Computer Hardware 3.0 Credits**
Covers the design and performance of computer hardware devices, including direct memory access, priority arbitration, double buffering, and bus standards. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECEC 355 [Min Grade: D]

**ECEC 412 Modern Processor Design 3.0 Credits**
This course introduces modern processor design in a systematic manner. It discusses dynamically scheduled superscalar techniques including multi-issue, dynamic instruction scheduling, speculative execution, and branch prediction; advanced cache designs, and new techniques including SMT and VLIW. The course provides a comprehensive coverage of modern processor architectures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D] or CS 281 [Min Grade: D]

**ECEC 413 Introduction to Parallel Computer Architecture 3.0 Credits**
This course provides an introduction to the fundamental principles and engineering trade-offs involved in designing modern parallel computers (multi-processors). Topics covered include, but are not limited to, shared-memory and message-passing programming, cache-coherence, synchronization, scalable distributed memory multi-processors, and interconnection techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D] or CS 281 [Min Grade: D]

**ECEC 414 High Performance Computing 3.0 Credits**
This course is an introduction to high performance computing, including both concepts and applications. Course contents will include discussions of different types of high performance computer architectures (multi-core/multi-threaded processors, parallel computers, etc.), the design, implementation, optimization and analysis of efficient algorithms for uni-processors, multi-threaded processors, and parallel computers, and high performance programming.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D] or (CS 281 [Min Grade: D] and CS 282 [Min Grade: D])

**ECEC 421 Introduction to Operating Systems I 3.0 Credits**
Covers basic concepts of computer operating systems, including multiprocessing and multiprogramming systems, lock operations, synchronization, and file structures. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECEC 355 [Min Grade: D] and CS 260 [Min Grade: D]

**ECEC 422 Introduction to Operating Systems I 3.0 Credits**
Further develops the topics of ECEC 421. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEC 421 [Min Grade: D]

**ECEC 431 Introduction to Computer Networks 3.0 Credits**
Covers topics in computer and telecommunications network design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECE 200 [Min Grade: D] and CS 260 [Min Grade: D]

**ECEC 432 Internet Architecture and Protocols 3.0 Credits**
Covers architecture, protocols, and services of the Internet with an
analytical approach focused on design principles; Internet architecture
and topology; architecture of web and mail servers; router architectures;
routing protocols; multicasting; multimedia over IP and associated
protocols; Quality-of-Service issues in the Internet.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 357 [Min Grade: D] or CS 472 [Min Grade: D]

**ECEC 433 Network Programming 3.0 Credits**
Covers application layer protocol and how applications use the transport
layer; principles and practice of network programming; the client-server
model; concurrent processing; introduction to sockets and related
functions client and server software design with examples; principles,
issues and challenges in e-mail and web application protocols; security
protocols; and network life system concepts.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 357 [Min Grade: D]

**ECEC 441 Robotic Computer Interface & Control I 3.0 Credits**
Covers fundamentals of robotics systems, including mechanics, actuators,
sensors, kinematics, and inverse kinematics. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECES 356 [Min Grade: D]

**ECEC 442 Robotic Computer Interface & Control II 3.0 Credits**
Covers robot dynamics, Lagrangian and Newton Euler methods, linear
control of robots, path planning, and computer implementation. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEC 441 [Min Grade: D]

**ECEC 443 Robotic Computer Interface & Control III 3.0 Credits**
Covers robot-computer interface methods, including redundancy,
optimal control, robustness, nonlinear control, adaptive control, and
multiprocessor control. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEC 442 [Min Grade: D]

**ECEC 451 Computer Arithmetic 3.0 Credits**
This course provides an introduction to number representations used in
computer arithmetic, issues of complexity in arithmetic operations, fixed
point arithmetic, floating point arithmetic, and residue number systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 200 [Min Grade: D] and ECEC 355 [Min Grade: D]

**ECEC 453 Image Processing Architecture 3.0 Credits**
This course covers applications of computing techniques and hardware
in image (still and video) processing. Methods of compression (lossless,
lossy), video compression, JPEG standards, MPEG standards,
processing requirements, and implementations for multimedia.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 200 [Min Grade: D] and ECES 301 [Min Grade: D]
and ECES 303 [Min Grade: D]

**ECEC 455 Intelligent System Architectures 3.0 Credits**
This course outlines the principles of designing the architectures for
intelligent systems. Methods of knowledge representation are compared
for a variety of engineering problems. Methods of sensing and behavior
generation are demonstrated for applications in large engineering and
information systems including autonomous robots. Principles of goal-
oriented computers are discussed, and modules of intelligent systems
architectures are described. Theoretical fundamentals and practical
techniques for learning are also covered.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** MATH 221 [Min Grade: D] and ECEC 355 [Min Grade: D]

**ECEC 457 Security in Computing 3.0 Credits**
The course introduces ideas from Cryptography and Fault Tolerant
Computing. Cryptography studies how to artificially create distortions that
being interwoven with computations mask them from eavesdropping.
Fault Tolerance studies techniques of suppressing effects of natural
noises that operate in computation channels. The course deals with both
some introductory issues in Public Key Cryptography and some important
aspects of designing Fault Tolerant Systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D]

**ECEC 459 Testing of Hardware 3.0 Credits**
Testing has become the largest expense item in the semiconductor
industry. There is rapidly being developed new techniques in testing,
design for test and built-in self-test because no existing set of techniques
can satisfy the existing and future needs. The course reviews, in a unified
way, important issues in testing and diagnosis of hardware. Together with
the "Security in Computing" course, it brings a design engineer student to
the state of the art level in the field.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D]

**ECEC 471 Introduction to VLSI Design 3.0 Credits**
This is an introductory course where systematic understanding, design
and analysis of digital VLSI integrated circuits will be covered. The course
will begin with a review of CMOS transistor operation and semiconductor
processes. Logic design with CMOS transistor and circuit families will
be described. Specifically, layout, design rules, and circuit simulation
will be addressed. Performance metrics will be analyzed in design and
simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECE 200 [Min Grade: D] or CS 270 [Min Grade: D]) and
(ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D])

**ECEC 472 VLSI Design & Automation 3.0 Credits**
Design and analysis of VLSI integrated circuits will be covered from circuits and systems design perspectives. First, system timing and arithmetic building blocks will be presented. Then, design automation will be presented by hierarchical design examples using hardware description languages (HDL) and physical design with VLSI CAD tools.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 355 [Min Grade: D] and (ECE 200 [Min Grade: D] or CS 270 [Min Grade: D])

**ECEC 473 Modern VLSI IC Design 3.0 Credits**
This is a project-oriented course where a high-complexity VLSI design project will be assigned to student teams. Team-work, task assignment and team communication will be mediated in an industry setting. Design tasks will cover the entire IC design flow range, from system specification to TRL description to timing and power analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 472 [Min Grade: D]

**ECEC 474 ASIC Design I 3.0 Credits**
This course will focus exclusively on digital CMOS Application Specific Integrated Circuit (ASIC) systems design and automation. The ASIC physical design flow, including logic synthesis, floorplanning, placement, clock tree synthesis, routing and verification will be presented. These back-end physical design flow steps will also be covered through hands-on practice using industrial VLSI CAD tools. Contemporary design practices will be reviewed and presented in experiments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 200 [Min Grade: D] and ECEC 355 [Min Grade: D]

**ECEC 475 ASIC Design II 3.0 Credits**
Design and analysis of Application Specific Integrated Circuits (ASICs) will be covered from a systems design perspective. System timing, arithmetic building block and memory block design processes will be presented. Design tasks in a quarter-long, small-complexity processor design project will cover the back-end of the IC design flow range, from RTL synthesis to timing and power analysis. Projects will be performed in a hierarchical group, similar to an industrial setting, with other graduate and undergraduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 474 [Min Grade: D]

**ECEC 490 Special Topics in Computer Engineering 12.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEC 497 Research In Computer Engineering 0.5-12.0 Credits**
Computer engineering students only. Requires independent research in a field approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is CE.

**ECEC 499 Independent Study in Computer Engineering 0.5-12.0 Credits**
Computer engineering students only. Requires independent study or research in a field approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is CE.
Cannot enroll if classification is Freshman or Sophomore

# Elec Computer Engr-Electroph Courses

**ECEE 302 Electronic Devices 4.0 Credits**
Covers principles of operation of semiconductor devices, including PN diodes, bipolar transistors, and field effect transistors (JFET, MOSFET, MESFET). Applications of PN junctions, including solar cells, led, laser diodes. Laboratories reinforce lecture material by allowing students to build, measure and analyze data from simple devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** TDEC 211 [Min Grade: D] or ENGR 220 [Min Grade: D]

**ECEE 304 Electromagnetic Fields & Waves 4.0 Credits**
Covers vector calculus, Coulomb's Law, Gauss' Law, Ampere's Law, Maxwell's equations, Electromagnetic (EM) fields in devices, EM fields in circuits, EM fields in machinery, EM waves, biological effects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATH 291 [Min Grade: D]

**ECEE 352 Analog Electronics 4.0 Credits**
Teaches the fundamentals of electronic circuit analysis and design by means of practical projects, such as a dc power supply and an audio amplifier. Covers design with discrete components as well as integrated circuit design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D] and ECES 301 [Min Grade: D]

**ECEE 354 Wireless and Optical Electronics 4.0 Credits**
Covers propagation of waves in various media as it relates to wireless communications: reflection, transmission, polarization, wave packets, dispersion, radiation and antennas, microwave electronic devices, optical wave guides, and fiber optics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D] and ECEE 304 [Min Grade: D]

**ECEE 390 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 421 Advanced Electronics I 4.0 Credits**
Application-and design-focused course. Analyzes feedback in electronic circuits such as operational amplifiers. Covers design and applications of active filters and other typical electronic circuitry. Includes experiments in the design of multistage transistor circuits, feedback loops, operational amplifiers, and active filters.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 352 [Min Grade: D]

**ECEE 422 Advanced Electronic Circuits I 3.0 Credits**
Application-and design-focused course. Covers analysis and design of communication circuits and non-linear active circuits; oscillators, mixers, IF and RF amplifiers; and AM and FM modulators.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 421 [Min Grade: D]

**ECEE 423 Advanced Electronics Circuits II 3.0 Credits**
Application-and design-focused course. Covers non-linear circuits; function and wave form generators; log-amp, multipliers, dividers, power amp, and phase-lock loops; and design of electronics needed to implement different logic circuit families.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 421 [Min Grade: D]

**ECEE 434 Digital Electronics 4.0 Credits**
Covers basic digital integrated circuit building blocks (inverters, nor and nand logic), CMOS logic gates (dc and transient behavior), drivers, and digital circuits and systems (PLA, gate array, memory). Experiments in semiconductor material characterization, device characterization, circuit and device simulations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D]

**ECEE 441 Lightwave Engineering I 3.0 Credits**
Covers fundamentals of wave propagation, including propagation in various fiber wave guides and field distributions, diffraction, attenuation, dispersion, information capacity, and other analytic and design considerations in fiber systems. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 304 [Min Grade: D]

**ECEE 442 Lightwave Engineering II 3.0 Credits**
Covers operating principles, construction, and characteristics of sources, couplers, and detectors used in optical systems. Includes equivalent circuit models and principles of generation, transmission, and reception. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 441 [Min Grade: D]

**ECEE 443 Lightwave Engineering III 3.0 Credits**
Covers applications of devices and systems in such areas as data, voice, and image trans-mission; industrial automation; process control; medicine; and computers. Includes basic measurement systems. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 442 [Min Grade: D]

**ECEE 451 Electroacoustics 3.0 Credits**
Applications-oriented course. Covers fundamentals of vibrating systems; equations of motion; acoustical, electrical, and mechanical analogs; properties of waves in fluids; acoustic impedance and plane wave transmission; application to design of transducers; and application of acoustic waves in medical imaging, non-destructive testing, and the biomedical field.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Junior or Pre-Junior or Sophomore

**ECEE 471 RF Components and Techniques 4.0 Credits**
This course covers microwave networks (Z, Y, S, T ABCD Parameters), signal flowgraph, impedance matching techniques (lumped and distributed, quarter wave transformers), circulators and isolators, directional couplers (branch line, Wilkinson, Lange, slot waveguide), and filters (lowpass, bandpass, bandstop, highpass). CAD laboratory and design projects are an integral part of this course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 354 [Min Grade: D]

**ECEE 472 RF Electronics 4.0 Credits**
This course covers static and dynamic characteristics of transistors, unipolar (MOSFET, MESFET, HEMT), bipolar (BJT, HBT), LNA design and realization, power amplifiers, distributed amplifiers, switches, limiters, phase shifters, detectors, mixers, oscillators (Colpitts, YIG turned, reflection, transmission, DRO). CAD laboratory and design projects are an integral part of this course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 471 [Min Grade: D]

**ECEE 473 Antennas and Radiating Systems 4.0 Credits**
This course covers short and magnetic dipole, radiation pattern, radiation resistance, directivity and gain, line antennas (dipoles, monopoles, V and inverted V antennas), helix, Yagi-Uda, log-periodic, aperture antennas (slot, horn and reflector), printed circuit antennas (patch and spiral), and phased antennas. CAD laboratory and design projects are an integral part of this course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 471 [Min Grade: D]

**ECEE 490 Special Topics in Electrophysics 12.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEE 497 Research in Electrophysics 0.5-12.0 Credits**
Requires independent research in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 499 Independent Study In Electrophysics 0.5-12.0 Credits**
Requires independent study in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

## Elec Computer Engr-Power Eng Courses

**ECEP 352 Electric Motor Control Principles 4.0 Credits**
Introduces machinery principles, magnetic circuits, three-phase circuits, the electrical and economic structure of the power industry, ac and dc machine fundamentals, and power electronic converters and their interfaces with electric motors. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D] (Can be taken Concurrently) (ECE 201 [Min Grade: D] or ECES 211 [Min Grade: D])

**ECEP 354 Energy Management Principles 4.0 Credits**
Covers principles of power engineering, including the electrical and economic structure of the power industry (distribution, subtransmission, and bulk transmission levels; environmental issues; the electrical system analysis; the thermal system analysis; links between electromechanics and thermodynamics; and safety issues). Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D] (Can be taken Concurrently) (ECE 201 [Min Grade: D] or ECES 211 [Min Grade: D])

**ECEP 371 Introduction to Nuclear Engineering 2.0 Credits**
This course introduces the student to the fundamental topic of nuclear engineering. This course should be the first course for students interested in the nuclear engineering minor, as all of the topics will be discussed in greater detail in other courses. Topics include atomic and nuclear structure, binding energy, reaction kinetics and energetics, and radioactive decay.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 201 [Min Grade: C] and (ENGR 210 [Min Grade: C] or CHE 206 [Min Grade: C])

**ECEP 372 Radiation Detection and Measurement 3.0 Credits**
Introduces students to the fundamentals of radiation detection, and applications of radiation detection equipment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 371 [Min Grade: D] or ECEP 404 [Min Grade: D] or MEM 371 [Min Grade: D]

**ECEP 380 Introduction to Renewable Energy 3.0 Credits**
Introduction to Renewable Energy is an undergraduate survey course for engineers, scientists and others interested in energy systems and applications. The course introduces students to the mix of current major electric power sources and the pressures that are forcing a transition to renewable sources. Wind and solar energy will be studied in detail, with others as time allows. Course culminates with an integrating off-grid energy system design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATH 122 [Min Grade: D] and (PHYS 102 [Min Grade: D] or PHYS 115 [Min Grade: D] or PHYS 154 [Min Grade: D])

**ECEP 390 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 402 Theory of Nuclear Reactors 4.0 Credits**
Introduces students to atomic and nuclear physics, radiation interaction with matter, components of nuclear reactors, neutron diffusion and moderation, nuclear reactor theory, and heat removal from nuclear reactors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENGR 210 [Min Grade: D]

**ECEP 403 Nuclear Power Plant Design & Operation 3.0 Credits**
Introduces students to the design of nuclear power plants. Topics covered include electrical transmission, non-nuclear related equipment, fluid flow, heat transfer, thermodynamics, heat exchangers, pump, valves, piping and nuclear reactor design. Course includes a final project which is the design of a nuclear power plant.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 404 Introduction to Nuclear Engineering 2.0 Credits**
Introduces the fundamental scientific, technical, social and ethical issues in nuclear engineering; nuclear reactions and readiation, radiation protection and control, nuclear energy production and utilization, nuclear fuel cycle, nuclear fuel cycle, nuclear materials, controlled fusion and thermonuclear plasma systems, basics of plasma physics and plasma chemistry, nuclear waste management, nuclear reactor safety, analysis of severe nuclear accidents, risk assessment and related issues of engineering ethics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 201 [Min Grade: D] and (ENGR 210 [Min Grade: D] or CHE 206 [Min Grade: D])

**ECEP 406 Introduction to Radiation Health Principles 3.0 Credits**
This course is intended to impart radiation safety knowledge to the nuclear engineering student. A fundamental knowledge of radiation safety is critical for all nuclear engineers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 371 [Min Grade: D] or ECEP 404 [Min Grade: D]

**ECEP 411 Power Systems I 3.0 Credits**
Covers steady state generator, transformer and transmission line modeling used for balanced steady state power system analysis including three-phase to single-phase model conversion, per-unit analysis, generator and line loadability, transformer and transmission line voltage regulation and reactive compensation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 352 [Min Grade: D]

**ECEP 412 Power Systems II 4.0 Credits**
Covers y-bus based analysis of power systems including steady-state power-flow models and algorithms, economic dispatch of power generation, load-frequency control and introduction to transient stability analysis including time-domain simulation and equal area criterion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 411 [Min Grade: D]

**ECEP 413 Power Systems III 3.0 Credits**
Covers Z-bus-based analysis of power systems including symmetrical component networks of generators, transformers, transmission lines and loads, symmetrical and unbalanced three-phase bus and line faults, and an introduction to power system protection.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 412 [Min Grade: D]

**ECEP 421 Modeling and Analysis of Electric Power Distribution Systems 3.0 Credits**
Introduction to power distribution systems; balanced and unbalanced systems, component and load modeling, radial and weekly meshed topologies; algorithms for unbalanced power studies including radial and general structure solver.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Corequisite**: ECEP 411

**ECEP 422 Power Distribution Automation and Control 3.0 Credits**
Focuses on distribution management systems and their application: including optimizing network operation - capacitor placement and control, network reconfiguration, service restoration. Modern solution technologies are addressed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 421 [Min Grade: C]

**ECEP 423 Service and Power Quality Distribution Systems 3.0 Credits**
Focus on power distribution systems: service and power quality assessment including stat estimation, voltage quality, trouble call analysis, service restoration, component and system reliability assessment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 422 [Min Grade: C]

**ECEP 431 Advanced Electromagnetic Energy Conversion I 4.0 Credits**
Covers theory and operation of alternating current machinery, with emphasis on design alternatives and the effects of design on performance. Includes construction of machine models from laboratory measurements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 352 [Min Grade: D]

**ECEP 432 Advanced Electromagnetic Energy Conversion II 4.0 Credits**
Covers dynamic behavior and transient phenomena of rotating machines and the mathematical models used to describe them, generalized machine theory, measurement of parameters for the mathematical models, and measurement of dynamic and transient behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 431 [Min Grade: D]

**ECEP 441 Protective Relaying 3.0 Credits**
Covers operating principles of electromechanical and static relays, fault clearance, and protection of individual parts of a power system. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 411 [Min Grade: D] (Can be taken Concurrently)ECEP 352 [Min Grade: D]

**ECEP 451 Power Electronic Converter Fundamentals 3.0 Credits**
Fundamentals of power electronics that include waveforms, basic power switch properties and magnetic circuits. Introduction to basic power electronic converter circuits: diode and phase-controlled rectifies and inverters; switch-mode converters. Applications to DC and AC power supply systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 352 [Min Grade: D]

**ECEP 452 Experimental Study of Power Electronic Converters 3.0 Credits**
Experimental study of common power electronic converters: diode rectifiers, phase-controlled rectifies, switch-mode inverters. Both hardware and software studies. Additional lectures on: Study of DC-DC switch-mode converters.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 451 [Min Grade: D]

**ECEP 453 Applications of Power Electronic Converters 3.0 Credits**
Provides a first look at various power electronic applications in residential, commercial and industrial sites. Examples include utility application such as static var compensators (SVC), thyristor switch capacitors (TSC), high voltage direct-current (HVDC) transmission systems among others. In addition, fundamentals of motor drives and their controls are covered. Examples include induction, DC synchronous and specialized motors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 451 [Min Grade: D]

**ECEP 461 High Voltage Laboratory 1.0 Credit**
Requires students to perform four basic experiments to become familiar with high-voltage techniques and then do a high-voltage design project of their own choosing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEP 352 [Min Grade: D]

**ECEP 471 Power Seminar I 0.5 Credits**
Discusses current developments in power system operation and research, concentrating on current and future energy sources.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEP 472 Power Seminar II 0.5 Credits**
Discusses current developments in power system operation and research, concentrating on generating stations, transmission lines, and substations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEP 473 Power Seminar III 0.5 Credits**
Discusses current developments in power system operation and research, concentrating on distribution, security, and economics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEP 480 Solar Energy Engineering 3.0 Credits**
Covers design of grid-connected and battery backup grid-connected photovoltaic systems. Both electrical and mechanical aspects are included. Topics include system components (solar cells, charge controllers, maximum power point trackers, inverters, etc.), system economics, computer and web-based design aids, electrical codes and standards, externalities of PV systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEE 302 [Min Grade: D] or ECEE 352 [Min Grade: D] or CHE 431 [Min Grade: D] or ECEP 380 [Min Grade: D]

**ECEP 490 Special Topics in Power Engineering 12.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECEP 497 Research in Power Systems 0.5-12.0 Credits**
Requires independent study in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 499 Independent Study In Power Engineering 0.5-12.0 Credits**
Requires independent study in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

# Elec Computer Engr-Systems Courses

**ECES 201 Introduction to Audio-Visual Signals 4.0 Credits**
This introductory engineering course will focus on the digital signal representations commonly used in prevailing entertainment media: audio, images, and video. It will explore how each medium is represented digitally and convey the signal processing concepts used in storing, manipulating, transmitting, and rendering such content. The goal of the course is to provide non-engineering students with a fundamental understanding of core digital signal processing methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATH 122 [Min Grade: D]

**ECES 301 Transform Methods and Filtering 4.0 Credits**
This course covers the engineering related concepts of signals and systems, their modeling and analysis. We discuss the problem of formulation of physical systems, plus mathematical solution of models (equations). Continuous-time signals and systems, discrete-time signals and systems, linear time-invariant systems, convolution integrals and sums, Fourier series, Fourier, Laplace and Z-transforms, and system functions will be studied.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D] or MATH 262 [Min Grade: D] or MATH 210 [Min Grade: D]) and ECE 201 [Min Grade: D]

**ECES 302 Transform Methods and Filtering 4.0 Credits**
Covers the Fourier series and the Fourier transform, sinusoidal steady-state analysis and filtering, discrete-time systems and the Z-transform, discrete Fourier transform, network functions and stability, magnitude, phase, poles and zeroes, Nyquist criterion, the Nyquist plot and root loci, stability of one-ports, sensitivity, worst-case design and failure-tolerance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** (TDEC 221 [Min Grade: D] or ENGR 232 [Min Grade: D] or MATH 262 [Min Grade: D] or MATH 210 [Min Grade: D]) and ECE 201 [Min Grade: D]

**ECES 303 Transform Methods II 3.0 Credits**
This course covers the engineering related concepts of signals and systems, their modeling and analysis. We discuss the problem of formulation of physical systems, plus mathematical solution of models (equations). Continuous-time signals and systems, discrete-time signals and systems, linear time-invariant systems, convolution integrals and sums, Fourier series, Fourier, Laplace and Z-transforms, and system functions will be studied.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 301 [Min Grade: D]

**ECES 304 Dynamic Systems and Stability 4.0 Credits**
Covers linear time-invariant circuits and systems; two-and multi-terminal resistors, operational-amplifier circuits, first-order circuits, linear and nonlinear second-order systems, state equation and state variables, eigenvalues and eigenvectors, zero-input response, qualitative behavior of x'=Ax (stability and equilibria), qualitative behavior of x'=f(x), phase portraits, equilibrium states.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D]

**ECES 306 Analog & Digital Communication 4.0 Credits**
Covers signal sampling and reconstruction; modulation, angle modulation; digital communications systems, digital transmission.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D]

**ECES 352 Introduction to Digital Signal Process 4.0 Credits**
Covers discrete-time signals, analog-digital conversion, time and frequency domain analysis of discrete-time systems, analysis using Z-transform, introduction to digital filters, discrete-time Fourier transform, Discrete Fourier Transform (DFT), and Fast Fourier Transform (FFT).
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D]

**ECES 354 Wireless, Mobile & Cellular Communications 4.0 Credits**
Covers concepts of wireless systems; propagation effects, including loss, dispersion, fading, transmission, and reception; mobile systems, including design of base units and mobile units; micro cells and pico cells; cell division, including frequency use and reuse; concepts of FDMA, TDMA, and CDMA; error rates and outage probability; and circuits and components for wireless and mobile systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 306 [Min Grade: D]

**ECES 356 Theory of Control 4.0 Credits**
Covers the foundations of control theory. Includes experiments and demonstrations during lectures and labs that may be jointly held, taking advantage of multimedia and computer-controlled apparatus.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 304 [Min Grade: D]

**ECES 358 Computer Control Systems 4.0 Credits**
Reviews principles of applications of computer control systems to a variety of industries and technologies, including manufacturing processes, robotic cells, machine cells, chemical processes, network control, investment portfolio control, and real-time expert and learning systems for diagnostics and quality control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 356 [Min Grade: D]

**ECES 390 Special Topics 4.0 Credits**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 411 Convex Optimization in Engineering Systems 3.0 Credits**
Covers fundamental of convex optimization including convex sets, convex functions, linear and nonlinear constraints, complementary slackness, Lagrange multipliers, Lagrangian duality, and quadralic programming. Focuses on applications (e.g., signal processing, communications, computer networking, and portfolio management). Focuses on use of Matlab or equivalent software.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D] and (ENGR 361 [Min Grade: D] or ECE 361 [Min Grade: D])

**ECES 412 Simulation of Stochastic Engineering Systems 3.0 Credits**
Covers algorithms for generation of pseudo-random numbers, generation of random variates using the inverse transform, acceptance rejection techniques, Monte Carlo simulation, basics of point and interval estimation and hypothesis testing. Coverage of Markov chains, Markov chain Monte Carlo, Metropolis algorithm, simulated annealing, as time permits. Applications include computer networks, statistical physics, derivative pricing. Focus on use of Matlab or equivalent software.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D] and (ENGR 361 [Min Grade: D] or ECE 361 [Min Grade: D])

**ECES 413 Strategies for Repeated Games 3.0 Credits**
Covers the gambler's ruin problem, optimality of bold play for
subfair games, the Martingale betting system, Kelly betting and the
maximum growth rate in superfair games, the multi-armed bandit and it
generalizations, Parrondo's paradox for coupled subfair games, basics of
auction theory. Focus on use of Matlab or equivalent software.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D]
and (ENGR 361 [Min Grade: D] or ECE 361 [Min Grade: D])

**ECES 421 Communications I 3.0 Credits**
Covers analog communications, including linear modulation methods
(AM, DSB, SSB), exponential modulation (FM, PM), and noise effects on
analog communication systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 306 [Min Grade: D]

**ECES 422 Communications II 3.0 Credits**
Covers analog (PAM, PPM) and digital (PCM, DM) pulse modulation
systems, entropy, source coding, and channel coding.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 421 [Min Grade: D]

**ECES 423 Communications III 3.0 Credits**
Covers digital transmission systems, baseband and passband, spread-
spectrum communications, and basics of wireless and mobile systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 422 [Min Grade: D]

**ECES 434 Applied Digital Signal Processing 4.0 Credits**
This course explores digital signal processing (DSP) concepts through
the context of current applications, which range from video encoding
to human genome analysis. Topics such as sampling, aliasing, and
quantization, are considered in terms of the constraints of particular
applications. Discrete-time linear systems, frequency-domain analysis,
and digital filtering using Discrete Fourier Transform are examined in-
depth and realized through application-specific lab projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 352 [Min Grade: D]

**ECES 435 Recent Advances in Digital Signal Processing 4.0 Credits**
Digital signal processing algorithms once thought to be impractical are
now implemented in devices, such as household appliances & mobile
phones. This course explores the computationally-intensive DSP methods
including short-time linear prediction, cepstral analysis, and complex
phase reconstruction as well as alternative signal representations and
transforms, including the Hilbert, Chirp, and Discrete Cosine Transforms.
Laboratory projects will focus on the implementation of these methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 352 [Min Grade: D]

**ECES 436 Multi-disciplinary Digital Signal Processing 4.0 Credits**
The applications of digital signal processing (DSP) span a wide range
of problem domains and disciplines. This course explores the multi-
disciplinary aspects of DSP by focusing on a core set of common methods
applicable to problems in many fields, such as periodicity detection,
signal and power spectrum estimation, and data modeling. Laboratory
projects will utilize experiments drawn from a diversity of fields, including
medicine, music analysis, image processing,voice/data communications
and robotics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 352 [Min Grade: D]

**ECES 444 Systems and Control I 4.0 Credits**
This course reviews classical control: analysis and design, state space
approach to systems analysis and control; Eigenvalue/Eigenvector
analysis, model decomposition, state space solutions and Cayley-
Hamilton technique and applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 356 [Min Grade: D]

**ECES 445 Systems and Control II 4.0 Credits**
This course covers Eigenvector single-value decomposition and modal
decomposition; controllability, observability and Kalman canonical forms;
state controllers and observers and the separation principle.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 444 [Min Grade: D]

**ECES 446 Systems and Control III 4.0 Credits**
This course covers linear quadratic control, non-linear stability and
analysis. Current topics in control include Robust, H-infinity, and Fuzzy
Control concepts.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 445 [Min Grade: D]

**ECES 462 Medical Robotics II 3.0 Credits**
This course will review the emerging, multidisciplinary field of Medical
Robotics. The course includes multiple site/field visits to observe Medical
Robot systems demonstrations and interaction with the medical team and
system manufacturers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 461 [Min Grade: D]

**ECES 490 Special Topics in Systems Engineering 12.0 Credits**
Provides special courses offered because of particular student or faculty
interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECES 497 Research in Systems Engineering 0.5-12.0 Credits**
Electrical engineering students only. Requires independent research in a
topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**ECES 499 Supervised Study in Systems Engineering 0.5-20.0 Credits**
Requires independent study in a topic approved by the faculty.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

# Electrical Computer Engr Courses

### ECE 101 Electrical and Computer Engineering in the Real World 1.0 Credit
This seminar introduces students to highly visible and compelling applications of ECE through the use of familiar real-world applications. The course will highlight some of the high-impact advances of ECE and the importance of ECE in our daily lives. Fundamental concepts, such as electricity, light, computing, networking, and signal processing will be introduced in this context and explained at an introductory level. This course is intended to inspire students to pursue ECE and will lead them directly into ECE 102.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECE 102 Applications of Electrical and Computer Engineering 2.0 Credits
Introduces the basic fundamentals of ECE through the use of real-world applications. The course will introduce Signals and Systems, Analog electronic basics, as well as Digital numbers and systems. The course will introduce students to basic ECE material, preparing the students for ECE 200 and ECE 201.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECE 121 Introduction to Entertainment Engineering 3.0 Credits
This introductory survey course will focus on the four prevailing entertainment media: music, images, video, and games. We will explore how each medium is represented digitally and reveal the technologies used to capture, manipulate and display such content. Technical standards used in everyday entertainment devices (mp3, H.264, JPEG 1080p, HDMI) will be explained in layman's terms. The goal is to provide students with technical literacy for using digital media.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECE 190 Special Topics 1.0-4.0 Credit
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

### ECE 200 Digital Logic Design 3.0 Credits
Number systems and representation, two's complement arithmetic, digital logic devices, switching algebra, truth tables, minimization of Boolean functions, combinational logic design and analysis, sequential circuit analysis and design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** CS 170 [Min Grade: D] or TDEC 132 [Min Grade: D] or CS 171 [Min Grade: D] or ENGR 103 [Min Grade: D] or ENGR 104 [Min Grade: D]

### ECE 201 Foundations of Electric Circuits 3.0 Credits
Covers basic electric circuit concepts and laws; circuit theorems; mesh and node methods; analysis of first-and second-order electric circuits; force and natural response; sinusoidal steady state analysis; complex frequency.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is CAE or classification is Freshman
**Prerequisites:** PHYS 211 [Min Grade: D] or TDEC 115 [Min Grade: D] or PHYS 281 [Min Grade: D] or PHYS 102 [Min Grade: D]

### ECE 203 Programming for Engineers 3.0 Credits
Fundamentals of computer organization; rudiments of programming including data types, arithmetic and logical expressions, conditional statements, control structures; problem solving techniques for engineers using programming; object-oriented programming; arrays; simulation of engineering systems; principles of good programming practice.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

### ECE 211 Electrical Engineering Principles 3.0 Credits
Not open to electrical or mechanical engineering students. Covers basic techniques of electric circuit analysis, electronic devices, amplifiers, operational amplifier, and fundamentals of instrumentation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is EE or major is MECH or classification is Freshman
**Prerequisites:** (MATH 201 [Min Grade: D] or ENGR 231 [Min Grade: D] or MATH 261 [Min Grade: D]) and (PHYS 211 [Min Grade: D] or PHYS 281 [Min Grade: D] or PHYS 102 [Min Grade: D])
**Corequisite**: ECE 212

### ECE 212 Electrical Engineering Principles Laboratory 1.0 Credit
Not open to electrical or mechanical engineering students. Includes experiments involving concepts discussed in ECE 211.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if major is EE or major is MECH or classification is Freshman
**Corequisite**: ECE 211

### ECE 290 Special Topics 1.0-4.0 Credit
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECE 361 Probability for Engineers 3.0 Credits**
This course will cover topics related to probability and statistics. Probability topics include sample space and probability, discrete and continuous random variables, expectation, variance, covariance, correlation, conditional expectation, conditional variance, the weak and strong law of large numbers and the central limit theorem. Statistics topics include properties of a random sample, principles of data reduction, and point estimation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENGR 202 [Min Grade: D] and (ENGR 231 [Min Grade: D] or MATH 261 [Min Grade: D])

**ECE 362 Engineering Statistics 3.0 Credits**
This course will cover topics related to statistics and probability. Probability topics include sample space and probability; discrete and continuous random variables, expectation, variance, the law of large numbers and the central limit theorem. Statistics topics include properties of a random sample, principles of data reduction, point estimation, hypothesis testing, interval estimation, and linear regression.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ENGR 202 [Min Grade: D] and ENGR 231 [Min Grade: D]) or (ENGR 202 [Min Grade: D] and MATH 261 [Min Grade: D])

**ECE 390 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECE 391 Introduction to Engineering Design Methods 1.0 Credit**
Introduces the design process, including information retrieval, problem definition, proposal writing, patents, and design notebooks. Includes presentations on problem areas by experts from industry, government, and education.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**ECE 491 [WI] Senior Design Project I 2.0 Credits**
Introduces the design process, including information retrieval, problem definition, proposal writing, patents, and design notebooks. Includes presentations on problem areas by experts from industry, government, and education. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**ECE 492 [WI] Senior Design Project II 2.0 Credits**
Continues ECE 491. Requires written and oral progress reports. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECE 491 [Min Grade: D]

**ECE 493 Senior Design Project III 4.0 Credits**
Continues ECE 492. Requires written and oral final reports, including oral presentations by each design team at a formal Design Conference open to the public and conducted in the style of a professional conference.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** ECE 492 [Min Grade: D]

# Electrical Engineering Lab Courses

**ECEL 301 [WI] Electrical Engineering Laboratory 2.0 Credits**
Offers laboratory experiences in each of the five ECE tracks: computers, controls/robotics, electronics, power and energy, and telecommunications. Each lab consists of a stand-alone module containing: lecture material providing basic theory, references, and laboratory experiments. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECE 200 [Min Grade: D] and ECE 201 [Min Grade: D] and (TDEC 132 [Min Grade: D] or TDEC 133 [Min Grade: D] or ENGR 104 [Min Grade: D] or ENGR 103 [Min Grade: D])

**ECEL 302 ECE Laboratory II 2.0 Credits**
Offers laboratory experiences in each of the five ECE tracks: computers, controls/robotics, electronics, power and energy, and telecommunications. Each lab consists of a stand-alone module containing: lecture material providing basic theory, references, and laboratory experiments. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECES 301 [Min Grade: D] (Can be taken Concurrently)ECEL 301 [Min Grade: D]

**ECEL 303 ECE Laboratory III 2.0 Credits**
Covers basic digital signal processing concepts, an introduction to analog-to-digital and digital-to-analog converters, and power supply design using analog IC devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ECEL 302 [Min Grade: D]

**ECEL 304 ECE Laboratory IV 2.0 Credits**
This course offers laboratory experience, using both modeling software and digital and analog hardware relevant to both electrical and computer engineers. Multi-week design projects and design teams are used to prepare students for Senior Design work.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEL 303 [Min Grade: D]

**ECEL 311 ECE Laboratory Methods I 3.0 Credits**
Introduces students to MATLAB and PSpice, industry standard CAD
software for electronics (analog and digital) and systems engineers. Solve
DC bias, DC sweep, AC sweep, and transient problems in PSpice and
MATLAB. Build and design simple digital circuits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECE 200 [Min Grade: D] and ECE 201 [Min Grade: D] and
ENGR 103 [Min Grade: D]

**ECEL 312 ECE Laboratory Methods II 3.0 Credits**
Covers introduction to transistor circuits, PSpice simulations of active
devices, transfer function analysis, Bode analysis, active filter analysis
and design. Programming and use of Microprocessors and/or FPGA.
Perform measurements on devices and circuits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEL 301 [Min Grade: D] or ECEL 311 [Min Grade: D]

**ECEL 401 Lightwave Engineering Laboratory 3.0 Credits**
Teaches fundamentals of interaction of light with matter. Waves and
photons. nterference and diffraction. Optical fibers and free-space optics.
Introduces students to optical communication and imaging.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D]
and ECEE 302 [Min Grade: D]) or (ECEL 311 [Min Grade: D] and ECEL
312 [Min Grade: D] and ECEE 304 [Min Grade: D])

**ECEL 402 Nano-Photonics Laboratory 3.0 Credits**
Teaches a fundamental knowledge of nanophotonic materials, devices,
and applications in a hands-on laboratory setting. Introduces students
to photonic bandgaps, photonic crystals, optical sensing methods,
holography methods and materials, concepts of surface plasmons and
Plasmon resonance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D]
and ECEE 304 [Min Grade: D]) or (ECEL 311 [Min Grade: D] and ECEL
312 [Min Grade: D] and ECEE 304 [Min Grade: D])

**ECEL 403 Bio-Photonics Laboratory 3.0 Credits**
Teaches the fundamentals of the interaction of light with matter.
Introduces students to different types of optical detection for biomedical
applications,Quantized states of matter, Energy levels of atoms and
molecules, Absorption, Scattering, Fluorescence, Imaging of cells and
molecules, Spectroscopy, and Cancer precursors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D]
and ECEE 304 [Min Grade: D]) or (ECEL 311 [Min Grade: D] or ECEL 312
[Min Grade: D] or ECEE 304 [Min Grade: D])

**ECEL 404 Software Defined Radio Laboratory 3.0 Credits**
This course introduces students to the concept of software defined
radio using the USRP hardware platform and GNU Radio software.
Functional blocks of wireless communications systems will be discussed,
programmed in Python, and tested on hardware.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D]
and ECES 301 [Min Grade: D] and ECES 303 [Min Grade: D]) or (ECEL
311 [Min Grade: D] and ECEL 312 [Min Grade: D] and ECES 301 [Min
Grade: D] and ECES 303 [Min Grade: D])

**ECEL 405 Digital Systems Laboratory 3.0 Credits**
Students will gain practical knowledge of digital systems and signal
processing by designing, simulating, constructing, testing and refining a
digital audio recording system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D]
and ECES 301 [Min Grade: D]) or (ECEL 311 [Min Grade: D] and ECEL
312 [Min Grade: D] and ECES 301 [Min Grade: D])

**ECEL 407 General Purpose GPU Programming 3.0 Credits**
This course will teach students how to develop parallel algorithms for the
GPU and implement them using the CUDA progamming interface.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (ECEL 301 [Min Grade: D] and ECEL 302 [Min Grade: D]
and ECEC 301 [Min Grade: D] and ECEC 355 [Min Grade: D]) or (ECEL
311 [Min Grade: D] and ECEL 312 [Min Grade: D] and ECEC 301 [Min
Grade: D] and ECEC 355 [Min Grade: D])

**ECEL 490 Special Topics 1.0-4.0 Credit**
Provides special courses offered because of particular student or faculty
interest.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Engineering

*Bachelor of Science in Engineering (BSE) Degree: 180.5 quarter credits*

## About the Program

The Bachelor of Science in Engineering major is an interdisciplinary
engineering major for students who do not intend to be practicing
engineers. Students in the Bachelor of Science in Engineering major
combine a rigorous engineering education in the College of Engineering
with interdisciplinary studies in fields outside of engineering such as law,
medicine, business, entrepreneurship, teaching, international studies,
public policy, music, art, environmental studies, and more. The Bachelor
of Science in Engineering major provides a strong grounding in the
foundations of engineering, in quantitative skills, and in the analytic
processes that engineers use in design of practical technology.

Drexel's Bachelor of Science in Engineering major was developed
to provide students with educational and professional challenges not
available in the traditional engineering curriculum.

## Program Objectives

The key objectives of the Bachelor of Science in Engineering program are to provide the student with:

- a strong foundation in science and mathematics
- a foundation of the fundamentals of engineering as a discipline
- a strong grounding in a second cognate area (either technical, pre-professional, cultural, global, or another area worked out between the student and his/her advisor)
- an integrating experience that ties the technical and the cognate areas together. Examples of such experiences may be, but are not limited to, research projects, capstone designs, a public service assignment, etc.

## Additional Information

Additional information about the Bachelor of Science in Engineering program is available on the Bachelor of Science in Engineering website (http://drexel.edu/engineering/programs/undergrad/Engineering) .

## Degree Requirements

**General Education/Liberal Studies Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| General Education Requirements [*] | | 24.0 |
| Free Electives | | 24.0 |

**Math and Science Requirements**

| | | |
|---|---|---|
| BIO 141 | Essential Biology | 4.5 |
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |

**Core Curriculum Requirements**

| | | |
|---|---|---|
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 121 | Computation Lab I | 2.0 |
| ENGR 122 | Computation Lab II | 1.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |

**Engineering Requirements**

| | |
|---|---|
| As part of the 45.0 credits of Engineering requirements, students must include a capstone experience (Senior design sequence, research project, etc. ) | 45.0 |

**Technical Electives**

| | |
|---|---|
| Students select 18.0 credits of 200-level (or higher) courses in BMES, MATH, CHEM, PHYS, BIO or College of Engineering courses. Advisor approval is required for technical electives. | 18.0 |
| **Total Credits** | **180.5** |

[*]    General Education Requirements.

## Sample Plan of Study

### 5 YR UG Co-op Concentration

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 121 | Computation Lab I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **16.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 122 | Computation Lab II | 1.0 |
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **18.0** |
| **Term 4** | | |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| Engineering course [*] | | 3.0 |
| | **Term Credits** | **13.0** |
| **Term 5** | | |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| Engineering course [*] | | 3.0 |

| | |
|---|---|
| General Education elective[*] | 3.0 |
| Free elective | 3.0 |
| **Term Credits** | **15.0** |
| **Term 6** | |
| Two Engineering courses[*] | 6.0 |
| General Education elective[*] | 3.0 |
| Free elective | 3.0 |
| **Term Credits** | **12.0** |
| **Term 7** | |
| Two Engineering courses[*] | 6.0 |
| General Education elective[*] | 3.0 |
| Technical elective | 3.0 |
| Free elective | 3.0 |
| **Term Credits** | **15.0** |
| **Term 8** | |
| Two Engineering eourses[*] | 6.0 |
| General Education elective[*] | 3.0 |
| Technical elective | 3.0 |
| Free elective | 3.0 |
| **Term Credits** | **15.0** |
| **Term 9** | |
| Two Engineering courses[*] | 6.0 |
| General Education elective[*] | 3.0 |
| Technical elective | 3.0 |
| Free elective | 3.0 |
| **Term Credits** | **15.0** |
| **Term 10** | |
| Senior Design Project I or Capstone course[*] | 3.0 |
| Engineering course[*] | 3.0 |
| General Education elective[*] | 3.0 |
| Technical elective | 3.0 |
| Free elective | 3.0 |
| **Term Credits** | **15.0** |
| **Term 11** | |
| Senior Design Project II or Capstone course[*] | 3.0 |
| Engineering course[*] | 3.0 |
| General Education elective[*] | 3.0 |
| Technical elective | 3.0 |
| Free elective | 3.0 |
| **Term Credits** | **15.0** |
| **Term 12** | |
| Senior Design Project III or Capstone course[*] | 3.0 |
| General Education elective[*] | 3.0 |
| Technical elective | 3.0 |
| Free elective | 3.0 |
| **Term Credits** | **12.0** |

**Total Credit: 180.5**

[*] See degree requirements.

## Facilities

From the start of their freshman year, students learn to use the equipment they are likely to need in their careers, such as oscilloscopes, signal generators, amplifiers, and power supplies. These skills make students more useful as co-op employees and give them a competitive advantage in their engineering careers.

## Computer/Design Center

The Drexel Curriculum boasts two types of lab experience: Instrumentation and Computer Design. Instrumentation Labs introduce Engineering Majors to the sight, sound, and feel of equipment such as digital multimeters, power supplies, oscilloscopes, and waveform generators. The Computer Labs imbue these pre-engineers with knowledge of software which will be vital in today's work environment.

# Engineering Technology

*Bachelor of Science: 187.5 - 189.0 quarter credits*

## About the Program

The BS in Engineering Technology program is designed for students who plan to pursue careers in a variety of design-, production-, and service-related positions. The engineering technology major provides an integrated educational experience directed toward the development of fundamental knowledge to the solution of practical technological problems. Graduates will be able to fill the gap that exists between the engineer/scientist and the technical and/or production workforce.

Concentrations are available in biomedical, electrical, mechanical, and industrial engineering technology:

- Biomedical Engineering Technology
- Electrical Engineering Technology
- Industrial Engineering Technology
- Mechanical Engineering Technology

All students enrolled in the program are required to take general education courses, including mathematics, sciences and liberal arts. All concentrations consist of core fundamental courses, technical electives, free electives, and a three-term senior design project, reflecting industrial practices. During their sophomore year, students need to choose one of the four available concentrations.

The program distinguishes itself from traditional engineering programs by placing emphasis on the application of theory, by integrating most courses with laboratory experience and by incorporating faculty with extensive industrial background.

The program includes full-time and part-time enrollment options. Students pursuing the full-time option can opt for a four-year program with a six-month internship or a five-year program with three six-month co-op cycles.

Engineering technology graduates are uniquely qualified to serve in a variety of functions requiring traditional and nontraditional technological skills. The program also prepares students for graduate study in a variety of fields, including engineering technology, engineering management, business administration, and health-care.

## Mission

The mission of the Engineering Technology program is to provide contemporary students with an academic foundation and practical education in engineering technology through an outstanding curriculum and applied research program, and the participation of our students in one of the nation's most successful cooperative educational programs.

## Engineering Technology Program Educational Objectives

The Engineering Technology program produces graduates who:

- apply discipline-specific theory, experiments and real world experience to interpret, analyze and solve current and emerging technical problems;
- communicate clearly and persuasively with technical and non-technical people in oral, written and graphical forms;
- function individually and on teams to design quality systems, components or processes in a timely, responsible and creative manner;
- demonstrate behavior consistent with professional ethics and are cognizant of social concerns as they relate to the practice of engineering technology;
- strive for professional growth and engage in lifelong learning.

## Engineering Technology Student Outcomes

The program's outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

- an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;
- an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;
- an ability to conduct standard tests and measurements, to conduct, analyze, and interpret experiments, and to apply experimental results to improve processes;
- an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives;
- an ability to function effectively as a member or leader on a technical team;
- an ability to identify, analyze, and solve broadly-defined engineering technology problems;
- an ability to apply written, oral, and graphical communication in both technical and non-technical environments, and an ability to identify and use appropriate technical literature;
- an understanding of the need for and an ability to engage in self-directed continuing professional development;
- an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;
- a knowledge of the impact of engineering technology solutions in a societal and global context;
- a commitment to quality, timeliness, and continuous improvement.

## Additional Information

The Engineering Technology program is accredited by the Engineering Technology Accreditation Commission of ABET. (http://www.abet.org)

For additional information, please visit the Engineering Technology (http://www.drexel.edu/engtech) web page.

## Career Opportunities

The Engineering Technology program is designed to meet employers' growing needs, created by the technology revolution, for college-educated problem-solvers. Career opportunities in engineering technology are virtually limitless with at least 5,500 companies in the region offering more than 150 current job openings for engineering technologists. As a leading urban university in the Greater Philadelphia region, Drexel's location offers access to a vast number of industries including:

- Defense
- Aerospace
- Power generation
- Public utilities
- Shipbuilding
- Railroad
- Manufacturing
- Environmental
- Chemical
- Pharmaceutical
- Medical care

With the skills developed in this program, students will be able to integrate academic theory and professional practice in order to communicate effectively with engineers, scientists, the production workforce, marketing professionals, company management, and ultimately the customer. Students may participate in the design, development, testing, and manufacturing of industrial machinery, electric and electronic equipment, medical devices, consumer products, and other equipment.

Engineering technologists can serve in industry in many capacities; some fields include:

- Automation design and process engineering
- Mechanical/production engineering
- Electrical engineering and electronics
- Field engineering
- Systems engineering and management
- Environmental engineering
- Quality control
- Sales and customer service
- Systems/programming
- Testing engineering

Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) page for more detailed information on post-graduate opportunities.

## Dual/Accelerated Degree

### Transfer Articulation Agreements

The College of Engineering has transfer articulation agreements with Delaware County Community College (http://www.dccc.edu) (DCCC)

and Burlington County College (http://www.bcc.edu) (BCC), leading to concurrent AS and BS degrees in appropriate areas of study.

As an added benefit, students can earn certifications recognized by industry and required by employers for entry into the workforce. Each certificate program, usually completed in six months to one year, provides credits that automatically apply to a student's degrees.

For more information contact:

College of Engineering
Gerry Willis, Program Manager
gtm23@drexel.edu
215-895-6253

Delaware County Community College
Admissions Office
admiss@dccc.edu
610-359-5050

Burlington County College
Megan Elrath, Associate Director
mre27@drexel.edu
856-222-9311 ext. 2053

## Engineering Technology Faculty

Richard Chiou, PhD *(Georgia Institute of Technology)*. Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Yalcin Ertekin, PhD *(University of Missouri-Rolla)*. Associate Clinical Professor. High speed machining with micromachining applications, machining process optimization and condition monitoring using multiple sensors, FEA simulation with 3D solid modeling applications, rapid prototyping and reverse engineering, quality and reliability improvement through statistically designed experiments, neural networks and data mining and Taguchi methods, CNC machine tool calibration characterization of cold fastening, clinching and self-pierced riveting processes, non-invasive surgical tool design, student learning enhancement using online simulation tools.

Vladimir Genis, PhD *(Kiev State University, Ukraine) Department Head, Engineering Technology*. Professor. Ultrasound wave propagation and scattering, ultrasound imaging, electronic instrumentation, piezoelectric transducers, and engineering education. Designed and developed diagnostic and therapeutic equipment for medical applications and electronic systems and techniques for defense-related and industrial applications.

Irina Ciobanescu Husanu, PhD *(Drexel University)*. Assistant Professor. Microgravity combustion, thermal-fluid science with applications in micro-combustion, fuel cells and research of alternative and green fuels, energy conversion and renewable energy, industrial experience in aerospace engineering areas (theoretical analysis, numerical simulations and experimental investigations), design and testing of propulsion systems, mechanical instrumentation, and developing industrial applications of aircraft engines.

Michael Mauk, PhD, PE *(University of Delaware)*. Assistant Clinical Professor. Rapid prototyping, microfluidics, alternative energy including solar energy and photovoltaics, semiconductor materials science, nanotechnology.

Warren Rosen, PhD *(Temple University)*. Assistant Clinical Professor. Computer networks; optical networks; high-performance switching; lightweight protocols.

# Engineering Technology

## Biomedical Engineering Technology Concentration

The biomedical engineering technology concentration focuses on the practice of medical equipment operation and support in the clinical environment. This concentration provides students with the knowledge they need to work in the medical field operating complicated diagnostic and patient care equipment.

During the first three years, students of all concentrations in engineering technology take electrical, mechanical, and industrial courses to get a solid, systematic background in different engineering fields. Students are required to complete general and concentration engineering technology courses, technical electives, and free elective courses that permit students great latitude in tailoring the program of study to match their career goals.

## Biomedical Engineering Technology Concentration

### Degree Requirements

**Humanities and Social Sciences Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| COM 111 | Principles of Communication | 3.0 |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| Liberal Studies electives | | 9.0 |
| **Basic Science Requirements** | | |
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| PHYS 103 | General Physics I | 4.0 |
| PHYS 104 | General Physics II | 4.0 |
| **Mathematics Requirements** | | |
| MATH 110 | Precalculus | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |
| **Engineering Technology Core** | | |
| EET 201 | Circuit Analysis I | 4.0 |
| EET 202 | Circuit Analysis II | 4.0 |
| EET 204 | Introduction to Nanotechnology | 3.0 |
| EET 205 | Digital Electronics | 4.0 |
| EET 207 | Introduction to Laboratory and Process Control | 3.0 |

| | | |
|---|---|---|
| EET 311 | Modeling of Engineering Systems | 4.0 |
| EET 319 | PLC Fundamentals | 4.0 |
| EET 401 | Applied Microcontrollers | 3.0 |
| EET 333 [WI] | Non-Destructive Evaluation of Materials | 4.0 |
| MET 100 | Graphical Communication | 3.0 |
| MET 101 | Manufacturing Materials | 4.0 |
| MET 204 | Applied Quality Control | 3.0 |
| MET 205 | Robotics and Mechatronics | 3.0 |
| MET 209 | Fluid Power | 3.0 |
| MET 213 | Applied Mechanics | 4.0 |
| MHT 205 | Thermodynamics I | 3.0 |
| MHT 226 | Measurement Techniques and Instrumentation | 3.0 |
| INDE 240 | Technology Economics | 3.0 |
| INDE 370 | Industrial Project Management | 3.0 |

**Biomedical Engineering Technology Concentration Requirements**

| | | |
|---|---|---|
| BET 301 | Healthcare Technology | 3.0 |
| BET 302 | Biomedical Electronics | 4.0 |
| BET 303 | Medical Imaging Systems | 3.0 |
| BET 305 | Clinical Laboratory Equipment | 3.0 |
| BIO 107 | Cells, Genetics & Physiology | 3.0 |
| BIO 108 | Cells, Genetics and Physiology Laboratory | 1.0 |
| BMES 302 | Laboratory II: Biomeasurements | 2.0 |
| BMES 335 | Biomedical Informatics I | 3.0 |
| BMES 391 | Biomedical Instrumentation I | 3.0 |
| BMES 488 | Medical Device Development | 3.0 |

**Technical Electives**

| | |
|---|---|
| Students select 6.0 additional credits from any BET, EET, MET, MHT, or INDE courses not already required. See advisor for specific courses. | 6.0 |

**Capstone Course Requirements**

| | | |
|---|---|---|
| MET 421 [WI] | Senior Design Project I | 3.0 |
| MET 422 | Senior Design Project II | 3.0 |
| MET 423 [WI] | Senior Design Project III | 3.0 |

**Miscellaneous**

| | | |
|---|---|---|
| EET 102 | Introduction to Engineering Technology | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| **Free Electives** | | 12.0 |
| **Total Credits** | | **187.5** |

# Biomedical Engineering Technology Concentration

## Sample Plan of Study

5 YR UG Co-op Concentration

| Term 1 | | Credits |
|---|---|---|
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| EET 102 | Introduction to Engineering Technology | 3.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| MATH 110 | Precalculus | 3.0 |
| PHYS 103 | General Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **19.5** |
| **Term 2** | | |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| MET 100 | Graphical Communication | 3.0 |
| PHYS 104 | General Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **14.5** |
| **Term 3** | | |
| EET 201 | Circuit Analysis I | 4.0 |
| EET 207 | Introduction to Laboratory and Process Control | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| MATH 122 | Calculus II | 4.0 |
| MET 101 | Manufacturing Materials | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **18.5** |
| **Term 4** | | |
| COM 111 | Principles of Communication | 3.0 |
| EET 202 | Circuit Analysis II | 4.0 |
| EET 205 | Digital Electronics | 4.0 |
| MHT 226 | Measurement Techniques and Instrumentation | 3.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |
| | **Term Credits** | **18.0** |
| **Term 5** | | |
| EET 204 | Introduction to Nanotechnology | 3.0 |
| EET 333 [WI] | Non-Destructive Evaluation of Materials | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| MET 205 | Robotics and Mechatronics | 3.0 |
| MHT 205 | Thermodynamics I | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 6** | | |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| EET 311 | Modeling of Engineering Systems | 4.0 |
| EET 319 | PLC Fundamentals | 4.0 |
| MET 213 | Applied Mechanics | 4.0 |
| | **Term Credits** | **19.0** |
| **Term 7** | | |
| EET 401 | Applied Microcontrollers | 3.0 |
| INDE 240 | Technology Economics | 3.0 |
| MET 204 | Applied Quality Control | 3.0 |
| MET 209 | Fluid Power | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 8** | | |
| BET 301 | Healthcare Technology | 3.0 |
| BET 302 | Biomedical Electronics | 4.0 |
| BIO 107 | Cells, Genetics & Physiology | 3.0 |

| | | |
|---|---|---|
| BIO 108 | Cells, Genetics and Physiology Laboratory | 1.0 |
| BMES 302 | Laboratory II: Biomeasurements | 2.0 |
| Free Elective | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 9** | | |
| BET 303 | Medical Imaging Systems | 3.0 |
| BET 305 | Clinical Laboratory Equipment | 3.0 |
| BMES 391 | Biomedical Instrumentation I | 3.0 |
| BMES 488 | Medical Device Development | 3.0 |
| INDE 370 | Industrial Project Management | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 10** | | |
| BMES 335 | Biomedical Informatics I | 3.0 |
| MET 421 [WI] | Senior Design Project I | 3.0 |
| Liberal Studies Elective | | 3.0 |
| Free Elective | | 3.0 |
| | **Term Credits** | **12.0** |
| **Term 11** | | |
| MET 422 | Senior Design Project II | 3.0 |
| Liberal Studies Elective | | 3.0 |
| Free Elective | | 3.0 |
| Technical Elective | | 3.0 |
| | **Term Credits** | **12.0** |
| **Term 12** | | |
| MET 423 [WI] | Senior Design Project III | 3.0 |
| Technical elective | | 3.0 |
| Liberal studies elective | | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **12.0** |

**Total Credit: 187.5**

# Engineering Technology Faculty

Richard Chiou, PhD *(Georgia Institute of Technology)*. Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Yalcin Ertekin, PhD *(University of Missouri-Rolla)*. Associate Clinical Professor. High speed machining with micromachining applications, machining process optimization and condition monitoring using multiple sensors, FEA simulation with 3D solid modeling applications, rapid prototyping and reverse engineering, quality and reliability improvement through statistically designed experiments, neural networks and data mining and Taguchi methods, CNC machine tool calibration characterization of cold fastening, clinching and self-pierced riveting processes, non-invasive surgical tool design, student learning enhancement using online simulation tools.

Vladimir Genis, PhD *(Kiev State University, Ukraine) Department Head, Engineering Technology*. Professor. Ultrasound wave propagation and scattering, ultrasound imaging, electronic instrumentation, piezoelectric transducers, and engineering education. Designed and developed diagnostic and therapeutic equipment for medical applications and electronic systems and techniques for defense-related and industrial applications.

Irina Ciobanescu Husanu, PhD *(Drexel University)*. Assistant Professor. Microgravity combustion, thermal-fluid science with applications in micro-combustion, fuel cells and research of alternative and green fuels, energy conversion and renewable energy, industrial experience in aerospace engineering areas (theoretical analysis, numerical simulations and experimental investigations), design and testing of propulsion systems, mechanical instrumentation, and developing industrial applications of aircraft engines.

Michael Mauk, PhD, PE *(University of Delaware)*. Assistant Clinical Professor. Rapid prototyping, microfluidics, alternative energy including solar energy and photovoltaics, semiconductor materials science, nanotechnology.

Warren Rosen, PhD *(Temple University)*. Assistant Clinical Professor. Computer networks; optical networks; high-performance switching; lightweight protocols.

# Courses

### BET 301 Healthcare Technology 3.0 Credits
An overview of medical equipment used in hospitals and other medical environments to diagnose and treat patients. Sensors and physiological signals will be explained. Equipment found in various hospital departments and medical specialties will also be discussed. Patient safety and regulations will be emphasized.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 201 [Min Grade: D] and EET 202 [Min Grade: D]

### BET 302 Biomedical Electronics 4.0 Credits
This course is an introduction to the fundamentals of analog electronics with an emphasis on biomedical applications. Students will be introduced to solid state devices including diodes, transistors, operational amplifiers, oscillators, and mixers and their use in power supplies, amplifiers and active filters.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 201 [Min Grade: D] and EET 202 [Min Grade: D]

### BET 303 Medical Imaging Systems 3.0 Credits
Introduces students to physical principles, instrumental design, data acquisition strategies, image reconstruction techniques, and clinical applications of imaging modalities most commonly used in clinical medicine. The particular emphasis is placed on the basic engineering design involved in each modality.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** BET 301 [Min Grade: D]

### BET 305 Clinical Laboratory Equipment 3.0 Credits
Clinical laboratory instrumentation and automation is described with emphasis on the demands of clinicians for diagnostic information. Special attention is given to reliability, ease of training, and cost effectiveness.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 201 [Min Grade: D] and EET 202 [Min Grade: D] and BET 301 [Min Grade: D]

# Engineering Technology

## Electrical Engineering Technology Concentration

The electrical engineering technology concentration provides an extensive background in electric circuit analysis and electronics. Students are required to study digital and analog electronics, digital computer design, analysis of electric power systems, and renewable energy.

During the first three years, students of all concentrations in engineering technology take electrical, mechanical, and industrial courses to get a solid, systematic background in different engineering fields. Students are required to complete general and concentration engineering technology courses, technical electives, and free elective courses that permit students great latitude in tailoring the program of study to match their career goals.

## Electrical Engineering Technology Concentration

### Degree Requirements

**Humanites and Social Sciences Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| COM 111 | Principles of Communication | 3.0 |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| Liberal studies electives | | 9.0 |

**Basic Science Requirements**

| | | |
|---|---|---|
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| PHYS 103 | General Physics I | 4.0 |
| PHYS 104 | General Physics II | 4.0 |

**Mathematics Requirements**

| | | |
|---|---|---|
| MATH 110 | Precalculus | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |

**Engineering Technology Core**

| | | |
|---|---|---|
| EET 201 | Circuit Analysis I | 4.0 |
| EET 202 | Circuit Analysis II | 4.0 |
| EET 204 | Introduction to Nanotechnology | 3.0 |
| EET 205 | Digital Electronics | 4.0 |
| EET 207 | Introduction to Laboratory and Process Control | 3.0 |
| EET 311 | Modeling of Engineering Systems | 4.0 |
| EET 319 | PLC Fundamentals | 4.0 |
| EET 333 [WI] | Non-Destructive Evaluation of Materials | 4.0 |
| EET 401 | Applied Microcontrollers | 3.0 |
| MET 100 | Graphical Communication | 3.0 |
| MET 101 | Manufacturing Materials | 4.0 |
| MET 204 | Applied Quality Control | 3.0 |
| MET 205 | Robotics and Mechatronics | 3.0 |
| MET 209 | Fluid Power | 3.0 |
| MET 213 | Applied Mechanics | 4.0 |
| MHT 205 | Thermodynamics I | 3.0 |
| MHT 226 | Measurement Techniques and Instrumentation | 3.0 |
| INDE 240 | Technology Economics | 3.0 |
| INDE 370 | Industrial Project Management | 3.0 |

**Electrical Engineering Technology Concentration Requirements**

| | | |
|---|---|---|
| EET 206 | Analog Electronics I | 4.0 |
| EET 313 | Signals and Systems I | 4.0 |
| EET 317 | Analog Electronics II | 4.0 |
| EET 322 | Energy Conversion | 4.0 |
| EET 323 | Electrical Systems Design | 3.0 |
| EET 324 | Power Electronics | 4.0 |
| EET 325 | Microprocessors | 3.0 |

**Electrical Engineering Technology (EET) Electives** 6.0

Select 6.0 additional credits from any BET, EET, MET, MHT or INDE courses not already required. See advisor for specific courses.

**Capstone Course Requirements**

| | | |
|---|---|---|
| MET 421 [WI] | Senior Design Project I | 3.0 |
| MET 422 | Senior Design Project II | 3.0 |
| MET 423 [WI] | Senior Design Project III | 3.0 |

**Miscellaneous**

| | | |
|---|---|---|
| EET 102 | Introduction to Engineering Technology | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| Free electives | | 14.0 |
| **Total Credits** | | **187.5** |

## Electrical Engineering Technology Concentration

### Sample Plan of Study

#### 5 YR UG Co-op

| Term 1 | | Credits |
|---|---|---|
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| EET 102 | Introduction to Engineering Technology | 3.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| MATH 110 | Precalculus | 3.0 |
| PHYS 103 | General Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **19.5** |
| **Term 2** | | |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| MET 100 | Graphical Communication | 3.0 |
| PHYS 104 | General Physics II | 4.0 |

| UNIV E101 | The Drexel Experience | 0.5 |
|---|---|---|
| | **Term Credits** | **14.5** |
| **Term 3** | | |
| EET 201 | Circuit Analysis I | 4.0 |
| EET 207 | Introduction to Laboratory and Process Control | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| MATH 122 | Calculus II | 4.0 |
| MET 101 | Manufacturing Materials | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **18.5** |
| **Term 4** | | |
| COM 111 | Principles of Communication | 3.0 |
| EET 202 | Circuit Analysis II | 4.0 |
| EET 205 | Digital Electronics | 4.0 |
| MHT 226 | Measurement Techniques and Instrumentation | 3.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |
| | **Term Credits** | **18.0** |
| **Term 5** | | |
| EET 204 | Introduction to Nanotechnology | 3.0 |
| EET 333 [WI] | Non-Destructive Evaluation of Materials | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| MET 205 | Robotics and Mechatronics | 3.0 |
| MHT 205 | Thermodynamics I | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 6** | | |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| EET 311 | Modeling of Engineering Systems | 4.0 |
| EET 319 | PLC Fundamentals | 4.0 |
| MET 213 | Applied Mechanics | 4.0 |
| | **Term Credits** | **19.0** |
| **Term 7** | | |
| EET 401 | Applied Microcontrollers | 3.0 |
| INDE 240 | Technology Economics | 3.0 |
| MET 204 | Applied Quality Control | 3.0 |
| MET 209 | Fluid Power | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 8** | | |
| EET 206 | Analog Electronics I | 4.0 |
| EET 322 | Energy Conversion | 4.0 |
| EET 325 | Microprocessors | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 9** | | |
| EET 313 | Signals and Systems I | 4.0 |
| EET 317 | Analog Electronics II | 4.0 |
| EET 323 | Electrical Systems Design | 3.0 |
| INDE 370 | Industrial Project Management | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 10** | | |

| EET 324 | Power Electronics | 4.0 |
|---|---|---|
| MET 421 [WI] | Senior Design Project I | 3.0 |
| Liberal studies elective | | 3.0 |
| Free elective | | 4.0 |
| | **Term Credits** | **14.0** |
| **Term 11** | | |
| MET 422 | Senior Design Project II | 3.0 |
| Technical elective | | 3.0 |
| Liberal studies elective | | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **12.0** |
| **Term 12** | | |
| MET 423 [WI] | Senior Design Project III | 3.0 |
| Technical elective | | 3.0 |
| Liberal studies elective | | 3.0 |
| Free elective | | 4.0 |
| | **Term Credits** | **13.0** |

**Total Credit: 187.5**

# Engineering Technology Faculty

Richard Chiou, PhD *(Georgia Institute of Technology).* Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Yalcin Ertekin, PhD *(University of Missouri-Rolla).* Associate Clinical Professor. High speed machining with micromachining applications, machining process optimization and condition monitoring using multiple sensors, FEA simulation with 3D solid modeling applications, rapid prototyping and reverse engineering, quality and reliability improvement through statistically designed experiments, neural networks and data mining and Taguchi methods, CNC machine tool calibration characterization of cold fastening, clinching and self-pierced riveting processes, non-invasive surgical tool design, student learning enhancement using online simulation tools.

Vladimir Genis, PhD *(Kiev State University, Ukraine) Department Head, Engineering Technology.* Professor. Ultrasound wave propagation and scattering, ultrasound imaging, electronic instrumentation, piezoelectric transducers, and engineering education. Designed and developed diagnostic and therapeutic equipment for medical applications and electronic systems and techniques for defense-related and industrial applications.

Irina Ciobanescu Husanu, PhD *(Drexel University).* Assistant Professor. Microgravity combustion, thermal-fluid science with applications in micro-combustion, fuel cells and research of alternative and green fuels, energy conversion and renewable energy, industrial experience in aerospace engineering areas (theoretical analysis, numerical simulations and experimental investigations), design and testing of propulsion systems, mechanical instrumentation, and developing industrial applications of aircraft engines.

Michael Mauk, PhD, PE *(University of Delaware).* Assistant Clinical Professor. Rapid prototyping, microfluidics, alternative energy including solar energy and photovoltaics, semiconductor materials science, nanotechnology.

Warren Rosen, PhD *(Temple University).* Assistant Clinical Professor. Computer networks; optical networks; high-performance switching; lightweight protocols.

# Courses

### EET 102 Introduction to Engineering Technology 3.0 Credits
The main objective of this course is to introduce the basic concepts and the fundamentals of Engineering Technology (ET). Students are introduced to the four tracks (electrical, mechanical, industrial, and biomedical) in ET and work on the selected topics designed to enhance the problem solving techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### EET 201 Circuit Analysis I 4.0 Credits
Introduction to the key electrical terms, basic laws and theorems of electric circuits by concentrating on Direct Current (DC) circuit analysis, power, and energy.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 104 [Min Grade: D] and MATH 110 [Min Grade: D]

### EET 202 Circuit Analysis II 4.0 Credits
Introduction to time domain (transient) analysis of R, L, C elements and energy storage in L and C circuits. The response of source-free RL, RC, and RLC circuits are developed followed by response to constant voltage and current sources.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 201 [Min Grade: D]

### EET 204 Introduction to Nanotechnology 3.0 Credits
The course provides an introduction to scientific notation, size relationships between nanometers and other metric measures, self assembly, molecular recognition, the history of nanotechnology, and the role and influence of nanotechnology in other technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHEM 111 [Min Grade: D] and CHEM 113 [Min Grade: D]

### EET 205 Digital Electronics 4.0 Credits
The objective of this course is to introduce AET students to fundamentals of digital electronics starting with the binary number system and proceeding to logic gates, Boolean algebra, combinational logic circuits, and the basic arithmetic units used in digital computers such as adders, counters and shift registers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 201 [Min Grade: D]

### EET 206 Analog Electronics I 4.0 Credits
Students are introduced to linear circuit analysis of passive and active semiconductor components, modeling of non-linear circuit elements, light and heat-dependent semiconductor devices, biasing of three-terminal devices, and semiconductor small-signal models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 201 [Min Grade: D] and EET 202 [Min Grade: D]

### EET 207 Introduction to Laboratory and Process Control 3.0 Credits
This course introduces students to programming techniques used to control laboratory experiments and industrial processes. The emphasis is on applications of LabView and C in real-world measurements and embedded systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### EET 307 Basic Power Systems I 3.0 Credits
Fundamentals of single-phase and three-phase power systems; introduction to symmetrical components and sequence impedances; power transfer modeling; the per-unit system; power transmission line impedance and admittances.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** EET 104 [Min Grade: D]

### EET 310 Industrial Application of Nanotechnology 3.0 Credits
This course introduces students to nanotechnology materials, devices, and processes from the perspective of product development and process engineering, manufacturing scale-up, quality assurance, and reliability. Laboratory projects provide students with hands-on experience in fabricating and characterizing nanomaterials and nanodevices, and their applications for renewable energy, solid-state lighting, novel functional materials, and biomedical engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHEM 111 [Min Grade: D] and CHEM 113 [Min Grade: D]

### EET 311 Modeling of Engineering Systems 4.0 Credits
Course introduces students to development and application of ordinary differential equations to systems analysis with emphasis on electrical systems. Particular attention is paid to the derivation of differential equations from given practical circuits used in industrial applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATH 122 [Min Grade: D] and EET 201 [Min Grade: D]

### EET 313 Signals and Systems I 4.0 Credits
Course introduces students to applications of the systems analysis to the design of useful circuits and devices used in industrial applications. Covers time and frequency domain circuit analysis (transfer function, convolution) to determine response of the system to the arbitrary input.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 311 [Min Grade: D]

### EET 317 Analog Electronics II 4.0 Credits
Students are introduced to four-layer diodes, power amplifiers, differential amplifiers, linear and non-linear operational amplifiers, feedbacks, oscillators, and active filters. Class discussions include practical circuits, troubleshooting, and case studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 206 [Min Grade: D]

**EET 319 PLC Fundamentals 4.0 Credits**
Introduces the fundamentals of programmable logic controllers, and
PLC application in process control. The course includes both lecture and
laboratory aimed at applying fundamental principles to practical projects.
The emphasis is on the basics of ladder logic, including timers, counters,
and program control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 205 [Min Grade: D]

**EET 320 Renewable Energy Systems 3.0 Credits**
This course provides an introduction to energy systems and renewable
energy resources, with a scientific examination of the energy field and
an emphasis on alternate energy sources and their technology and
applications. The class explores society's present needs and future
energy demands, examines conventional energy sources and systems,
including fossil fuels and then focuses on alternate, renewable energy
sources such as solar, wind power, geothermal and fuel cells.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 103 [Min Grade: D] and PHYS 104 [Min Grade: D]

**EET 322 Energy Conversion 4.0 Credits**
The course covers the fundamentals and the principles of electrical
machines and transformers, with an emphasis on their application and
installation. The course covers transformer, dc, ac and special machines.
Novel energy conversion techniques such as Fuel Cell and Batteries are
also discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 202 [Min Grade: D]

**EET 323 Electrical Systems Design 3.0 Credits**
This course covers the basics of industrial systems, including safety,
grounding, protection, lighting, distribution, commonly found in residential,
commercial and industrial environment. The course formulates the
application of standards and codes such as NEC, NEMA and IEEE.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 202 [Min Grade: D]

**EET 324 Power Electronics 4.0 Credits**
The course covers the basics of the industrial and power electronics over
a spectrum of applications and provides an introduction to the emerging
technologies in these fields. The course is accompanied by laboratory
using hardware and software simulation tools.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 202 [Min Grade: D]

**EET 325 Microprocessors 3.0 Credits**
Introduces student to fundamentals of microprocessing using an
application-oriented approach. Includs fundamental principles and system
requirements supplemented with specific implementation examples and
practical circuits with detailed design considerations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 205 [Min Grade: D]

**EET 333 [WI] Non-Destructive Evaluation of Materials 4.0 Credits**
The course presents principles of ultrasound nondestructive evaluation
of materials combining projects and hands-on experience with lectures.
Students learn the physical principles of measurements of sound velocity
in different materials, attenuation coefficients, directivity pattern of
transducers and location and dimensions of heterogeneities in materials,
such as flaws and cavities. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 103 [Min Grade: D] and PHYS 104 [Min Grade: D]

**EET 335 Acoustic Emission 4.0 Credits**
The course presents principles of acoustic emission using practical
applications in various industries. Physical principles of acoustic emission
generation, propagation and detection in engineering materials and
structures are presented. This includes principles of stress and strain
and the underlying materials science of material deformation, crack
growth and failure. Students learn how these principles are utilized to
build technical applications of acoustic emission considered as an NDE
method.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 103 [Min Grade: D] and PHYS 104 [Min Grade: D]

**EET 401 Applied Microcontrollers 3.0 Credits**
The course is an introduction to microcontroller hardware and software
with an emphasis on embedded control applications. Topics covered
include microcontroller architectures, programming, analog and digital
input/output, timing, debugging and PC-based software development
tools.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 205 [Min Grade: D]

**EET 402 Control Engineering 3.0 Credits**
The course covers fundamental of control theory and their applications,
including, linear systems and feedback, linear system operation and
stability, standard methods applicable to the linear systems and basic for
designs and applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 311 [Min Grade: D] and EET 313 [Min Grade: D]

**EET 404 Signals and Systems II 3.0 Credits**
Introduces the analysis of electric circuits under steady sinusoidal
conditions, applications of Laplace transformation and complex frequency
analysis, and Fourier analysis for representing an arbitrary time function
as a sum of sinusoidal functions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 313 [Min Grade: D] and EET 311 [Min Grade: D]

**EET 406 Communication Systems 3.0 Credits**
This course introduces AET student to fundamentals of Communication Systems using an integrated approach to analog and digital communications. Design and applications of contemporary communication systems are emphasized via the reduction theory to practice.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 311 [Min Grade: D] and EET 313 [Min Grade: D]

**EET 407 Power Systems Fundamentals 3.0 Credits**
The course covers the basic principles of the power systems, electric grid, methods to analyze electric grid systems and basic power system protection and stability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 202 [Min Grade: D] and EET 322 [Min Grade: D]

**EET 409 Optical System Design 3.0 Credits**
This course introduces ET students to fundamentals of optics and optical systems using an application-oriented approach. Special attention is given to fundamental principles of optical systems and their requirements supplemented with specific applications-based examples.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 104 [Min Grade: D]

# Engineering Technology

## Industrial Engineering Technology Concentration

The industrial engineering technology concentration provides students with knowledge and skills in management and relevant engineering technology disciplines for manufacturing, service, and healthcare enterprises, including automation, logistics, scheduling, simulation, maintainability, and advanced manufacturing processes. Students learn how to co-ordinate, integrate, and optimize people, machines, materials, and energy to improve efficiency, sustainability, quality, and environment.

During the first three years, students of all concentrations in engineering technology take electrical, mechanical, and industrial courses to get a solid, systematic background in different engineering fields. Students are required to complete general and concentration engineering technology courses, technical electives, and free elective courses that permit students great latitude in tailoring the program of study to match their career goals.

## Industrial Engineering Technology Concentration

## Degree Requirements

**Humanities and Social Sciences Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| COM 111 | Principles of Communication | 3.0 |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| Liberal Studies electives | | 9.0 |
| **Basic Science Requirements** | | |
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| PHYS 103 | General Physics I | 4.0 |
| PHYS 104 | General Physics II | 4.0 |
| **Mathematics Requirements** | | |
| MATH 110 | Precalculus | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |
| **Engineering Technology Core** | | |
| EET 201 | Circuit Analysis I | 4.0 |
| EET 202 | Circuit Analysis II | 4.0 |
| EET 204 | Introduction to Nanotechnology | 3.0 |
| EET 205 | Digital Electronics | 4.0 |
| EET 207 | Introduction to Laboratory and Process Control | 3.0 |
| EET 311 | Modeling of Engineering Systems | 4.0 |
| EET 319 | PLC Fundamentals | 4.0 |
| EET 333 [WI] | Non-Destructive Evaluation of Materials | 4.0 |
| EET 401 | Applied Microcontrollers | 3.0 |
| MET 100 | Graphical Communication | 3.0 |
| MET 101 | Manufacturing Materials | 4.0 |
| MET 204 | Applied Quality Control | 3.0 |
| MET 205 | Robotics and Mechatronics | 3.0 |
| MET 209 | Fluid Power | 3.0 |
| MET 213 | Applied Mechanics | 4.0 |
| MHT 205 | Thermodynamics I | 3.0 |
| MHT 226 | Measurement Techniques and Instrumentation | 3.0 |
| INDE 240 | Technology Economics | 3.0 |
| INDE 370 | Industrial Project Management | 3.0 |
| **Industrial Engineering Technology Concentration Requirements** | | |
| ACCT 115 | Financial Accounting Foundations | 4.0 |
| ECON 202 | Principles of Macroeconomics | 4.0 |
| FIN 301 | Introduction to Finance | 4.0 |
| INDE 300 | Quality Management | 3.0 |
| INDE 350 | Industrial Engineering Simulation | 3.0 |
| INDE 363 | Operations Research for Engineering II | 3.0 |
| INDE 365 | Systems Analysis Methods I | 3.0 |
| INDE 366 | Systems Analysis Methods II | 3.0 |
| INDE 375 | Quality Improvement by Experimental Design | 4.0 |
| **IET Technical Electives** | | |
| Students select 6.0 additional credits from any BET, EET, MET, MHT, INDE, OPM, or MKT courses not already required. See advisor for specific courses. | | 6.0 |
| **Capstone Course Requirements** | | |
| MET 421 [WI] | Senior Design Project I | 3.0 |

| MET 422 | Senior Design Project II | 3.0 |
| MET 423 [WI] | Senior Design Project III | 3.0 |
| **Miscellaneous** | | |
| EET 102 | Introduction to Engineering Technology | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| **Free Electives** | | 8.0 |
| **Total Credits** | | **186.5** |

# Industrial Engineering Technology Concentration

## Sample Plan of Study

5 YR UG Co-op Concentration

| Term 1 | | Credits |
| --- | --- | --- |
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| EET 102 | Introduction to Engineering Technology | 3.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| MATH 110 | Precalculus | 3.0 |
| PHYS 103 | General Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **19.5** |
| **Term 2** | | |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| MET 100 | Graphical Communication | 3.0 |
| PHYS 104 | General Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **14.5** |
| **Term 3** | | |
| EET 201 | Circuit Analysis I | 4.0 |
| EET 207 | Introduction to Laboratory and Process Control | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| MATH 122 | Calculus II | 4.0 |
| MET 101 | Manufacturing Materials | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **18.5** |
| **Term 4** | | |
| COM 111 | Principles of Communication | 3.0 |
| EET 202 | Circuit Analysis II | 4.0 |
| EET 205 | Digital Electronics | 4.0 |
| MHT 226 | Measurement Techniques and Instrumentation | 3.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |
| | **Term Credits** | **18.0** |
| **Term 5** | | |
| EET 204 | Introduction to Nanotechnology | 3.0 |
| EET 333 [WI] | Non-Destructive Evaluation of Materials | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| MET 205 | Robotics and Mechatronics | 3.0 |

| MHT 205 | Thermodynamics I | 3.0 |
| --- | --- | --- |
| | **Term Credits** | **16.0** |
| **Term 6** | | |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| EET 311 | Modeling of Engineering Systems | 4.0 |
| EET 319 | PLC Fundamentals | 4.0 |
| MET 213 | Applied Mechanics | 4.0 |
| | **Term Credits** | **19.0** |
| **Term 7** | | |
| EET 401 | Applied Microcontrollers | 3.0 |
| INDE 240 | Technology Economics | 3.0 |
| MET 204 | Applied Quality Control | 3.0 |
| MET 209 | Fluid Power | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 8** | | |
| ACCT 115 | Financial Accounting Foundations | 4.0 |
| ECON 202 | Principles of Macroeconomics | 4.0 |
| INDE 300 | Quality Management | 3.0 |
| INDE 350 | Industrial Engineering Simulation | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 9** | | |
| FIN 301 | Introduction to Finance | 4.0 |
| INDE 363 | Operations Research for Engineering II | 3.0 |
| INDE 365 | Systems Analysis Methods I | 3.0 |
| INDE 370 | Industrial Project Management | 3.0 |
| | **Term Credits** | **13.0** |
| **Term 10** | | |
| INDE 366 | Systems Analysis Methods II | 3.0 |
| MET 421 [WI] | Senior Design Project I | 3.0 |
| Liberal studies elective | | 3.0 |
| Free electives | | 5.0 |
| | **Term Credits** | **14.0** |
| **Term 11** | | |
| INDE 375 | Quality Improvement by Experimental Design | 4.0 |
| MET 422 | Senior Design Project II | 3.0 |
| Technical elective (See advisor) | | 4.0 |
| Liberal studies elective | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 12** | | |
| MET 423 [WI] | Senior Design Project III | 3.0 |
| Technical elective (See advisor) | | 3.0 |
| Liberal studies elective | | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **12.0** |

**Total Credit: 187.5**

# Engineering Technology Faculty

Richard Chiou, PhD *(Georgia Institute of Technology)*. Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Yalcin Ertekin, PhD *(University of Missouri-Rolla)*. Associate Clinical Professor. High speed machining with micromachining applications, machining process optimization and condition monitoring using multiple sensors, FEA simulation with 3D solid modeling applications, rapid prototyping and reverse engineering, quality and reliability improvement through statistically designed experiments, neural networks and data mining and Taguchi methods, CNC machine tool calibration characterization of cold fastening, clinching and self-pierced riveting processes, non-invasive surgical tool design, student learning enhancement using online simulation tools.

Vladimir Genis, PhD *(Kiev State University, Ukraine) Department Head, Engineering Technology*. Professor. Ultrasound wave propagation and scattering, ultrasound imaging, electronic instrumentation, piezoelectric transducers, and engineering education. Designed and developed diagnostic and therapeutic equipment for medical applications and electronic systems and techniques for defense-related and industrial applications.

Irina Ciobanescu Husanu, PhD *(Drexel University)*. Assistant Professor. Microgravity combustion, thermal-fluid science with applications in micro-combustion, fuel cells and research of alternative and green fuels, energy conversion and renewable energy, industrial experience in aerospace engineering areas (theoretical analysis, numerical simulations and experimental investigations), design and testing of propulsion systems, mechanical instrumentation, and developing industrial applications of aircraft engines.

Michael Mauk, PhD, PE *(University of Delaware)*. Assistant Clinical Professor. Rapid prototyping, microfluidics, alternative energy including solar energy and photovoltaics, semiconductor materials science, nanotechnology.

Warren Rosen, PhD *(Temple University)*. Assistant Clinical Professor. Computer networks; optical networks; high-performance switching; lightweight protocols.

# Courses

### INDE 240 Technology Economics 3.0 Credits
Techniques for project decisions: benefit cost, present worth and annual worth analysis, rate of return, minimum attractive rate of return, capital budgeting, risk analysis, and depreciation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### INDE 300 Quality Management 3.0 Credits
This is a course about managing quality. It will introduce quality concepts necessary for an organization to remain competitive in today's economy. Discussion will focus on the tools and techniques necessary to manage quality processes within an organization.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** MATH 122 [Min Grade: D]

### INDE 301 Health Systems Introduction 3.0 Credits
Emphasis on the application of industrial engineering methodologies to analyze and solve health systems challenges. Critical evaluation of the utility of key industrial engineering concepts and tools for assessing and modeling health care problems and challenges in health care delivery.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Pre-Junior or Senior.

### INDE 340 Introduction to Decision Analysis 3.0 Credits
Overview of modeling techniques and methods used in decision analysis, including multiattribute utility models, decision trees, and Bayesian models. Psychological components of decision making are discussed. Elicitation techniques for model building are emphasized. Practical applications through real world model building are described and conducted.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Pre-Junior or Senior.
**Prerequisites:** STAT 262 [Min Grade: D] and MATH 122 [Min Grade: D]

### INDE 350 Industrial Engineering Simulation 3.0 Credits
Covers techniques and application of computer simulation of existing or proposed real world systems and processes. Models of such systems or processes are often complex, precluding traditional analytical techniques. Students will build simulation models and do simulations with commercial simulation software, analyze and interpret the results, and to plan simulation studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** STAT 261 [Min Grade: D]

### INDE 351 Intelligent Manufacturing Systems 3.0 Credits
Design and simulation of intelligent manufacturing systems with special emphasis on sensor-integrated robotic assembly tasks. Fundamentals of artificial intelligence, application of robotics, sensors, vision, network integration, and flexible assembly work cells. Industry based case studies and working examples.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

### INDE 361 Quality Control 3.0 Credits
Covers theory and methods for design and analysis of quality control systems, including solutions to problems of product specifications, process control, acceptance inspection, and other means of quality assurance. Fall. Alternate years.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** STAT 261 [Min Grade: D]

**INDE 362 Operations Research for Engineering I 3.0 Credits**
Introduces systems sciences, including linear programming and other linear optimization methods, simplex method, primal-dual solution methods, the transportation method, pert-cpm and other network techniques, and dynamic programming. Requires development and presentation of simulation term-project proposals. Winter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATH 261 [Min Grade: D]
**Corequisite**: MATH 261

**INDE 363 Operations Research for Engineering II 3.0 Credits**
Covers single and multi-episode probabilistic inventory models, queuing theory, single and multichannel systems, production scheduling and other assignment methods, Markov processes, Poisson processes and other stochastic systems, and replacement theory. Includes selected case studies. Applications: queuing, reliability, inventory, and finance. Requires development and presentation of term-project simulation models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** INDE 362 [Min Grade: D]

**INDE 364 Special Topics in Industrial Engineering 0.5-12.0 Credits**
Provides special courses offered based on student or faculty interests. All terms. Variable.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**INDE 365 Systems Analysis Methods I 3.0 Credits**
Provides an introduction to the concepts and techniques used in analysis of complex systems. Covers the origins and structure of modern systems and the step-wise development of complex systems and the organizations of system development projects. Systems Development Lifecycle (SDLC) from concept development, engineering development, post-development.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**INDE 366 Systems Analysis Methods II 3.0 Credits**
OO (Object Oriented) Methodology and UML (Universal Modeling Language) modeling, within the SDLC (System Development Life Cycle) framework, are covered in this class. There are two components to OO systems Analysis and Design; The ORM (Object- Relationship Model) is a way to describe or represent objects, classes of objects, relationships between objects and classes, and memberships of the real world. The OBM (Object-Behavior Model) is a means of describing the behavior of objects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** INDE 365 [Min Grade: D]

**INDE 367 Data Processing 3.0 Credits**
Covers the information ?based skills necessary for Industrial Engineers. It is a project based course. Particular attention is paid to real world database problems. This course explains data acquisition and database systems. The course focuses on designing databases for given problems. Students will use different database techniques. Introduction to SQL.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**INDE 370 Industrial Project Management 3.0 Credits**
Provides an overview of the roles, responsibilities, and management methods of technology in project management. Emphasizes scheduling of various projects, monitoring, control and learning from projects. Three interrelated objectives of budget, schedule, and specifications are also introduced. The course assumes no prior knowledge in management techniques and is intended to teach students how to develop approaches and styles of management for service and manufacturing industry projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**INDE 375 Quality Improvement by Experimental Design 4.0 Credits**
Methods for Design and analyzing industrial experiments. Blocking; randomization; multiple regression; factorial and fractional experiments; response surface methodology; Taguchi's robust design; split plot experimentation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** STAT 261 [Min Grade: D] or STAT 201 [Min Grade: D]

**INDE 399 Independent Study in Industrial Engineering 0.5-12.0 Credits**
Various topics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**INDE 400 Designs of Program Evaluation Systems 3.0 Credits**
Focus on evaluation broadly conceived to include evaluation of programs as well as within business organizations. The context of the class is evaluation in the health care sector, particularly long term care. Emphasis placed on the development of valid and practical models, and the identification and measurement of short-term and long-term intervention outcomes. Covers principles of research design, evaluation, and measurement issues.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** STAT 261 [Min Grade: D] or STAT 201 [Min Grade: D] or STAT 211 [Min Grade: D]

**INDE 461 Methods of Engineering and Measurement 3.0 Credits**
Covers fundamentals for developing methods improvements and measurement of these improvements through time study and standard data. Includes analysis and design of man-and-machine work systems and application to typical problems in work measurements. Fall. Alternate years.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** POM 311 [Min Grade: D]

**INDE 462 Industrial Plant Design 3.0 Credits**
Covers design of a product-oriented facility, including process design, materials handling, work area design, storage and warehousing, and service-area planning. Includes complete final plant layout and presentation of term project. Winter. Alternate years.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** INDE 461 [Min Grade: D]

**INDE 463 Production Management 3.0 Credits**
Covers production planning and control systems, including materials, equipment, and manpower requirements; manufacturing planning and control, including production scheduling, inventory, and quality control; analytical methods for inventory control; and production planning and methods. Spring. Alternate years.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** INDE 462 [Min Grade: D]

**INDE 467 Decision Processes 3.0 Credits**
Covers advanced methods of analyzing decision-making under uncertainty, including expected value concepts and criteria, decision tree analysis, preference theory concepts, probabilistic risk assessment, risk analysis using simulation techniques, and decisions to purchase imperfect information. Uses case studies relating to facility siting, resource exploration and development, and new technology deployment and market penetration. Fall. Alternate years.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATH 261 [Min Grade: D]

**INDE 468 Analysis of Experimental Data 3.0 Credits**
Covers use of linear and non-linear models to identify cause and estimate effect. Includes randomization and blocking with paired comparisons, significance testing and confidence intervals, factorial designs, least squares regression analysis, response surface methods, analysis of variance, and Box-Jenkins and other time series forecasting methods. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATH 261 [Min Grade: D]

**INDE 469 Organization Planning and Control 3.0 Credits**
Analyzes human, capital, and physical resource planning, allocation, and control, including human factors and man-machine interface, technological innovation, concepts of behavioral science, and structure and dynamics of industrial organizations. Uses a case study approach to situational analysis. Spring. Alternate years.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** POM E311 [Min Grade: D] and POM 461 [Min Grade: D]

**INDE 470 Engineering Quality Methods 3.0 Credits**
Methods for controlling and improving industrial processes. Control charts; process capability; multifactor experiments; screening experiments; robust designs. Understanding of the continuous quality improvement tied to a real life project improvement.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**INDE 490 Senior Project Design 4.0 Credits**
Design methodology and engineering principles applied to open-ended design problems with inherent breadth and innovation. This course integrates the knowledge acquired in the various courses of the undergraduate curriculum to an open-ended design effort and applies the knowledge gained to the solution of contemporary engineering problem. Requires written and oral final reports, including oral presentations by each design team at a formal design conference open to the public and conducted in the style of a professional conference. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** INDE 470 [Min Grade: D] (Can be taken Concurrently)

# Engineering Technology

## Mechanical Engineering Technology Concentration

The mechanical engineering technology concentration stresses on the design, development, testing, and manufacturing of industrial machinery, consumer and biomedical products, CNC (Computer Numerical Control), prototyping machinery, and similar equipment. The concentration includes study in computer graphics, statics, dynamics, stress analysis, fluid dynamics, and Computer Aided Engineering (CAE) tools, including instrumentation and testing procedures of various industrial systems.

During the first three years, students of all concentrations in engineering technology take electrical, mechanical, and industrial courses to get a solid, systematic background in different engineering fields. Students are required to complete general and concentration engineering technology courses, technical electives, and free elective courses that permit students great latitude in tailoring the program of study to match their career goals.

# Mechanical Engineering Technology Concentration

## Degree Requirements

**Humanities and Social Sciences Requirements**

| | | |
|---|---|---|
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| COM 111 | Principles of Communication | 3.0 |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| Liberal Studies electives | | 9.0 |

**Basic Science Requirements**

| | | |
|---|---|---|
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| PHYS 103 | General Physics I | 4.0 |
| PHYS 104 | General Physics II | 4.0 |

**Mathematics Requirements**

| | | |
|---|---|---|
| MATH 110 | Precalculus | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |

**Engineering Technology Core**

| | | |
|---|---|---|
| EET 201 | Circuit Analysis I | 4.0 |
| EET 202 | Circuit Analysis II | 4.0 |
| EET 204 | Introduction to Nanotechnology | 3.0 |
| EET 205 | Digital Electronics | 4.0 |
| EET 311 | Modeling of Engineering Systems | 4.0 |
| EET 207 | Introduction to Laboratory and Process Control | 3.0 |
| EET 319 | PLC Fundamentals | 4.0 |
| EET 333 [WI] | Non-Destructive Evaluation of Materials | 4.0 |
| EET 401 | Applied Microcontrollers | 3.0 |
| MET 100 | Graphical Communication | 3.0 |
| MET 101 | Manufacturing Materials | 4.0 |
| MET 204 | Applied Quality Control | 3.0 |
| MET 205 | Robotics and Mechatronics | 3.0 |
| MET 209 | Fluid Power | 3.0 |
| MET 213 | Applied Mechanics | 4.0 |
| MHT 205 | Thermodynamics I | 3.0 |
| MHT 226 | Measurement Techniques and Instrumentation | 3.0 |
| INDE 240 | Technology Economics | 3.0 |
| INDE 370 | Industrial Project Management | 3.0 |

**Mechanical Engineering Technology Concentration Requirements**

| | | |
|---|---|---|
| MET 316 | Computer Numerical Control | 3.0 |
| MET 407 | Manufacturing Processes | 3.0 |
| MET 408 | MFG Information Management | 3.0 |
| MHT 206 | Thermodynamics II | 3.0 |
| MHT 222 | Applied Dynamics I | 3.0 |
| MHT 301 | Fluid Mechanics I | 3.0 |
| MHT 314 | Thermo and Heat Transfer Analysis | 3.0 |
| MHT 401 | Mechanical Design I | 4.0 |

**MHT Technical Electives**

| | | |
|---|---|---|
| Students select 6.0 additional credits from any BET, EET, MET, MHT or INDE courses not already required. See advisor for specific courses. | | 6.0 |

**Capstone Course Requirements**

| | | |
|---|---|---|
| MET 421 [WI] | Senior Design Project I | 3.0 |
| MET 422 | Senior Design Project II | 3.0 |
| MET 423 [WI] | Senior Design Project III | 3.0 |

**Miscellaneous**

| | | |
|---|---|---|
| EET 102 | Introduction to Engineering Technology | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| **Free Electives** | | 15.0 |
| **Total Credits** | | **187.5** |

Mechanical Engineering Technology Concentration

Sample Plan of Study

5 YR UG Co-op Concentration

| Term 1 | | Credits |
|---|---|---|
| CHEM 111 | General Chemistry I | 4.0 |
| CHEM 113 | General Chemistry I Laboratory | 1.5 |
| EET 102 | Introduction to Engineering Technology | 3.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| MATH 110 | Precalculus | 3.0 |
| PHYS 103 | General Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **19.5** |

| Term 2 | | |
|---|---|---|
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| MATH 121 | Calculus I | 4.0 |
| MET 100 | Graphical Communication | 3.0 |
| PHYS 104 | General Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **14.5** |

| Term 3 | | |
|---|---|---|
| EET 201 | Circuit Analysis I | 4.0 |
| EET 207 | Introduction to Laboratory and Process Control | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| MATH 122 | Calculus II | 4.0 |
| MET 101 | Manufacturing Materials | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **18.5** |

| Term 4 | | |
|---|---|---|
| COM 111 | Principles of Communication | 3.0 |
| EET 202 | Circuit Analysis II | 4.0 |
| EET 205 | Digital Electronics | 4.0 |

| | | |
|---|---|---|
| MHT 226 | Measurement Techniques and Instrumentation | 3.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |
| | **Term Credits** | **18.0** |
| **Term 5** | | |
| EET 204 | Introduction to Nanotechnology | 3.0 |
| EET 333 [WI] | Non-Destructive Evaluation of Materials | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| MET 205 | Robotics and Mechatronics | 3.0 |
| MHT 205 | Thermodynamics I | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 6** | | |
| COM 230 | Techniques of Speaking | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| EET 311 | Modeling of Engineering Systems | 4.0 |
| EET 319 | PLC Fundamentals | 4.0 |
| MET 213 | Applied Mechanics | 4.0 |
| | **Term Credits** | **19.0** |
| **Term 7** | | |
| EET 401 | Applied Microcontrollers | 3.0 |
| INDE 240 | Technology Economics | 3.0 |
| MET 204 | Applied Quality Control | 3.0 |
| MET 209 | Fluid Power | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 8** | | |
| MET 316 | Computer Numerical Control | 3.0 |
| MET 408 | MFG Information Management | 3.0 |
| MHT 206 | Thermodynamics II | 3.0 |
| MHT 222 | Applied Dynamics I | 3.0 |
| MHT 301 | Fluid Mechanics I | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 9** | | |
| INDE 370 | Industrial Project Management | 3.0 |
| MET 407 | Manufacturing Processes | 3.0 |
| MHT 314 | Thermo and Heat Transfer Analysis | 3.0 |
| MHT 401 | Mechanical Design I | 4.0 |
| | **Term Credits** | **13.0** |
| **Term 10** | | |
| MET 421 [WI] | Senior Design Project I | 3.0 |
| Liberal studies elective | | 3.0 |
| Free electives | | 7.0 |
| | **Term Credits** | **13.0** |
| **Term 11** | | |
| MET 422 | Senior Design Project II | 3.0 |
| Technical elective (See advisor) | | 3.0 |
| Liberal etudies elective | | 3.0 |
| Free elective | | 4.0 |
| | **Term Credits** | **13.0** |
| **Term 12** | | |
| MET 423 [WI] | Senior Design Project III | 3.0 |
| Technical elective (See advisor) | | 3.0 |
| Liberal studies Elective | | 3.0 |

| | |
|---|---|
| Free elective | 4.0 |
| **Term Credits** | **13.0** |

**Total Credit: 187.5**

# Engineering Technology Faculty

Richard Chiou, PhD *(Georgia Institute of Technology)*. Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Yalcin Ertekin, PhD *(University of Missouri-Rolla)*. Associate Clinical Professor. High speed machining with micromachining applications, machining process optimization and condition monitoring using multiple sensors, FEA simulation with 3D solid modeling applications, rapid prototyping and reverse engineering, quality and reliability improvement through statistically designed experiments, neural networks and data mining and Taguchi methods, CNC machine tool calibration characterization of cold fastening, clinching and self-pierced riveting processes, non-invasive surgical tool design, student learning enhancement using online simulation tools.

Vladimir Genis, PhD *(Kiev State University, Ukraine) Department Head, Engineering Technology.* Professor. Ultrasound wave propagation and scattering, ultrasound imaging, electronic instrumentation, piezoelectric transducers, and engineering education. Designed and developed diagnostic and therapeutic equipment for medical applications and electronic systems and techniques for defense-related and industrial applications.

Irina Ciobanescu Husanu, PhD *(Drexel University)*. Assistant Professor. Microgravity combustion, thermal-fluid science with applications in micro-combustion, fuel cells and research of alternative and green fuels, energy conversion and renewable energy, industrial experience in aerospace engineering areas (theoretical analysis, numerical simulations and experimental investigations), design and testing of propulsion systems, mechanical instrumentation, and developing industrial applications of aircraft engines.

Michael Mauk, PhD, PE *(University of Delaware)*. Assistant Clinical Professor. Rapid prototyping, microfluidics, alternative energy including solar energy and photovoltaics, semiconductor materials science, nanotechnology.

Warren Rosen, PhD *(Temple University)*. Assistant Clinical Professor. Computer networks; optical networks; high-performance switching; lightweight protocols.

# Manufacturing Engr Technology Courses

**MET 100 Graphical Communication 3.0 Credits**
Introduces engineering graphics and fundamentals of computer aided design using the interactive software package AutoCAD on a personal computer.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Freshman.

**MET 101 Manufacturing Materials 4.0 Credits**
Covers tests used to characterize properties of ceramic, polymeric, and metallic materials and how material properties influence their use and manufacturing. Includes laboratory work on ASTM and industrial testing procedures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHEM 111 [Min Grade: D] and CHEM 113 [Min Grade: D]

**MET 201 Introduction to Manufacturing Processes 3.0 Credits**
Introduces manufacturing and its managed activities: research and development, production, marketing, industrial relations, and finance. Includes laboratory work in organization, staffing, and operating a model manufacturing enterprise.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Pre-Junior or Sophomore
**Prerequisites:** MATH 110 [Min Grade: D]

**MET 202 Computer-Aided Drafting 4.0 Credits**
Introduces computer design using an interactive software package on a microcomputer.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Pre-Junior or Sophomore

**MET 204 Applied Quality Control 3.0 Credits**
Covers variables, procedures, and processes of total quality control within the manufacturing industries. Includes instrumentation for material evaluation, attribute inspection and sampling, supervising for organizational quality improvements, and statistical control. Emphasizes directed laboratory experiences.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** STAT 201 [Min Grade: D]

**MET 205 Robotics and Mechatronics 3.0 Credits**
Provides a comprehensive technical introduction to robotics and automation in manufacturing. Topics include flow line production, material handling, group technology, and flexible and mechatronics-integrated manufacturing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** PHYS 103 [Min Grade: D] and MATH 110 [Min Grade: D]

**MET 209 Fluid Power 3.0 Credits**
Covers the fundamentals of hydraulic systems with an emphasis on applications of Bernoulli's equation. Topics include component types and designs, hydraulic circuit analysis, and design of hydraulic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 103 [Min Grade: D] and PHYS 104 [Min Grade: D]

**MET 213 Applied Mechanics 4.0 Credits**
Covers elements of statics and strength of materials with specific applications to manufacturing problems. Topics include the design of bolted connections, simple structures, centroids, moments of inertia and beam design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 103 [Min Grade: D] and MET 101 [Min Grade: D] and MATH 122 [Min Grade: D]

**MET 301 Advanced Design Graphics 3.0 Credits**
Covers the theory and practice of industry's parts and assembly drawings with a specialization in tolerance and geometric dimensioning. Discusses industrial procedures and standards.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 100 [Min Grade: D]

**MET 307 HazMat for Manufacturing 3.0 Credits**
Covers the characteristics of hazardous substances and wastes, medical surveillance for plant personnel, toxicology, respirators and protective clothing, environmental direct reading indicators, decontamination procedures, and safe working practices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** BIO 161 [Min Grade: D] and CHEM 162 [Min Grade: D] and CHEM 164 [Min Grade: D]

**MET 308 Maritime Manufacturing 3.0 Credits**
Provides an overview of the key engineering standards, laws, and regulations governing the construction of commercial vessels in the United States and methods of complying with these requirements. Focuses on the ship manufacturing process and the installation and testing of ship systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**MET 310 Advanced Robotics and Mechatronics 3.0 Credits**
Covers applied topics related to the integration of computer, robotics, and internet-based automation technologies in modern manufacturing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 205 [Min Grade: D]

**MET 316 Computer Numerical Control 3.0 Credits**
Discusses theory and application of computer numerical control machines in the manufacturing environment. The laboratory focuses on the programming and operation of CNC machine tools.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATH 110 [Min Grade: D] and MET 100 [Min Grade: D]

**MET 380 Special Topic in Manufacturing 1.0-5.0 Credit**
Covers selected topics that meet student interest and faculty capabilities. May be taken more than once if topics vary. Students may enroll in more than one section in a term when different topics are covered in each section.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if classification is Senior.

**MET 402 Manufacturing Design with CAD 3.0 Credits**
Covers design of tools and fixtures for manufacturing, including general-purpose work holders, modular and dedicated fixtures, jigs, fixturing principles, degree of freedom, locating and clamping components, wire frame and solid modeling, and 3d to 2D conversion. Students design models of fixtures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 301 [Min Grade: D]

**MET 403 Three Dimensional Modeling 3.0 Credits**
Covers three-dimensional design with emphasis on manufacturing and industrial standards. Includes computer-aided-manufacturing using solid, surface, and wire-frame models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 100 [Min Grade: D]

**MET 404 Digital Instrumentation 3.0 Credits**
Covers digital technology and its application in manufacturing. Covers variables, procedures, and processes of total quality control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EET 201 [Min Grade: D]

**MET 407 Manufacturing Processes 3.0 Credits**
Covers a systematic understanding of the operations, applications, and planning of manufacturing processes. Discusses quantitative evaluations of processing parameters influencing product quality.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 101 [Min Grade: D] and MATH 122 [Min Grade: D]

**MET 408 MFG Information Management 3.0 Credits**
Covers information management in manufacturing. Topics include cost estimation and control, manufacturing resources planning (MRP), just-in-time (JIT), production and inventory controls, management information systems (MIS), supply chain management (SCM), and other advanced information management technology.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 205 [Min Grade: D] and MATH 122 [Min Grade: D]

**MET 409 Green Manufacturing 3.0 Credits**
Covers life cycle analysis, pollution prevention, recycling, and lean manufacturing, including characteristics of hazardous substances and wastes, medical surveillance for plant personnel, toxicology, respirators and protective, environmental direct reading indicators, decontamination procedures and safe working practices for MFG.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHEM 111 [Min Grade: D] and CHEM 113 [Min Grade: D]

**MET 411 Advanced Computer Numerical Control 3.0 Credits**
This course covers applied topics related to the integration of computer, CNC machines, and internet-based automation technologies in modern manufacturing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 316 [Min Grade: D]

**MET 421 [WI] Senior Design Project I 3.0 Credits**
This course constitutes the first course of a three-quarter course sequence. It aims to train the students in identifying projects of relevance to the society, in planning and scheduling a solution, and in entrepreneurial activities that may result from the project. The course is also intended to cover an industrial project starting from the proposal writing and conceptual design to final steps. This course is focused on proposal writing. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**MET 422 Senior Design Project II 3.0 Credits**
This course constitutes the second course of a three-quarter course sequence and continues MET 421. It aims to train the students in maintaining the progress of a project on schedule, including resolving any team conflicts. It also trains them how to prepare oral, and submit written progress reports. The students supply summary reports to his/her advisor. This course is focused on following standard design steps from the conceptual to final design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 421 [Min Grade: D]

**MET 423 [WI] Senior Design Project III 3.0 Credits**
This is the final installment of a 3 course sequence. The course objective is to train students in a project from the initial conceptual design stage to the preliminary and the final design completion, how to conduct design reviews, and how to document and present findings, design concepts, and conclusion in both oral and written formats. Students are also required to build a working prototype of their final design concept and present it during final presentation of the project.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 422 [Min Grade: D]

# Mechanical Engr Technology Courses

**MHT 201 Kinematics 3.0 Credits**
Study of four-bar linkages, sliders, and other devices using orthogonal of vectors, instantaneous centers, equivalent linkages, and effective cranks. Graphic solutions are emphasized, including an introduction to computer software.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Sophomore
**Prerequisites:** PHYS 103 [Min Grade: D]

**MHT 205 Thermodynamics I 3.0 Credits**
Students are introduced to the general theory of heat and matter; laws of thermodynamics; energy-transformation principles and availability of energy; and properties and processes for substances and ideal gases.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 103 [Min Grade: D] and MATH 122 [Min Grade: D] and MET 209 [Min Grade: D]

**MHT 206 Thermodynamics II 3.0 Credits**
First and second law analysis of power cycle components. Analysis of gas power cycles, including Otto & Diesel engines and Brayton cycle turbines. Analysis of traditional power plant cycles, including Rankine, Refrigeration and heat pump.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 205 [Min Grade: D]

**MHT 214 Technology Laboratory I 3.0 Credits**
Conduct experiments to determine the physical properties of incompressible fluids and to measure the flow rates of velocities utilizing pilot tubes, office plates, Venturi and Weirs flow meter, U-tube differential manometers and piezometers. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** MHT 301 [Min Grade: D] (Can be taken Concurrently)

**MHT 220 Applied Statics 3.0 Credits**
Explores forces, moments, couples, statistics of particles, and rigid bodies in two and three dimensions. Examines external and internal distributed forces, first moments and centroids, and structures such as trusses, frames and machines.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 282 [Min Grade: D] and MATH 122 [Min Grade: D]

**MHT 222 Applied Dynamics I 3.0 Credits**
Topics include friction, second moments, and virtual work; kinematics of particles-rectilinear and curvilinear motions of dynamic particles-force, mass and acceleration, work and energy.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 103 [Min Grade: D] or MATH 122 [Min Grade: D]

**MHT 224 Applied Dynamics II 3.0 Credits**
Impulse and momentum of particles; kinematics and dynamics of rigid bodies-force-mass and acceleration; dynamics of rigid bodies - work and energy. Impulse and momentum; introduction to mechanical vibration.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 222 [Min Grade: D]

**MHT 226 Measurement Techniques and Instrumentation 3.0 Credits**
Basic concepts of measurement and measurement systems and techniques, causes of errors and error propagation; uncertainty analysis, data collection and analysis using statistical methods, data acquisition systems; students perform experimental laboratory activities involving various measurement sensors and instruments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 104 [Min Grade: D] and STAT 201 [Min Grade: D] and EET 207 [Min Grade: D]

**MHT 295 Environmental Control Plasma Laboratory 2.0 Credits**
The course presents engineering principles of non-thermal plasma application to air cleaning from Volatile Organic Compounds by combining hands-on laboratory experience with lectures. The students learn the engineering and physical principles of non-equilibrium plasma systems using the unique pulsed corona system of the Drexel Plasma Institute Environmental Laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHEM 111 [Min Grade: D] and CHEM 113 [Min Grade: D]

**MHT 301 Fluid Mechanics I 3.0 Credits**
Examine hydrostatics; principles governing fluids at rest; pressure measurement; hydrostatic forces on submerged areas and objects; simple dams. Discuss fluid flow in pipes under pressure; fluid energy; power and friction loss; Bernoulli's theorem. Flow measurement.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 205 [Min Grade: D] and MET 213 [Min Grade: D] and MET 209 [Min Grade: D]

**MHT 310 Applied Strength of Materials I 3.0 Credits**
Topics include axially loaded members, stress and strain, allowable stresses, factor of safety, temperature effects, indeterminate members, torsional stresses and deformation. Students also examine shear moment beams; and flexural and transverse shearing stresses in beams.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 222 [Min Grade: D]

**MHT 312 Applied Strength of Materials II 3.0 Credits**
A study of determinate and indeterminate bean deflections and reactions by superposition, integration and moment area methods. Topics include combined stresses; principal stresses; Mohr's circle; and theories of failure.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 310 [Min Grade: D]

**MHT 314 Thermo and Heat Transfer Analysis 3.0 Credits**
Explores basic thermodynamic and heat transfer concepts and relations including fundamental of conduction, convection, and radiation using modern experiential methods to analyze thermodynamics systems and the related heat transfer mechanisms.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 205 [Min Grade: D]

**MHT 316 Fluid Mechanics Laboratory 3.0 Credits**
Conduct experiments to determine the physical properties of incompressible fluids and to measure the flow rate of velocities as the fluid flows through open channels, partially filled conduits, conduits under pressure, pipe networks, and turbines and pumps.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 301 [Min Grade: D]

**MHT 401 Mechanical Design I 4.0 Credits**
An introduction to mechanical design, the design process, design factors, creativity, optimization, human factors, and value engineering. Topics include simple design, properties and selection of materials; stress concentrations; strength under combined stresses; theories of failure; impact; and fluctuating and repeated loads.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MET 100 [Min Grade: D] and MET 213 [Min Grade: D]

**MHT 402 Mechanical Design II 4.0 Credits**
Topics include deformation and design of belt drives, chair drives, detachable fasteners and bearings, lubrication, and journal bearings. Covers stresses and power transmission of spur, bevel, and worm gear, shaft design, and clutches and brakes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 401 [Min Grade: D]

**MHT 403 Fluid Mechanics II 3.0 Credits**
Consider pipe networks and reservoir systems, flow in open channels and uniform flow energy, friction loss, minor losses, velocity distribution, alternate stages of flow, critical flow, non-uniform flow, accelerated, retarded flow and hydraulic jump.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MHT 301 [Min Grade: D]

**MHT 404 Advanced Materials 3.0 Credits**
Lectures on inorganic materials, i.e., polymers, glasses, ceramics, concrete, wood, and materials having important electrical and magnetic properties; also a summary of the most up-to-date applications for the fabrication and uses of both metals and nonmetals.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** MET 101 [Min Grade: D]

**MHT 405 HVAC 3.0 Credits**
Heating, Ventilation, and Air Conditioning (HVAC) focuses on air conditioning principles, including psychometrics and heat pumps. Examines calculation of heating and cooling loads in accordance with ASHRAE practices, principles of gas compression, analysis of vapor compression; refrigeration systems, low temperature refrigeration cycles, and absorption refrigeration systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** MHT 206 [Min Grade: D]

# Minor in Engineering Management

This minor focuses on the management of technical organizations. The required courses enhance an engineer's resume to show understanding of management and leadership behaviors, economics, and systems engineering and thinking.

While this minor is primarily designed to provide engineering management knowledge and skills to other engineers, with the equivalent science background students from other majors (biomedical engineering science, for example) can also complete this minor.

## Prerequisites

The common engineering core curriculum prerequisites are required of all students in the college of engineering. Students from other colleges will need the appropriate background prerequisite courses.

**Required Courses**

| | | |
|---|---|---|
| BLAW 201 | Business Law I | 4.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| ECON 201 | Principles of Microeconomics | 4.0 |
| ECON 202 | Principles of Macroeconomics | 4.0 |
| EGMT 462 | Introduction to Engineering Management | 3.0 |
| or MEM 462 | Introduction to Engineering Management | |
| EGMT 465 | Introduction to Systems Engineering | 3.0 |
| ORGB 300 [WI] | Organizational Behavior | 4.0 |
| **Total Credits** | | **25.0** |

## Additional Information

More information is available on the Engineering Management Minor (http://www.drexel.edu/egmt/programs/minor) web page.

# Engineering Policy Analysis Minor

An increasingly complex, interrelated, and technological society has come to rely on quantitative models of engineering systems to make decisions. While these models are used to make decisions in domains as varied as telecommunications, energy, and environmental quality, a common set of tools for the use of such models in decision making has been developed and forms the basis of an emerging discipline in engineering policy analysis. The practitioners of this discipline need training in mathematical and social science analytic approaches, as well as an understanding of the human factors that inevitably influence real-world policy choices. The minor in engineering policy analysis is designed to introduce students to these topics.

This minor broadens the exposure of engineering students to societal issues and provides an initial introduction to analytic skills which they may use both in engineering practice and as managers (given that many engineers become managers both in the private and public sector). Graduates will have additional training and credentials relevant not only to engineering careers, but also to other fields, including urban planning, management consulting, and public administration.

The program provides a basis for students to evaluate their interest and aptitude for graduate studies in fields such as business administration, public administration, and public policy. For pre-law students, the minor introduces them to analytic methods that inform the establishment and interpretation of laws as a mechanism of public policy implementation.

Students are required to complete a total of 24.0 credits. At least 12.0 of these credits may not be counted as part of their major.

**Applied Quantitative Methods (6.0 credits)**
Students select one sequence in probability and statistics consisting of one introductory course and one advanced course. Any introductory course may be combined with advanced course provided that the prerequisites of the advanced course are met.

**Introductory Course Options**

| Select one of the following: | | 3.0-4.0 |
|---|---|---|
| CHE 335 | Statistics and Design of Experiments | |
| ENGR 361 | Statistical Analysis of Engineering Systems | |
| MATH 311 | Probability and Statistics I | |
| MEM 361 | Engineering Reliability | |
| STAT 205 | Statistical Inference I | |

**Advanced Course Options**

| Select one of the following: | | 3.0-4.0 |
|---|---|---|
| MATH 312 | Probability and Statistics II | |
| STAT 206 | Statistical Inference II | |
| ENVE 750 | Data-based Engineering Modeling | |

**Additional Quantitative Method Electives**

| MATH 300 | Numerical Analysis I |
|---|---|
| MATH 305 | Introduction to Optimization Theory |
| MATH 318 [WI] | Mathematical Applications of Statistical Software |
| STAT 321 | Statistical Decision Methods |
| OPR 320 | Linear Models for Decision Making |
| OPR 330 | Advanced Decision Making and Simulation |

**Policy Analytic Methods (11.0)**

Students are required to take at least 11.0 credits, including a course on capital investment decision making and a two-course sequence in economics.

| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
|---|---|---|
| ECON 201 | Principles of Microeconomics | 4.0 |
| ECON 202 | Principles of Macroeconomics | 4.0 |

**Additional Policy Analytic Methods Electives**

| ECON 250 | Game Theory and Applications |
|---|---|
| ECON 301 | Microeconomics |
| ECON 330 | Managerial Economics |
| ECON 334 | Public Finance |
| ECON 351 | Resource and Environmental Economics |
| ENVS 370 | Practice of Environmental Economics |

| ENVE 727 | Risk Assessment |
|---|---|

**Human Factors (6.0)**

| Select two of the following: | | 6.0 |
|---|---|---|
| PSCI 110 | American Government I | |
| PSCI 211 | American Government II | |
| PSCI 220 | Constitutional Law I | |
| PSCI 329 | Theories of Justice | |
| PSCI 331 | Environmental Politics | |
| PSCI 372 | City in United States Political Development | |
| SOC 215 | Sociology of Work | |
| SOC 240 | Urban Sociology | |
| SOC 347 | Introduction to Environmental Policy Analysis | |

**Elective**

| One additional credit of coursework is required for the minor. This credit may be any of the three areas above. It is permissible to count 3.0 of the credits from a 4.0 credit class towards fulfilling one of the other areas, thereby using the 4th credit to meet the elective credit requirement. | 1.0 |
|---|---|

| **Total Credits** | **24.0** |
|---|---|

# Environmental Engineering

*Bachelor of Science in Environmental Engineering (BSENE): 193.5 quarter credits*

## About the Program

Environmental engineering is concerned with the design of systems, policies and processes to protect human, animal, and plant populations from the effects of adverse environmental factors, including toxic chemicals and wastes, pathogenic bacteria, and global warming, and to design systems that enable a more sustainable society.

Environmental engineers try to minimize the effect of human activities on the physical and living environment so that we can all live more healthy and sustainable lives. This field builds on other branches of engineering, especially civil, chemical, and mechanical engineering. It also builds on information from many of the sciences, such as chemistry, physics, hydrology, geology, atmospheric science, and several specializations of biology (ecology, microbiology, and biochemistry). Students who elect to study environmental engineering will become familiar with many of these areas because maintaining and improving the environment requires that problems be evaluated and solutions found using a multidisciplinary approach.

## Mission

The mission of the undergraduate environmental engineering program at Drexel University is to graduate outstanding engineers who can identify, evaluate and solve complex environmental problems, and who desire to continue their education on a lifelong basis.

## Program Educational Objectives

Environmental engineering graduates will become professionals who analyze, design, construct, manage or operate facilities or systems to protect or enhance the environment of people and other living things, or advance knowledge of the field.

## Student Outcomes

The department's student outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

a) an ability to apply knowledge of mathematics, science, and engineering;

b) an ability to design and conduct experiments, as well as to analyze and interpret data;

c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

d) an ability to function on multidisciplinary teams;

e) an ability to identify, formulate, and solve engineering problems;

f) an understanding of professional and ethical responsibility;

g) an ability to communicate effectively;

h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;

i) a recognition of the need for, and an ability to engage in life-long learning;

j) a knowledge of contemporary issues;

k) an ability to use the techniques, skills, and modern engineering tools necessary for environmental engineering practice.

## Additional Information

The Environmental Engineering program is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

For more information about this major, visit the Civil, Architectural and Environmental Engineering Department (http://www.cae.drexel.edu) and the BS in Environmental Engineering (http://www.drexel.edu/cae/academics/environmental-engineering) page.

## Degree Requirements

**General Education/Liberal Studies Requirements**

| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
|---|---|---|
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| General Education Requirements * | | 15.0 |
| **Engineering Core Courses** | | |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| BIO 141 | Essential Biology | 4.5 |
| CS 121 | Computation Laboratory I | 1.0 |
| CS 122 | Computation Laboratory II | 1.0 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| ENGR 361 | Statistical Analysis of Engineering Systems | 3.0 |
| **Environmental Engineering Requirements** | | |
| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| CAEE 211 | Measurements in Civil, Architectural and Environmental Engineering II | 4.0 |
| CHE 201 | Process Material Balances | 3.0 |
| CHEM 230 | Quantitative Analysis | 4.0 |
| CHEM 231 [WI] | Quantitative Analysis Laboratory | 2.0 |
| CHEM 241 | Organic Chemistry I | 4.0 |
| CHEM 242 | Organic Chemistry II | 4.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| CIVE 320 | Introduction to Fluid Flow | 3.0 |
| CIVE 330 | Hydraulics | 4.0 |
| CIVE 430 | Hydrology | 3.0 |
| CIVE 431 | Hydrology-Ground Water | 3.0 |
| ENVE 300 | Introduction to Environmental Engineering | 3.0 |
| ENVE 302 | Environmental Transport and Kinetics | 3.0 |
| ENVE 410 | Solid and Hazardous Waste | 3.0 |
| ENVE 421 | Water and Waste Treatment II | 3.0 |
| ENVE 422 | Water and Waste Treatment Design | 3.0 |
| ENVE 435 | Groundwater Remediation | 3.0 |
| ENVE 460 or ENVE 465 | Fundamentals of Air Pollution Control Indoor Air Quality | 3.0 |
| ENVE 485 | Professional Environmental Engineering Practice | 1.0 |
| ENVE 486 | Environmental Engineering Processes Laboratory I | 2.0 |
| ENVE 487 | Environmental Engineering Processes Laboratory II | 2.0 |
| ENVE 491 [WI] | Senior Project Design I | 3.0 |
| ENVE 492 [WI] | Senior Design Project II | 3.0 |
| ENVE 493 [WI] | Senior Design Project III | 3.0 |
| ENVS 284 [WI] or BIO 221 | Physiological and Population Ecology Microbiology | 3.0 |
| ENVS 401 | Chemistry of the Environment | 3.0 |

| Technical Electives | | 12.0 |
|---|---|---|
| **Total Credits** | | **193.5** |

\* General Education Requirements.

# Sample Plan of Study

### 5 YR UG Co-op Concentration

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| CS 121 | Computation Laboratory I | 1.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **15.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| CS 122 | Computation Laboratory II | 1.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 4** | | |
| CAEE 201 | Introduction to Infrastructure Engineering | 3.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 5** | | |
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |

| ENVS 284 [WI] or BIO 221 | Physiological and Population Ecology Microbiology | 3.0 |
|---|---|---|
| | **Term Credits** | **15.0** |
| **Term 6** | | |
| CHE 201 | Process Material Balances | 3.0 |
| CHEM 230 | Quantitative Analysis | 4.0 |
| CHEM 231 [WI] | Quantitative Analysis Laboratory | 2.0 |
| CIVE 320 | Introduction to Fluid Flow | 3.0 |
| ENGR 361 | Statistical Analysis of Engineering Systems | 3.0 |
| ENVE 300 | Introduction to Environmental Engineering | 3.0 |
| | **Term Credits** | **18.0** |
| **Term 7** | | |
| CAEE 211 | Measurements in Civil, Architectural and Environmental Engineering II | 4.0 |
| CIVE 330 | Hydraulics | 4.0 |
| ENVE 302 | Environmental Transport and Kinetics | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| General Education elective\* | | 3.0 |
| | **Term Credits** | **17.0** |
| **Term 8** | | |
| CHEM 241 | Organic Chemistry I | 4.0 |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| CIVE 430 | Hydrology | 3.0 |
| ENVS 401 | Chemistry of the Environment | 3.0 |
| General Education elective\* | | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 9** | | |
| CHEM 242 | Organic Chemistry II | 4.0 |
| Technical elective | | 3.0 |
| Free elective | | 3.0 |
| General Education elective\* | | 3.0 |
| | **Term Credits** | **13.0** |
| **Term 10** | | |
| ENVE 485 | Professional Environmental Engineering Practice | 1.0 |
| ENVE 491 [WI] | Senior Project Design I | 3.0 |
| ENVE 465 or 460 | Indoor Air Quality Fundamentals of Air Pollution Control | 3.0 |
| Technical elective | | 3.0 |
| Technical Elective | | 3.0 |
| | **Term Credits** | **13.0** |
| **Term 11** | | |
| CIVE 431 | Hydrology-Ground Water | 3.0 |
| ENVE 410 | Solid and Hazardous Waste | 3.0 |
| ENVE 421 | Water and Waste Treatment II | 3.0 |
| ENVE 486 | Environmental Engineering Processes Laboratory I | 2.0 |
| ENVE 492 [WI] | Senior Design Project II | 3.0 |

| | | |
|---|---|---|
| Technical elective | | 3.0 |
| | **Term Credits** | **17.0** |
| **Term 12** | | |
| ENVE 422 | Water and Waste Treatment Design | 3.0 |
| ENVE 435 | Groundwater Remediation | 3.0 |
| ENVE 487 | Environmental Engineering Processes Laboratory II | 2.0 |
| ENVE 493 [WI] | Senior Design Project III | 3.0 |
| General Education elective[*] | | 3.0 |
| | **Term Credits** | **14.0** |

**Total Credit: 193.5**

[*]    See degree requirements.

# Co-op/Career Opportunities

Environmental Engineers pursue careers with many different industries, such as chemical, pharmaceutical and manufacturing, in groundwater and hazardous waste remediation, in water or wastewater treatment, in air pollution abatement and control, and in mining. Some also join environmental consulting firms which serve several engineering areas. In addition, some students go to graduate school. The breadth of an environmental engineering education prepares the student to follow many career paths.

# Co-op Experiences

Past co-op employers of Environmental Engineering majors have included:

- Exelon, Philadelphia, PA
- U.S. Environmental Protection Agency, Philadelphia, PA
- Philadelphia Water Department, Philadelphia, PA
- Sun Co., Philadelphia, PA
- Aqua America, Bryn Mawr, PA
- Fairmount Park Commission, Philadelphia, PA
- Weston Solutions, West Chester, PA
- CDM Consultants, Philadelphia PA and other offices

# Dual/Accelerated Degree

The Accelerated Program of the College of Engineering provides opportunities for highly talented and strongly motivated students to progress toward their educational goals essentially at their own pace. Through advanced placement, credit by examination, flexibility of scheduling, and independent study, the program makes it possible to complete the undergraduate curriculum and initiate graduate study in less than the five years required by the standard curriculum.

# Bachelor's/Master's Dual Degree Program

Drexel offers a combined BS/MS degree program for our top engineering students who want to obtain both degrees in the same time period as most students obtain a Bachelors degree.

For more information on this program visit the Department's BS/MS Dual Degree Program (http://www.drexel.edu/cae/academics/environmental-engineering/Accelerated%20and%20Dual%20Degree%20Programs %20CAEE) page.

# Minor in Environmental Engineering

The Environmental Engineering minor focuses on pollution control and is primarily designed to broaden the professional capabilities of engineering students. For example, chemical and mechanical engineers working in process and manufacturing plants will be provided with a better understanding of the natural context of their facilities, better equipped to perform fate and risk analyses, and better able to apply the appropriate technology to control air and water discharges.

While this minor is designed to provide technical knowledge and skills to other engineers, with the appropriate prerequisites students from disciplines other than engineering can also complete this minor.

The minor consists of five required core courses and nine additional credits taken from a list of options.

### Prerequisites

The common engineering core curriculum prerequisites are required of all students in the College of Engineering. Students from other colleges will need the appropriate background in physics, mathematics and thermodynamics.

### Required Courses

| | | |
|---|---|---|
| CAEE 210 | Measurements in Civil, Architectural and Environmental Engineering I | 3.0 |
| ENVE 300 | Introduction to Environmental Engineering | 3.0 |
| ENVE 302 | Environmental Transport and Kinetics | 3.0 |
| CIVE 330 | Hydraulics | 4.0 |
| ENVS 401 | Chemistry of the Environment | 3.0 |
| Select three of the following: | | 8.0 |
| ENVE 410 | Solid and Hazardous Waste | |
| ENVE 460 | Fundamentals of Air Pollution Control | |
| ENVE 486 | Environmental Engineering Processes Laboratory I | |
| ENVE 487 | Environmental Engineering Processes Laboratory II | |
| CIVE 430 | Hydrology | |
| **Total Credits** | | **24.0** |

# Facilities

The Department is well equipped with state-of-the-art facilities:

- The department computer labs are in operation: a computer-assisted design (CAD) and computerized instructional lab; and a graduate-level lab (advanced undergraduates can become involved in graduate-level work)
- External labs are used for surveying, building diagnostics, and surface and ground-water measurements
- Molecular microbiology laboratory to conduct PCR and qPCR analyses, as well as classical measurements
- Analytical equipment for chemical contaminants
- Instrumentation for characterization of indoor and outdoor atmospheric aerosols

# Minor in Entertainment Engineering

Digital technologies have revolutionized the world of entertainment and created a new field combining the foundations of electrical engineering with entertainment media. This minor is designed for students with the technical literacy to effectively use, as well as develop, new tools for digital content creation and manipulation for entertainment applications.

The entertainment engineering minor consists of a minimum of six (6) required courses and an additional two (2) elective courses.

## Entertainment Engineering Option for Non-Engineering Majors

The minor assumes students have a background in mathematics (equivalent to Calculus II). Courses taken to meet these pre-requisite requirements will not count toward the minor.

**Required Courses**

| | | |
|---|---|---|
| DIGM 105 | Overview of Digital Media | 3.0 |
| ECE 101 | Electrical and Computer Engineering in the Real World | 1.0 |
| ECE 121 | Introduction to Entertainment Engineering | 3.0 |
| ECES 201 | Introduction to Audio-Visual Signals | 4.0 |
| ECES 352 | Introduction to Digital Signal Process | 4.0 |
| PSY 101 | General Psychology I | 3.0 |
| **Electives** | | |
| Select one of the following: | | 3.0 |
| PSY 213 | Sensation and Perception | |
| CS 337 | The Psychology of Human-Computer Interaction | |
| Select one of the following: | | 3.0 |
| FMVD 110 | Basic Shooting and Lighting | |
| FMVD 115 | Basic Editing | |
| FMVD 120 | Basic Sound | |
| MIP 133 | Digital Audio Workstations I | |
| **Total Credits** | | **24.0** |

## Additional Information

Additional information about this minor is available on the ECE Department (http://www.ece.drexel.edu) website.

For advising questions, please e-mail advising@ece.drexel.edu (%20advising@ece.drexel.edu) .

To make an appointment, please call 215.895.2241
Drop-in hours: Please e-mail advising@ece.drexel.edu (%20advising@ece.drexel.edu) for up-to-date drop-in availability.

# Minor in Global Engineering

The Minor in Global Engineering is designed to train engineering students to become global citizens, skilled in meeting the challenges of a global work environment. Coursework in this minor aims at developing students' international historical, political, and cultural awareness as well as their knowledge of international business in order to succeed in the global economy. In addition to the required coursework, students must successfully complete an experience abroad prior to graduation. Experiences other than approved Study Abroad (http://www.drexel.edu/studyabroad) or Co-Op Abroad programs must receive prior approval from the College of Engineering Associate Dean for Undergraduate Affairs.

## Foreign language

Foreign language is not required for the Minor in Global Engineering, but it may be required as a prerequisite to a student's experience abroad. In addition, a student can choose to apply as many as eight (8) credits of 200-level or higher foreign language toward the credit requirements for the minor.

## Restrictions

Currently, only students enrolled in either the the College of Engineering or the School of Biomedical Engineering, Science and Health Systems can enroll in this minor.

**Required Courses**

| | | |
|---|---|---|
| ENGR 280 | Introduction to Global Engineering | 2.0 |
| Select seven of the following (a minimum of one course from each of the three categories): | | 22.0 |
| **International Business** | | |
| INTB 200 | International Business | |
| BLAW 340 | International Business Law | |
| ECON 342 | Economic Development [*] | |
| INTB 332 | Multinational Corporations [*] | |
| INTB 334 | International Trade [*] | |
| INTB 336 | International Money and Finance [*] | |
| **Political Science/History** | | |
| PSCI 140 | Introduction to Comparative Political Analysis | |
| PSCI 150 | International Politics | |
| PSCI 351 | International Organizations: The United Nations | |
| PSCI 352 | Ethics and International Relations | |
| PSCI 353 | International Human Rights (i) | |
| PSCI 354 | United States & the Third World | |
| PSCI 357 | The European Union | |
| HIST 220 | History of American Business | |
| HIST 259 | History of Europe in the 20th Century | |
| **Culture and Communications** | | |
| IAS 359 | Culture and Values (recommended) | |
| COM 360 | International Communication | |
| PHIL 335 | Global Ethical Issues [**] | |
| SOC 330 | Developing Nations and the International Division of Labor | |
| WMST 240 | Women and Society in a Global Context | |
| **Total Credits** | | **24.0** |

[*] Require ECON 201 and ECON 202 as pre-requisites.

[**] Requires PHIL 105 as a prerequisite.

***Note***: Students may petition the College of Engineering's Associate Dean for Undergraduate Affairs for permission to apply other courses they believe relevant to the Minor in Global Engineering toward their credit requirements. Such requests will be handled on a case-by-case basis.

# Materials Science and Engineering

*Bachelor of Science in Materials Science and Engineering (BSMSE): 192.0 quarter credits*

## About the Program

Materials science and engineering (MSE) is concerned with the production, structure, characterization, properties and utilization of metals, ceramics, polymers, composites, electronic, optical, nano- and bio-compatible materials. Materials scientists and engineers play a key role in our increasingly complex technological society by extending the limited supply of materials, improving existing materials, and developing and designing new and superior materials and processes with an awareness of their cost, reliability, safety, and societal/environmental implications.

Students majoring in materials science and engineering (MSE) receive a thorough grounding in the basic sciences and engineering of all materials. All students are required to take course sequences that include materials processing, thermodynamics and kinetics of materials, and their physical and mechanical behavior, plus laboratories designed to familiarize them with the instruments and advanced techniques used to characterize materials and evaluate their structure, properties and performance. A number of custom tracks allow upper level students to focus their technical electives in areas of specialization, including nanoscale materials and nanotechnology, biomaterials, electronic and photonic materials, soft materials and polymers, advanced materials design and processing, or in a custom track. In addition, several required senior level courses emphasize the role of materials selection and specification in design.

Throughout the senior year, students majoring in materials science and engineering work on a capstone senior design project over the course of three terms, with guidance from a faculty advisor and graduate student mentor. Students, working individually or in small groups, synthesize information from their courses to arrive at solutions to real-world engineering problems.

Some recent senior design projects include:

- Analyzing Nonskid Material for Naval Applications
- Core-Cladding Electrospun Nanofibers for Controlled Release Applications
- Adsorption of Antiobiotics onto Nanodiamond Platforms
- Effect of Nickel Distribution on Hardenability
- Synthesis and Characterization of $Mo_2GaC$, $Mo_2GaN$ and $Mo_2AlC$ MAX Phases
- Design and Synthesis of ITO-Free Flexible Organic Solar Cells.

## Mission Statement

The Department of Materials Science and Engineering (http://www.materials.drexel.edu) will provide our BS, MS and PhD graduates with the technical and theoretical knowledge, design capabilities, professionalism, and communications skills necessary for them to excel in leadership positions in academia, industry, and government at the national and international levels.

## Vision

Materials science and engineering is a multi-disciplinary field that is at the forefront of all emerging technologies. Advances in the understanding of the process-structure-property-performance relationships of materials will be critical for future developments in energy storage and power generation, biomaterials and nanomaterials. The Department of Materials Science and Engineering at Drexel University is recognized as a leader in these areas through its teaching and scholarly research.

## Program Educational Objectives

The educational objectives of the Materials Science and Engineering BS degree program are:

- Materials Science and Engineering program graduates possess the core technical competencies in their field necessary to successfully interface with other engineering disciplines in the workplace.
- At least 30% of Materials Science and Engineering program graduates have progressed towards graduate education.
- Materials Science and Engineering program graduates are leaders in their chosen fields.
- Materials Science and Engineering program graduates are engaged in lifelong learning.
- Materials Science and Engineering program graduates posses written and verbal communication skills appropriate for professional materials engineers and/or scientists.

## Student Outcomes

The department's student outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

a. an ability to apply knowledge of mathematics, science and engineering.

b. an ability to design and conduct experiments, as well as to analyze and interpret data.

c. an ability to design a material, system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.

d. an ability to function on multidisciplinary teams.

e. an ability to identify, formulate and solve *materials* engineering problems.

f. an understanding of professional and ethical responsibility.

g. an ability to communicate effectively.

h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context.

i. a recognition of the need for, and an ability to engage in, life-long learning.

j. a knowledge of contemporary issues.

k. an ability to use the techniques, skills and modern engineering tools necessary for materials science and engineering practice.

## Additional Information

The Materials Science and Engineering program is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

For additional information about this major, contact:

Sarit Kunz
Academic Program Coordinator
215.895.2328
skunz@coe.drexel.edu

# Degree Requirements

**General Education/Liberal Studies Requirements**

| | | |
|---|---|---|
| ECON 201 | Principles of Microeconomics | 4.0 |
| ECON 202 | Principles of Macroeconomics | 4.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| Technical Electives/Track Courses * | | 12.0 |
| Non-designated General Education Requirements ** | | 9.0 |
| Free Electives | | 6.0 |

**Foundation Requirements**

| | | |
|---|---|---|
| CHE 335 | Statistics and Design of Experiments | 3.0 |
| CHEC 353 | Physical Chemistry and Applications III | 4.0 |
| CHEM 241 | Organic Chemistry I | 4.0 |
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| BIO 141 | Essential Biology | 4.5 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| ENGR 180 | Special Topics in Engineering (Computation Lab I) | 2.0 |
| ENGR 180 | Special Topics in Engineering (Computation Lab II) | 1.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |

**Professional Requirements**

| | | |
|---|---|---|
| MATE 214 | Introduction to Polymers | 4.0 |

| | | |
|---|---|---|
| MATE 221 | Introduction to Mechanical Behavior of Materials | 3.0 |
| MATE 240 | Thermodynamics of Materials | 4.0 |
| MATE 245 | Kinetics of Materials | 4.0 |
| MATE 280 | Advanced Materials Laboratory | 4.0 |
| MATE 315 | Processing Polymers | 4.5 |
| MATE 341 | Defects in Solids | 3.0 |
| MATE 345 | Processing of Ceramics | 4.5 |
| MATE 351 | Electronic and Photonic Properties of Materials | 4.0 |
| MATE 355 | Structure and Characterization of Crystalline Materials | 3.0 |
| MATE 366 [WI] | Processing of Metallic Materials | 4.5 |
| MATE 370 | Mechanical Behavior of Solids | 3.0 |
| MATE 410 | Case Studies in Materials | 3.0 |
| MATE 455 | Biomedical Materials | 3.0 |
| MATE 460 | Engineering Computational Laboratory | 4.0 |
| MATE 491 [WI] | Senior Project Design I | 2.0 |
| MATE 492 | Senior Project Design II | 2.0 |
| MATE 493 [WI] | Senior Project Design III | 4.0 |
| **Total Credits** | | **192.0** |

\* A "Track" is a sequence of 4-5 technical electives (12-18 credits) with an underlying connection to a specific area of materials science and engineering. With the rapid expansion of the technical and scientific knowledge in the field of materials science and engineering, organizing technical electives into thematic tracks benefits students. Combined with relevant co-op experiences and senior design, the tracks can provide strong evidence of specialization, which will benefit students in future job searches.
Technical electives can be taken during the junior and (mostly during) the senior year. For planning reasons, better coordination with senior design, and to accommodate students with an out-of-cycle schedule (e.g., transfer students), tracks need to be declared by the beginning of the pre-junior year. Students may change their track selection after consulting with their MSE department advisor.

\*\* Non-designated General Education Requirements.

# Sample Plan of Study

**5 YR UG Co-op Concentration**

| Term 1 | | Credits |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| COOP 101 | Career Management and Professional Development | 0.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 180 | Special Topics in Engineering (Computation Lab I) | 2.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **16.5** |
| Term 2 | | |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| CHEM 102 | General Chemistry II | 4.5 |

| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
|---|---|---|
| ENGR 180 | Special Topics in Engineering (Computation Lab II) | 1.0 |
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **18.0** |
| **Term 4** | | |
| CHEM 241 | Organic Chemistry I | 4.0 |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **18.0** |
| **Term 5** | | |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| MATE 221 | Introduction to Mechanical Behavior of Materials | 3.0 |
| Free elective | | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 6** | | |
| ECON 201 | Principles of Microeconomics | 4.0 |
| MATE 214 | Introduction to Polymers | 4.0 |
| MATE 240 | Thermodynamics of Materials | 4.0 |
| MATE 355 | Structure and Characterization of Crystalline Materials | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 7** | | |
| ECON 202 | Principles of Macroeconomics | 4.0 |
| MATE 245 | Kinetics of Materials | 4.0 |
| MATE 315 | Processing Polymers | 4.5 |
| MATE 341 | Defects in Solids | 3.0 |
| | **Term Credits** | **15.5** |
| **Term 8** | | |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| MATE 280 | Advanced Materials Laboratory | 4.0 |
| MATE 366 [WI] | Processing of Metallic Materials | 4.5 |
| MATE 370 | Mechanical Behavior of Solids | 3.0 |
| Technical elective/Track course | | 3.0 |
| | **Term Credits** | **17.5** |
| **Term 9** | | |

| CHEC 353 | Physical Chemistry and Applications III | 4.0 |
|---|---|---|
| MATE 345 | Processing of Ceramics | 4.5 |
| MATE 351 | Electronic and Photonic Properties of Materials | 4.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| | **Term Credits** | **15.5** |
| **Term 10** | | |
| MATE 455 | Biomedical Materials | 3.0 |
| MATE 460 | Engineering Computational Laboratory | 4.0 |
| MATE 491 [WI] | Senior Project Design I | 2.0 |
| General education elective* | | 3.0 |
| Technical elective/Track course | | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 11** | | |
| CHE 335 | Statistics and Design of Experiments | 3.0 |
| MATE 492 | Senior Project Design II | 2.0 |
| Free elective | | 3.0 |
| Technical elective/Track course | | 3.0 |
| General education elective* | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 12** | | |
| MATE 410 | Case Studies in Materials | 3.0 |
| MATE 493 [WI] | Senior Project Design III | 4.0 |
| Technical elective/Track course | | 3.0 |
| General education elective* | | 3.0 |
| | **Term Credits** | **13.0** |

**Total Credit: 192.0**

\*     See degree requirements.

# Co-op/Career Opportunities

Examples of industries in which materials science and engineering graduates play major roles include: base metals industries; specialist alloys; advanced ceramics; petrochemical; biomaterials and implants; pharmaceuticals; consumer products; electronics and photonics; nanotechnology; power generation; energy conversion, storage and conservation (fuel cells, advanced batteries, supercapacitors and solar cells); environmental protection and remediation; information and telecommunications; and transportation (aerospace, automotive, bicycles, railways).

Typical job functions include design and development of new materials, materials selection for specific applications, manufacturing, performance and failure analysis, quality control and testing, research and development, technical management, sales and marketing, teaching, technical services, and technical writing.

Please visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) for more detailed information on co-op and post-graduate opportunities.

# Dual/Accelerated Degree

## Accelerated Program

The Accelerated Program of the College of Engineering provides opportunities for highly talented and motivated students to progress toward their educational goals essentially at their own pace. These options include opportunities for accelerated studies, dual degrees, as well as a combined bachelor's/master's (BS/MS) program. Primarily through advanced placement, credit by examination, flexibility of scheduling, and independent study, this "fast-track" makes it possible to complete the undergraduate curriculum and initiate graduate studies in less than the five years required by the standard curriculum.

## Dual Degree Bachelor's Programs

With careful planning, students can complete two full degrees in the time usually required to complete one. For detailed information, students should contact their advisors.

## Bachelor's/Master's Dual Degree Program

Exceptional students can also pursue a master of science (MS) degree in the same period as the bachelor of science (BS). The combined BS/MS degree in Materials Science and Engineering differs from the standard BS degree in that there are two Co-op periods instead of three and in the last two years, specific graduate courses are taken.

For more information about this program, please visit the Department's BS/MS Dual Degree Program (http://www.mse.drexel.edu/academics/undergrad/bs-ms) page.

## Minor in Materials Engineering

In addition to the core engineering curriculum and the courses required for majors in chemical, civil, electrical, or mechanical engineering, engineering students from other majors can obtain a minor in materials engineering by taking 24.0 credits from the courses listed below.

### Required Courses

| | | |
|---|---|---|
| MATE 221 | Introduction to Mechanical Behavior of Materials | 3.0 |
| Select six (at least 21.0 credits) of the following: | | 21.0 |
| MATE 214 | Introduction to Polymers [*] | |
| MATE 240 | Thermodynamics of Materials | |
| MATE 245 | Kinetics of Materials | |
| MATE 280 | Advanced Materials Laboratory | |
| MATE 341 | Defects in Solids | |
| MATE 351 | Electronic and Photonic Properties of Materials | |
| MATE 355 | Structure and Characterization of Crystalline Materials | |
| MATE 370 | Mechanical Behavior of Solids [**] | |
| MATE 455 | Biomedical Materials | |
| **Total Credits** | | **24.0** |

[*]  MATE 214 requires CHEM 241 as a pre-requisite. If MATE 214 is elected, the credits for CHEM 241 can count toward the 21 credits.

[**]  MATE 370 requires MATH 201 as a pre-requisite. If MATE 370 is elected, the credits for MATH 201 can count toward the 21 credits.

**Note**:Only one of the prerequisites (either or MATH 201) can count toward the required 24.0 credits. In other words, both MATE 214 and MATE 370 can be used to fulfill the requirements for the minor, but only the pre-requisite for one of those courses will be calculated into the 24.0 credits. Similarly, MATH 201 or CHEM 241 cannot be counted alone as fulfilling the requirements for this minor. The credits for MATH 201 or CHEM 241 will only count toward the minor when the course(s) is/are taken as a prerequisite for MATE 214 or MATE 370. Substitution for these courses of equivalent courses offered by other departments and/or institutions may be made with the approval of the Department of Materials Science and Engineering on a case-by-case basis.

At least two-thirds of the content of a substitute course must be the same as that of the course in the list above. It is imperative that students check each course carefully with respect to prerequisites since some may be included in the list above and some may be from other departments. Courses taken outside the department as prerequisites do not count towards the 24.0 credits required for the minor. They may, however, be used as technical or free electives in students' home department. Students pursuing the minor in Materials Science and Engineering are also encouraged to select a senior design topic that relates to the field of materials.

## Facilities

**Biomaterials and Biosurfaces Laboratory**
This laboratory contains 10 kN biaxial and 5 kN uniaxial servo-hydraulic mechanical testing machines, a Fluoroscan X-ray system, a microscopic imaging system, a spectra fluorometer, a table autoclave, centrifuge, vacuum oven, $CO_2$ incubators, biological safety cabinet, thermostatic water baths, precision balance and ultrasonic sterilizer.

**Nanobiomaterials and Cell Engineering Laboratory**
This laboratory contains fume hood with vacuum/gas dual manifold, vacuum pump and rotary evaporator for general organic/polymer synthesis; gel electrophoresis and electroblotting for protein characterization; bath sonicator, glass homogenizer and mini-extruder for nanoparticle preparation; centrifuge; ultrapure water conditioning system; precision balance; pH meter and shaker.

**Ceramics Processing Laboratory**
This laboratory contains a photo-resist spinner, impedance analyzer, Zeta potential meter, spectrofluorometer, piezoelectric d33 meter, wire-bonder, and laser displacement meter.

**Dynamic Characterization Laboratory**
This laboratory contains metallographic sample preparation (sectioning, mounting and polishing) facilities; inverted metallograph; microhardness tester; automated electropolishing for bulk and TEM sample preparation; SEM tensile stage for EBSD; magneto-optical Kerr effect (MOKE) magnetometer.

**MAX Phase Ceramics Processing Laboratory**
This laboratory contains a vacuum hot-press; cold isostatic press (CIP) and hot isostatic press (HIP) for materials consolidation and synthesis; precision dilatometer; laser scattering particle size analyzer; impedance analyzer, creep testers, and assorted high temperature furnaces.

**Mechanical Testing Laboratory**
This laboratory contains mechanical and closed-loop servo-hydraulic testing machines, hardness testers, impact testers, equipment for fatigue testing, metallographic preparation facilities and a rolling mill with twin 6" diameter rolls.

**Mesoscale Materials Laboratory**
This laboratory contains instrumentation for growth, characterization, device fabrication, and design and simulation of electronic, dielectric,

ferroelectric and photonic materials. Resources include physical and chemical vapor deposition and thermal and plasma processing of thin films, including oxides and metals, and semiconductor nanowire growth. Facilities include pulsed laser deposition, atomic layer deposition, chemical vapor deposition, sublimation growth, and resistive thermal evaporation. Variable-temperature high-vacuum probe station and optical cryostats including high magnetic field, fixed and tunable-wavelength laser sources, several monochromators for luminescence and Raman scattering spectroscopies, scanning electron microscopy with electron beam lithography, and a scanning probe microscope.

### Nanomaterials Laboratory
This laboratory contains instrumentation for testing and manipulation of materials under microscope, high-temperature autoclaves, Sievert's apparatus; glove-box; high-temperature vacuum and other furnaces for the synthesis of nano-carbon coatings and nanotubes; electro-spinning system for producing nano-fibers.

### Oxide Films and Interfaces Laboratory
This laboratory contains an oxide molecular beam epitaxy (MBE) thin film deposition system; physical properties measurement system for electronic transport and magnetometry measurements from 2 – 400K, up to 9 T fields; 2 tube furnaces.

### Powder Processing Laboratory
This laboratory contains vee blenders, ball-mills, sieve shaker + sieves for powder classification, several furnaces (including one with controlled atmosphere capability); and a 60-ton Baldwin press for powder compaction.

### Soft Matter Research and Polymer Processing Laboratories
These laboratories contain computerized thermal analysis facilities including differential scanning calorimeters (DSC), dynamic mechanical analyzer (DMA) and thermo-gravimetric analyzer (TGA); single-fiber tensile tester; strip biaxial tensile tester; vacuum evaporator; spincoater; centrifuge; optical microscope with hot stage; liquid crystal tester; microbalance; ultrasonic cleaner; laser holographic fabrication system; polymer injection molder and single screw extruder.

### Natural Polymers and Photonics Laboratory
This laboratory contains a spectroscopic ellipsometer for film characterization; high purity liquid chromatography (HPLC) system; lyophilizer; centrifuge; refractometer; electro-spinning system for producing nano-fibers.

### X-ray Tomography Laboratory
This laboratory contains a high resolution X-ray tomography instrument and a cluster of computers for 3D microstructure reconstruction; mechanical stage, a positioning stage and a cryostage for in-situ testing. For more information on departmental facilities, please visit the Department's Facilities page at http://www.materials.drexel.edu/research/facilities/

### Centralized Research Facilities
The Department of Materials Science & Engineering relies on Core Facilities within the University for materials characterization and micro- and nano-fabrication. These facilities contain state-of-the-art materials characterization instruments, including environmental and variable pressure field-emission scanning electron microscopes with Energy Dispersive Spectroscopy (EDS) for elemental analysis, and Orientation Image Microscopy (OIM) for texture analysis; a Transmission Electron Microscope (TEM) with STEM capability and TEM sample preparation equipment; a dual beam focused ion beam (FIB) system for nano-characterization and nano fabrication; a femtosecond/ terahertz laser

Raman spectrometer; visible and ultraviolet Raman micro spectrometers with a total of 7 excitation wavelengths for non-destructive chemical and structural analysis and Surface Enhanced Raman (SERS); a Fourier Transform Infrared (FTIR) spectrometer with a microscope and full array of accessories; a Nanoindenter; an X-ray Photoelectron Spectrometer (XPS)/Electron Spectroscopy for Chemical Analysis (ESCA) system; and X-Ray Diffractometers (XRD), including small angle/wide angle X-Ray scattering (SAX/WAX).

More details of these instruments, information how to access them and instrument usage rates can be found at http://crf.coe.drexel.edu/

## Materials Science and Engineering Faculty

Michel Barsoum, PhD *(Massachusetts Institute of Technology) A. W. Grosvenor Professor*. Professor. Processing and characterization of novel ceramics and ternary compounds, especially the MAX and 2-D MXene phases.

Hao Cheng, PhD *(Northwestern University)*. Assistant Professor. Drug delivery, molecular self-assembly, cell-nanomaterial interactions, regenerative medicine and cell membrane engineering.

Yury Gogotsi, PhD *(Kiev Polytechnic Institute) Director, A. J. Drexel Nanotechnology Institute*. Distinguished University & Trustee Chair Professor. Nanomaterials; carbon nanotubes; nanodiamond; graphene; MXene; materials for energy storage, supercapacitors, and batteries.

Richard Knight, PhD *(Loughborough University) Associate Department Head and Undergraduate Advisor*. Teaching Professor. Thermal plasma technology; thermal spray coatings and education; plasma chemistry and synthesis.

Christopher Y. Li, PhD *(University of Akron)*. Professor. Soft and hybrid materials for optical, energy, and bio applications; polymeric materials, nanocomposites, structure and properties.

Michele Marcolongo, PhD, PE *(University of Pennsylvania) Department Head*. Professor. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Steven May, PhD *(Northwestern University)*. Assistant Professor. Synthesis of complex oxide films, superlattices, and devices; materials for energy conversion and storage; magnetic and electronic materials; x-ray and neutron scattering.

Ekaterina Pomerantseva, PhD *(Moscow State University, Russia)*. Assistant Professor. Solid state chemistry; electrochemical characterization, lithium-ion batteries, energy generation and storage; development and characterization of novel nanostructured materials, systems and architectures for batteries, supercapacitors and fuel cells.

Caroline L. Schauer, PhD *(SUNY Stony Brook) Graduate Advisor*. Associate Professor. Polysaccharide thin films and nanofibers.

Wei-Heng Shih, PhD *(Ohio State University)*. Professor. Colloidal ceramics and sol-gel processing; piezoelectric biosensors, optoelectronics, and energy harvesting devices; nanocrystalline quantum dots for bioimaging, lighting, and solar cells.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering*. Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces;

scanning probe microscopy; laser spectroscopy, including Raman scattering.

Mitra Taheri, PhD *(Carnegie Mellon University) Hoeganaes AssociateProfessor of Metallurgy*. Associate Professor. Development of the ultrafast Dynamic Transmission Electron Microscope (DTEM) for the study of laser-induced microstructural evolution/phase transformations in nanostructured materials; use of various *in-situ* Transmission Electron Microscopy techniques.

Garritt Tucker, PhD *(Georgial Institute of Technology)*. Assistant Professor. Computational materials science and engineering; microstructural evolutiona nd material behavior in extreme environments; interfacial-driven processes for improving material functionality; multi-scale physics modeling.

Christopher Weyant, PhD *(Northwestern University)*. Associate Teaching Professor.

Antonios Zavaliangos, PhD *(Massachusetts Institute of Technology) A.W. Grosvenor Professor*. Professor. Constitutive modeling; powder compaction and sintering; pharmaceutical tableting, X-ray tomography.

## Interdepartmental Faculty

Jason B. Baxter, PhD *(University of California, Santa Barbara)*. Associate Professor. Solar cells, semiconductor nanomaterials, ultrafast spectroscopy.

Adam K. Fontecchio, PhD *(Brown University) Associate Dean for Undergraduate Affairs; Associate Director, Expressive and Creative Interactive Technologies (EXCITE) Center*. Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Alexander Fridman, DSc, PhD *(Moscow Institute of Physics and Technology) Mechanical Engineering and Mechanics, John A. Nyheim Endowed University Chair Professor, Director of the Drexel Plasma Institute*. Professor. Plasma science and technology; pollutant mitigation; super-adiabatic combustion; nanotechnology and manufacturing.

Haviva M. Goldman, PhD *(City University of New York) Neurobiology and Anatomy*. Associate Professor. Understanding how the size and shape of whole bones, as well as the distribution quantity and quality of the mineralized tissue that forms the bone, reflect both evolutionary constraints of skeletal growth and development, and responsiveness to mechanical loading during life.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

E. Caglan Kumbur, PhD *(Pennsylvania State University)*. Associate Professor. Next generation energy technologies; fuel cell design and development.

Kenneth K.S. Lau, PhD *(Massachusetts Institute of Technology)*. Associate Professor. Surface science; nanotechnology; polymer thin films and coatings; chemical vapor deposition.

Bahram Nabet, PhD *(University of Washington)*. Professor. Optoelectronics; fabrication and modeling; fiber optic devices; nanoelectronics; nanowires.

Giuseppe R. Palmese, PhD *(University of Delaware) Department Head, Chemical and Biological Engineering*. Professor. Reacting polymer systems; nanostructured polymers; radiation processing of materials; composites and interfaces.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor. Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Karl Sohlberg, PhD *(University of Delaware)*. Associate Professor. Computational and theoretical materials-related chemistry: (1) complex catalytic materials; (2) mechanical and electrical molecular devices.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

## Emeritus Faculty

Roger D. Corneliussen, PhD *(University of Chicago)*. Professor Emeritus. Fracture, blends and alloys, as well as compounding.

Roger D. Doherty, PhD *(Oxford University)*. Professor Emeritus. Metallurgical processing; thermo-mechanical treatment.

Ihab L. Kamel, PhD *(University of Maryland)*. Professor Emeritus. Nanotechnology, polymers, composites, biomedical applications, and materials-induced changes through plasma and high energy radiation.

Jack Keverian, PhD *(Massachusetts Institute of Technology)*. Professor Emeritus. Rapid parts manufacturing, computer integrated manufacturing systems, strip production systems, technical and/or economic modeling, melting and casting systems, recycling systems.

Alan Lawley, PhD *(University of Birmingham, England)*. Professor Emeritus. Mechanical and physical metallurgy, powder metallurgy, materials engineering design, engineering education.

## Courses

**MATE 100 Materials for Emerging Technologies 2.0 Credits**
Evolution of materials engineering; education and the profession; concepts, tools, and techniques; selection and design using metals, ceramics, polymers, and composites; application of materials in a technological society; and materials of the future.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 101 Fundamentals of Materials 4.0 Credits**
Examines principles underlying structure, properties, and behavior of engineering materials, including metals, ceramics, and polymers. Covers topics including bonding; crystal structure; defect structure; alloying; mechanical, electronic, and magnetic properties in relation to structure; phase equilibria; phase transformations; and oxidation and corrosion. All terms.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (CHEM 103 [Min Grade: D] or CHEM 163 [Min Grade: D]) and (CHEM 102 [Min Grade: D] or CHEM 162 [Min Grade: D])

**MATE 214 Introduction to Polymers 4.0 Credits**
Covers polymer molecular structure, polymerization methods, semi-crystalline polymers, glass transition, polymer solution in blends, mechanical properties, and characterization methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 221 [Min Grade: D] and (MATH 201 [Min Grade: D] or MATH 261 [Min Grade: D] or ENGR 231 [Min Grade: D]) and CHEM 241 [Min Grade: D]

**MATE 221 Introduction to Mechanical Behavior of Materials 3.0 Credits**
Covers mechanics of materials, materials under load, application to materials testing, rate-dependent response to materials, fracture materials, fatigue behavior, manufacturing, and materials processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** TDEC 211 [Min Grade: D] or ENGR 220 [Min Grade: D]

**MATE 240 Thermodynamics of Materials 4.0 Credits**
Covers the fundamental laws of thermodynamics, statistical meaning of entropy, thermodynamic functions, heat capacity, reactions in gases and condensed phases, phase diagrams, solutions, and reaction equilibria in condensed solutions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 221 [Min Grade: D] and (TDEC 202 [Min Grade: D] or ENGR 210 [Min Grade: D])

**MATE 245 Kinetics of Materials 4.0 Credits**
Covers chemical reaction kinetics, thermodynamics and structure of crystal defects, diffusion equations and numerical methods of solution, kinetics in interfacial phenomena, and diffusional transformations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 240 [Min Grade: D]

**MATE 280 Advanced Materials Laboratory 4.0 Credits**
The goal of the course is to introduce students to state-of-the-art experimental techniques for analysis of structure, composition and properties of materials. Electron microscopy, Raman spectroscopy, indentation and thermal analysis will be described.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (TDEC 212 [Min Grade: D] or ENGR 220 [Min Grade: D]) and (TDEC 232 [Min Grade: D] or ENGR 202 [Min Grade: D])

**MATE 315 Processing Polymers 4.5 Credits**
Covers polymer processing, viscous flow and melt rheology, injection molding, extrusion, mechanical behavior, and applications and design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 214 [Min Grade: D]

**MATE 341 Defects in Solids 3.0 Credits**
Main classes of crystalline defects: vacancies, dislocations, stacking faults, surfaces, grain boundaries, geometry, energy considerations, and movement of defects. Defects in specific crystallographic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is MSE.
**Prerequisites:** MATE 355 [Min Grade: D]

**MATE 345 Processing of Ceramics 4.5 Credits**
Covers powder production, materials characterization, stability of powder suspensions, rheological and viscoelastic properties of slurries, green-body consolidation, drying, sintering, and structure-property relationships.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 355 [Min Grade: D] (Can be taken Concurrently)

**MATE 351 Electronic and Photonic Properties of Materials 4.0 Credits**
Electrons, principles of quantum mechanics, bonding, free electrons, and band theory solids; lattice vibrations, electronic and vibrational heat capacity; semiconductors and semiconductor devices; dielectrics, magnetic and optoelectronic materials and devices; superconductivity; applications and implications for energy-harvesting, conversion and storage.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 355 [Min Grade: D] (Can be taken Concurrently)

**MATE 355 Structure and Characterization of Crystalline Materials 3.0 Credits**
Bonding in solids; classification of metals, semiconductors, and insulators; crystal systems; crystallographic systems in specific engineering materials, relationships, X-ray generation, X-ray absorption and emission; reciprocal space; geometric representation of crystals, small and wide angle scattering, electron microscope imaging and diffraction.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is MSE.
**Prerequisites:** ENGR 220 [Min Grade: D] and MATE 221 [Min Grade: D]

**MATE 366 [WI] Processing of Metallic Materials 4.5 Credits**
Covers solidification processing, casting and welding, heat flow analysis, solid-state transformations, precipitation hardening, transformations in steels, martensite transformations, and industrial case studies. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 245 [Min Grade: D] and MATE 341 [Min Grade: D]

**MATE 370 Mechanical Behavior of Solids 3.0 Credits**
Covers continuum mechanics: three-dimensional stress and strain, hydrostatic and deviatoric components, and isotropic elasticity; Mises yield criterion; fracture criteria; linear elastic fracture mechanics; materials selection; defect-tolerant and defect-free fatigue design; notch effects; and statistics of variation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 221 [Min Grade: D] and ENGR 231 [Min Grade: D]

**MATE 410 Case Studies in Materials 3.0 Credits**
Covers interaction of materials processing and design, materials selection, the design-failure interface, cost and capacity in manufacturing. Taught via case studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 221 [Min Grade: D]

**MATE 450 The Nuclear Fuel Cycle & Materials 3.0 Credits**
Nuclear fuel cycle, including extraction, enrichment, transmutation in a nuclear reactor, reprocessing, waste processing, repository performance. Materials for nuclear reactors, mechanical and thermal performance, radiation damage.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENGR 220 [Min Grade: D] and (MEM 371 [Min Grade: D] or ECEP 404 [Min Grade: D]) and ECEP 402 [Min Grade: D]

**MATE 455 Biomedical Materials 3.0 Credits**
Familiarizes students with natural tissues and the implants designed to replace them, treating both components as engineering materials. Includes a review of fundamental topics of materials structure and testing, and case studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**MATE 458 Advanced Biomaterials 3.0 Credits**
Tissue Engineering, matrices, cells, scaffold, engineering properties, constitutive relations, absorbable polymers, cell seeding, cellular isolation, cell-scaffold interaction. May be repeated for credit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if classification is Senior.

**MATE 460 Engineering Computational Laboratory 4.0 Credits**
Covers numerical techniques, finite differences and finite elements, convergence, and applications in engineering design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 221 [Min Grade: D] and (TDEC 222 [Min Grade: D] or ENGR 232 [Min Grade: D]) and (TDEC 114 [Min Grade: D] or MATH 200 [Min Grade: D])

**MATE 473 Electronic, Magnetic and Optical Characterization of Energy Materials 3.0 Credits**
This course will examine the selection criteria for component materials in each of these applications and cover how critical properties – electronic conductivity, mobility, ionic conductivity, magnetization, optical absorption, Seebeck coefficient – are measured.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 351 [Min Grade: D]

**MATE 476 Recycling of Materials 3.0 Credits**
This course will examine the selection criteria for recycling component materials. Recycling involves both reusing materials for energy applications and reprocessing materials into new products.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 240 [Min Grade: D] and MATE 245 [Min Grade: D]

**MATE 482 Materials for Energy Storage 3.0 Credits**
The course will address principles of operation of electrochemical energy storage devices and describe materials used in those devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENGR 220 [Min Grade: D]

**MATE 483 Environmental Effects on Materials 3.0 Credits**
Environmental degradation is explored with a focus on electrochemical corrosion reactions in metals and alloys due to atmospheric, aqueous, chemical or elevated temperature exposure. In addition, high temperature degradation of ceramics and degradation of polymers due to exposure to heat, light and chemicals will be addressed. The role of these environmental effects during service and the impact on performance and reliability will be explored.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 245 [Min Grade: D]

**MATE 491 [WI] Senior Project Design I 2.0 Credits**
Introduces the design process, including information retrieval, problem definition, proposal writing, patents, and design notebooks. Includes presentations on problem areas by experts from industry, government, and education. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**MATE 492 Senior Project Design II 2.0 Credits**
Continues MATE 491. Requires written and oral progress reports.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 491 [Min Grade: D]

**MATE 493 [WI] Senior Project Design III 4.0 Credits**
Continues MATE 492. Requires written and oral final reports, including oral presentations by each design team at a formal Design Conference open to the public and conducted in the style of a professional conference. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MATE 492 [Min Grade: D]

**MATE 495 Special Topics in Materials 0.5-12.0 Credits**
By arrangement. Covers selected topics of current interest in materials engineering. May be taken for multiple course credit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**MATE 499 Independent Study 0.5-12.0 Credits**
Provides independent study and/or research on a topic approved by the department.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

# Mechanical Engineering

*Bachelor of Science in Mechanical Engineering (BSME): 192.5 quarter credits*

## About the Program

The role of the mechanical engineer in today's society is rapidly changing. Advances in manufacturing, transportation, infrastructure systems, materials, communications, and high-performance computing have introduced new demands, opportunities, and challenges for mechanical engineers. What was once an individual endeavor has now become a team activity. Today's industries require that mechanical engineers possess diverse interdisciplinary skills, a global viewpoint, entrepreneurial and managerial abilities, and an understanding of the forces governing the marketplace.

Traditionally, mechanical engineers have been associated with industries like automotive, transportation, and power generation, and with activities involving the design, analysis, and manufacturing of products useful to society. While today such activities are still dominated by mechanical engineers, the spectrum of opportunities for these professionals has expanded tremendously. For example, mechanical engineers are involved in the design and analysis of biomedical instrumentation, electronic components, smart structures, and advanced materials; they are involved in sophisticated studies of human motion, control of satellites, and the development of more efficient energy-transfer techniques.

Drexel's Department of Mechanical Engineering and Mechanics (http://www.drexel.edu/coe/departments/mech_eng) prides itself on providing its students with a comprehensive program of courses, laboratories, design projects, and co-op experiences. The MEM curriculum is designed to balance technical breadth (provided by a set of fundamental required core courses) with technical depth (provided by optional concentrations that emphasize particular fields within the profession). Thus, the MEM program not only prepares its graduates to become successful mechanical engineers needed in industry and government, but also provides an excellent springboard to pursue graduate studies in medical

sciences, law, business, information technology, and any other disciplines where technological and analytical skills play an important role.

## Mission Statement

The mission of the Department of Mechanical Engineering and Mechanics of Drexel University is to transfer and acquire knowledge through: (a) the education of engineers for leadership in industry, business, academia, and government; and (b) the establishment of internationally recognized research programs. This mission is accomplished by the delivery of an outstanding curriculum, by the participation of our students in one of the nation's most prestigious co-operative educational programs, and by the scholarly activities of the faculty.

## Program Educational Objectives

- Graduates will be successful in careers that deal with the design, simulation and analysis of engineering systems, experimentation and testing, manufacturing, technical services, and research.
- Graduates will enter and complete academic and professional programs in engineering, business, management, law and medicine.
- Graduates will communicate effectively with peers and be successful working with and leading multi-disciplinary and multi-cultural teams.
- Graduates will recognize the global, legal, societal, and ethical contexts of their work.
- Graduates will advance in their careers; for example, assuming increasing levels of responsibility and acquiring professional licensure.

## Student Outcomes

The department's student outcomes reflect the skills and abilities that the curriculum is designed to provide to students by the time they graduate. These are:

a) an ability to apply knowledge of mathematics, science, and engineering;

b) an ability to design and conduct experiments, as well as to analyze and interpret data;

c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

d) an ability to function on multidisciplinary teams;

e) an ability to identify, formulate, and solve engineering problems;

f) an understanding of professional and ethical responsibility;

g) an ability to communicate effectively;

h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;

i) a recognition of the need for, and an ability to engage in life-long learning;

j) a knowledge of contemporary issues;

k) an ability to use the techniques, skills, and modern engineering tools necessary for mechanical engineering and mechanics practice.

## Additional Information

The Mechanical Engineering and Mechanics program is accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org) .

For additional information about this major, contact:

Dane Zdunowski
dzdunowski@coe.drexel.edu
215.895.2336
Randell 115

Sheena Butler
sbutler@coe.drexel.edu
215.895.1474
Randell 115

# Degree Requirements

The mechanical engineering and mechanics curriculum is designed to balance technical breadth (provided by a set of fundamental required core courses) with technical depth (provided by optional concentrations that emphasize particular fields within the profession).

**General Education/Liberal Studies Requirements**

| | | |
|---|---|---|
| HIST 285 | Technology in Historical Perspective | 3.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| UNIV E101 | The Drexel Experience | 2.0 |
| General Education Requirements [*] | | 12.0 |

**Mathematics Requirements**

| | | |
|---|---|---|
| MATH 121 | Calculus I | 4.0 |
| MATH 122 | Calculus II | 4.0 |
| MATH 200 | Multivariate Calculus | 4.0 |

**Physics Requirements**

| | | |
|---|---|---|
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |

**Chemistry/Biology Requirements**

| | | |
|---|---|---|
| CHEM 101 | General Chemistry I | 3.5 |
| CHEM 102 | General Chemistry II | 4.5 |
| BIO 141 | Essential Biology | 4.5 |

**Design/Laboratory Requirements**

| | | |
|---|---|---|
| CS 121 | Computation Laboratory I | 1.0 |
| CS 122 | Computation Laboratory II | 1.0 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |

**Engineering Requirements**

| | | |
|---|---|---|
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |

**Engineering Economics Requirements**

| | | |
|---|---|---|
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |

**Materials Requirements**

| | | |
|---|---|---|
| ENGR 220 | Fundamentals of Materials | 4.0 |

**Mechanical Requirements**

| | | |
|---|---|---|
| MEM 201 | Foundations of Computer Aided Design | 3.0 |
| MEM 202 | Statics | 3.0 |
| MEM 220 | Basic Fluid Mechanics | 4.0 |
| MEM 230 | Mechanics of Materials I | 4.0 |
| MEM 238 | Dynamics | 4.0 |
| MEM 255 | Introduction to Controls | 4.0 |
| MEM 310 | Thermodynamic Analysis I | 4.0 |
| MEM 311 | Thermal Fluid Science Laboratory | 2.0 |
| MEM 331 | Experimental Mechanics I | 2.0 |
| MEM 351 | Dynamic Systems Laboratory I | 2.0 |
| MEM 333 | Mechanical Behavior of Materials | 3.0 |
| MEM 345 | Heat Transfer | 4.0 |
| MEM 355 | Performance Enhancement of Dynamic Systems | 4.0 |
| MEM 361 | Engineering Reliability | 3.0 |
| MEM 435 | Introduction to Computer-Aided Design and Manufacturing | 4.0 |
| MEM 491 [WI] | Senior Design Project I | 3.0 |
| MEM 492 [WI] | Senior Design Project II | 3.0 |
| MEM 493 [WI] | Senior Design Project III | 3.0 |

**Elective Courses**

| | |
|---|---|
| MEM Fundamental Courses [**] | 12.0 |
| MEM Open Electives (Any two MEM courses 300 level or higher.) | 6.0-8.0 |
| COE Electives (Any 2 College of Engineering courses, including MEM courses, 300 level or higher.) | 6.0-8.0 |
| Math/Science Electives (300+ level MATH, PHYS, BIO, CHEM, CHEC, and ENVS.) | 6.0-8.0 |
| Free Electives | 6.0-8.0 |
| **Total Credits** | **192.5** |

[*]   General Education Requirements.

[**]   All MEM students must complete a minimum of four of the MEM Fundamentals courses. (See List Below)

**MEM Fundamental Courses**

Select four of the following:

| | | |
|---|---|---|
| MEM 320 | Fluid Dynamics I | |
| MEM 330 | Mechanics of Materials II | |
| MEM 410 | Thermodynamic Analysis II | |
| MEM 417 | Introduction to Microfabrication | |
| MEM 423 | Mechanics of Vibration | |
| MEM 431 | Machine Design I | |
| MEM 437 | Manufacturng Process I | |
| MEM 440 | Thermal Systems Design | |

| MEM 458 | Micro-Based Control Systems I |
| MEM 459 | Control Applications of DSP Microprocessors |

# Sample Plan of Study

**5 YR UG Co-op Concentration**

| Term 1 | | Credits |
| --- | --- | --- |
| CHEM 101 | General Chemistry I | 3.5 |
| CS 121 | Computation Laboratory I | 1.0 |
| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
| ENGR 100 | Beginning Computer Aided Drafting for Design | 1.0 |
| ENGR 101 | Engineering Design Laboratory I | 2.0 |
| MATH 121 | Calculus I | 4.0 |
| UNIV E101 | The Drexel Experience | 1.0 |
| | **Term Credits** | **15.5** |
| **Term 2** | | |
| CHEM 102 | General Chemistry II | 4.5 |
| COOP 001 | Co-op Essentials | 0.0 |
| CS 122 | Computation Laboratory II | 1.0 |
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGR 102 | Engineering Design Laboratory II | 2.0 |
| MATH 122 | Calculus II | 4.0 |
| PHYS 101 | Fundamentals of Physics I | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 3** | | |
| BIO 141 | Essential Biology | 4.5 |
| CS 123 | Computation Laboratory III | 1.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| ENGR 103 | Engineering Design Laboratory III | 2.0 |
| MATH 200 | Multivariate Calculus | 4.0 |
| PHYS 102 | Fundamentals of Physics II | 4.0 |
| UNIV E101 | The Drexel Experience | 0.5 |
| | **Term Credits** | **19.0** |
| **Term 4** | | |
| ENGR 201 | Evaluation & Presentation of Experimental Data I | 3.0 |
| ENGR 220 | Fundamentals of Materials | 4.0 |
| ENGR 231 | Linear Engineering Systems | 3.0 |
| MEM 202 | Statics | 3.0 |
| PHYS 201 | Fundamentals of Physics III | 4.0 |
| | **Term Credits** | **17.0** |
| **Term 5** | | |
| ENGR 202 | Evaluation & Presentation of Experimental Data II | 3.0 |
| ENGR 210 | Introduction to Thermodynamics | 3.0 |
| ENGR 232 | Dynamic Engineering Systems | 3.0 |
| MEM 201 | Foundations of Computer Aided Design | 3.0 |
| MEM 238 | Dynamics | 4.0 |
| | **Term Credits** | **16.0** |
| **Term 6** | | |

| | | |
| --- | --- | --- |
| CIVE 240 [WI] | Engineering Economic Analysis | 3.0 |
| HIST 285 | Technology in Historical Perspective | 3.0 |
| MEM 230 | Mechanics of Materials I | 4.0 |
| MEM 310 | Thermodynamic Analysis I | 4.0 |
| Free Elective | | 3.0 |
| | **Term Credits** | **17.0** |
| **Term 7** | | |
| MEM 220 | Basic Fluid Mechanics | 4.0 |
| MEM 255 | Introduction to Controls | 4.0 |
| MEM 331 | Experimental Mechanics I | 2.0 |
| MEM 333 | Mechanical Behavior of Materials | 3.0 |
| PHIL 315 | Engineering Ethics | 3.0 |
| | **Term Credits** | **16.0** |
| **Term 8** | | |
| MEM 311 | Thermal Fluid Science Laboratory | 2.0 |
| MEM 355 | Performance Enhancement of Dynamic Systems | 4.0 |
| MEM 435 | Introduction to Computer-Aided Design and Manufacturing | 4.0 |
| MEM 345 | Heat Transfer | 4.0 |
| MEM Fundamentals Course[*] | | 3.0 |
| | **Term Credits** | **17.0** |
| **Term 9** | | |
| MEM 351 | Dynamic Systems Laboratory I | 2.0 |
| MEM 361 | Engineering Reliability | 3.0 |
| Two MEM Fundamentals Courses[*] | | 6.0 |
| General Education Elective[*] | | 3.0 |
| | **Term Credits** | **14.0** |
| **Term 10** | | |
| MEM 491 [WI] | Senior Design Project I | 3.0 |
| General Education Elective[*] | | 3.0 |
| A MEM or College of Engineering Elective (300+) | | 3.0 |
| MEM Fundamentals Course[*] | | 3.0 |
| Math/Science Course[*] | | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 11** | | |
| MEM 492 [WI] | Senior Design Project II | 3.0 |
| General Education Elective[*] | | 3.0 |
| Any 300-level or Higher MEM Elective | | 3.0 |
| A MEM or College of Engineering Elective (300+) | | 3.0 |
| Math/Science Course[*] | | 3.0 |
| | **Term Credits** | **15.0** |
| **Term 12** | | |
| MEM 493 [WI] | Senior Design Project III | 3.0 |
| Free Electives | | 3.0 |
| Any 300-level or Higher MEM Elective | | 3.0 |

| | |
|---|---|
| General Education Elective[*] | 3.0 |
| **Term Credits** | **12.0** |

**Total Credit: 192.5**

\* See degree requirements.

# Co-op/Career Opportunities

Mechanical engineers are employed in a growing number of areas, including aerospace, automotive, biomechanics, computer systems, electronic entertainment, energy, environmental, health care, manufacturing, nuclear technology, and utilities.
Most mechanical engineering graduates begin full-time employment immediately upon graduation. However, there are a number of graduates who go on to pursue master's and/or doctoral degrees in mechanical engineering. The graduate schools that Drexel's mechanical engineers have attended include Harvard, UC Berkeley, and the University of Pennsylvania.
Visit the Drexel Steinbright Career Development Center (http://www.drexel.edu/scdc) for more detailed information on co-op and post-graduate opportunities.

# Dual/Accelerated Degree

## Accelerated Program

The Accelerated Program of the College of Engineering provides opportunities for highly talented and strongly motivated students to progress toward their educational goals essentially at their own pace. These options include opportunities for accelerated studies, dual degrees, a combined bachelor's/master's program as well as participation in the University Honors Program (http://www.drexel.edu/honors) .

Primarily through advanced placement, credit by examination, flexibility of scheduling, and independent study, the "fast track" makes it possible to complete the undergraduate curriculum and initiate graduate study in less than the five years required by the standard curriculum.

## Dual Degree Bachelor's Programs

With careful planning, you can complete two full degrees in the time usually required to complete one. The double major option works best in closely related areas. For detailed information please contact your advisor.

## Bachelor's/Master's (BS/MS) Dual Degree Program

Exceptional students can also pursue a master of science degree in the same period as the bachelor of science. For MEM undergraduate students, the following are the possible graduate programs for the Master's degree in the BS/MS dual degree program:

- Electrical Engineering
- Computer Engineering
- Material Science Engineering
- Mechanical Engineering and Mechanics
- Biomedical Engineering
- Chemical Engineering

BS/MS students must be in the 5-year co-op option, must have a 3.2 GPA to gain admission, and must maintain a 3.0 GPA while in the program. For more information about this program, visit the College of Engineering BS/MS Dual Degree Program page.

# Minor in Mechanical Engineering and Mechanics

Any undergraduate student in good standing who has completed more than 30.0 credits at Drexel may apply for the minor in mechanical engineering.

The minor must contain a minimum of 24.0 MEM credits according to the following distribution: (a) 16.0 credits from any four of the 4-credit required course options; (b) at least eight credits from additional required courses or from the laboratory components and recommended electives.

| **Required Course Options** | | |
|---|---|---|
| Select four of the following: | | 16.0 |
| MEM 220 | Basic Fluid Mechanics | |
| MEM 230 | Mechanics of Materials I | |
| MEM 238 | Dynamics | |
| MEM 255 | Introduction to Controls | |
| MEM 310 | Thermodynamic Analysis I | |
| MEM 345 | Heat Transfer | |
| MEM 355 | Performance Enhancement of Dynamic Systems | |
| MEM 361 | Engineering Reliability | |
| MEM 435 | Introduction to Computer-Aided Design and Manufacturing | |
| Select three of the following: | | 8.0 |
| **Laboratories** | | |
| MEM 311 | Thermal Fluid Science Laboratory | |
| MEM 331 | Experimental Mechanics I | |
| MEM 351 | Dynamic Systems Laboratory I | |
| **Recommended Electives** | | |
| MEM 320 | Fluid Dynamics I | |
| MEM 330 | Mechanics of Materials II | |
| MEM 361 | Engineering Reliability | |
| MEM 410 | Thermodynamic Analysis II | |
| MEM 420 | Aerodynamics | |
| MEM 423 | Mechanics of Vibration | |
| MEM 425 | Aircraft Design & Performance | |
| MEM 430 | Advanced Stress Analysis | |
| MEM 437 | Manufacturng Process I | |
| MEM 438 | Manufacturing Process II | |
| MEM 440 | Thermal Systems Design | |
| MEM 453 | Aircraft Flight Dynamics & Control I | |
| MEM 455 | Introduction to Robotics | |
| MEM 458 | Micro-Based Control Systems I | |
| MEM 459 | Control Applications of DSP Microprocessors | |
| MEM 462 [WI] | Introduction to Engineering Management | |
| **Total Credits** | | **24.0** |

# Facilities

Advanced Design and Manufacturing Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=6)

This laboratory provides research opportunities in design ethodology,computer-aided design, analysis and manufacturing, and materials processing and manufacturing. Facilities include various computers and software, I-DEAS, Pro/E,ANSYS, MasterCAM, Mechanical DeskTop, SurfCAM, Euclid, Strim, ABQUS, and more.The machines include two Sanders Model Maker rapid prototyping machines, a BridgePort CNC Machining Center, a BOY 220 injection molding machine, an Electra high-temperature furnace for metal sintering, infiltration, and other heat treatment.

Biofluid Mechanics Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=5)
The biofluid mechanics laboratory conducts computational and experimental research on the dynamics of flow in the cardiovascular and respiratory system, and the effects of flow on biological processes, particularly hemostasis and thrombosis. Lab resources include high-performance engineering workstations, commercial computational fluid dynamics (CFD) software, and basic experimental facilities including Laser Doppler Velocimetry (LDV), pressure and flow transducers, pumps, and microscopes.

Biomechanics Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=2)
Emphasis in this laboratory is placed on understanding the mechanical properties of human joints, characterization of the mechanical properties of biological materials, studies of human movements, and design and development of artificial limbs. Facilities include a 3-D kinematic measuring system, Instron testing machine, and microcomputers for data acquisition and processing. Additional biomechanical laboratory facilities are available at Moss Rehab.

Combustion and Fuels Chemistry Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
Emphasis in this laboratory is placed on developing an understanding of both the chemical and physical factors that control and, hence, can be used to tailor combustion processes for engineering applications. Facilities include continuous spectroscopic reaction monitoring systems, static reactors, combustion bombs, flat flame burner systems, flow reactors, and complete analytical and monitoring instrumentation.

Combustion and Thermal-Science Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=9)
Research is conducted in the areas of (1) low temperature hydrocarbon oxidation, (2) cool flames, (3) auto-ignition, (4) flame instabilities, (5) flame structure, (6) flame ignition, and (7) flame extinction (quelching). New ways to improve fuel efficiency in practical combustors and recover waste energy in the transportation sector are also being explored.

*Combustion Emissions/Engine Laboratory*
In this laboratory the effects of engine operating variables, fuel type, ambient conditions, and control devices on engine performance and emissions are studied. The laboratory contains both diesel and spark ignition engines, as well as extensive engine and emissions monitoring instrumentation, including dynamometers and continuous gaseous emission analyzers. The laboratory has a high-pressure flow reactor for detailed kinetic studies of hydrocarbon oxidation processes in engines.

*Composite Mechanics Laboratory*
Emphasis in this laboratory is placed on the characterization of performance of composite materials. Current interest includes damage mechanisms, failure processes, and time-dependent behavior in resin-, metal-, and ceramic-matrix composites. Major equipment includes servo-hydraulic and electromechanical Instron testing machines,

strain/displacement monitoring systems, environmental chambers, microcomputers for data acquisition and processing, composites fabrication facility, interferometric displacement gauge, X-radiography, and acoustic emission systems.

Drexel Plasma Institute
The Drexel Plasma Institute (DPI) was formed in 2002 to stimulate and coordinate research projects related to plasma and other modern high energy engineering techniques. Today the DPI is an active multidisciplinary organization involving 23 faculty members from 6 engineering departments working in close collaboration with School of Biomedical Engineering, College of Arts and Sciences and College of Nursing and Health Professions.

*Heat Transfer Laboratory*
The heat transfer laboratory is outfitted with an array of instrumentation and equipment for conducting single- and multiphase heat transfer experiments in controlled environments. Facilities include computer-controlled data acquisition (LabVIEW and MacAdios) systems, a Newport holographic interferometric system with associated lasers and optics, image enlargers, power amplifiers, precision voltmeters, slip-ring assemblies, and an IBM RISC/6000 workstation for large-scale computing and simulation. A draft-free room is available with independent temperature control for carrying out natural convection experiments. An experimental test-rig is available for studying heat transfer from rotating surfaces. A bubble column has been recently built to study multiphase flow and heat transfer problems. Facilities are also available for measuring thermal conductivities of thin films using a thermal comparator.

*Industrial Robot Performance Laboratory*
Emphasis in this laboratory is placed on determining the relationship between robot design parameters and performance criteria.

*Microcomputer Controls Laboratory*
This laboratory provides an environment conducive to appreciating aspects of systems and control through hands-on experiments. They range from data acquisition and processing to modeling of dynamical systems and implementing a variety of controllers to control systems, such as DC motors and the inverted pendulum. Active research is being conducted on control reconfiguration in the event of actuator failures in aircrafts.

*Non-Newtonian Fluid and Heat Transfer Laboratory*
Emphasis in this laboratory is placed on the study of hydrodynamic and thermal performance of various non-Newtonian viscoelastic fluids in complex flow geometries. Facilities and equipment include a 20-foot-long recirculating flow loop with a 500-gallon reservoir tank and a thermal conductivity measurement cell. A complete data acquisition system provides fully automated experimental operation and data reduction. State-of-the-art finite element codes provide three-dimensional flow and heat transfer simulations of flows in complex geometrics, with a complete post-processing graphic capability backed by template.

*Polymer Processing Laboratory*
This laboratory is devoted to understanding the basic controlling parameters in polymer processing and the procedures for communicating between the automated processing machine and the rest of the manufacturing facilities, such as the material handling system and the intelligent monitoring system. Facilities include a BOY 55-ton injection molding machine with necessary equipment for processing fiber-reinforced polymers, an IBM microcomputer for data acquisition and control, a Macintosh II microcomputer with software for mold design and

process simulation, a Brookfield digital viscometer, and a Tinius Olsen tensile strength tester for material property evaluation.

Precision Instrumentation and Metrology Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=7)
This laboratory is focused on activities related to precision measurement, computer-aided inspection, and precision instrument design. Facilities include 3D Coordinate Measuring Machine (Brown & Sharpe) with Micro Measurement and Reverse engineering software, Surface Profilometer, and Laser Displacement Measuring System.

Program for Robotics, Intelligent Sensing, and Mechatronics (PRISM) Laboratory (http://prism.mem.drexel.edu)
The PRISM Laboratory is a state-of-the-art laboratory for pursuing research in the areas of medical robotics, haptic (sense of touch) and vision feedback through a user interface for augmenting a surgeon's capability in performing surgery, and visual servoing.The laboratory is equipped with a robotic arm, haptic interface devices, head-mounted display for immersion in the surgical environment, and dedicated hardware and software for the above research areas.

*Rheology Laboratory*
Emphasis in this laboratory is placed on developing tools for rheological property measurement of various non-Newtonian fluids, including friction-reducing viscoelastic fluids, molten polymers, coal-water slurries, ceramic slurries, and bonding cements for biomedical applications. A capillary tube viscometer, falling ball and needle viscometers, and Brookfield rotating viscometer are available. In particular, the capillary tube viscometer is designed to allow fully automated operation, thus avoiding time-consuming data collection procedures. A high-temperature and high-pressure capillary tube viscometer is under development, so that viscosities of advanced polymer materials can be measured at relatively high temperatures and shear rates.

*Stress Wave and Ballistics Laboratory*
Emphasis in this laboratory is placed on studying the effects of stress waves in structures. Equipment and facilities include a pendulum impact system, small air gun, high-air-pressure mass accelerator, drop impact system, exploding wire, explosion chamber, and instrumented charpy impact system.

Rapid Product Development Center (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=4)
This center provides fundamental research, educational instruction, and engineering services in product design and manufacturing, solid freeform fabrication, and computer-aided tissue engineering.The center is equipped with state-of-the-art CAD/CAE/CAM, medical imaging processing, and 3D reconstruction software, and a rapid prototyping system.

# Mechanical Engineering and Mechanics Faculty

Jonathan Awerbuch, DSc *(Technion, Israel Institute of Technology)*. Professor. Mechanics of composites; fracture and fatigue; impact and wave propagation; structural dynamics.

Nicholas P. Cernansky, PhD *(University of California-Berkeley) Hess Chair Professor of Combustion*. Professor. Combustion chemistry and kinetics; combustion generated pollution; utilization of alternative and synthetic fuels.

Bor-Chin Chang, PhD *(Rice University)*. Professor. Computer-aided design of multivariable control systems; robust and optimal control systems.

Young I. Cho, PhD *(University of Illinois-Chicago)*. Professor. Heat transfer; fluid mechanics; non-Newtonian flows; biofluid mechanics; rheology.

Alisa Clyne, PhD *(Harvard-Massachusetts Institute of Technology)*. Associate Professor. Cardiovascular biomechanics.

Bakhtier Farouk, PhD *(University of Delaware) Billings Professor of Mechanical Engineering*. Professor. Heat transfer; combustion; numerical methods; turbulence modeling; materials processing.

Alexander Fridman, DSc, PhD *(Moscow Institute of Physics and Technology) Mechanical Engineering and Mechanics, John A. Nyheim Endowed University Chair Professor, Director of the Drexel Plasma Institute*. Professor. Plasma science and technology; pollutant mitigation; super-adiabatic combustion; nanotechnology and manufacturing.

Ani Hsieh, PhD *(University of Pennsylvania)*. Assistant Professor. Multi-robot systems, decentralized and distributed control, bio-inspired control, swarm robotics.

Andrei Jablokow, PhD *(University of Wisconsin; Madison)*. Associate Teaching Professor. Computational kinematics; geometric modeling.

Antonios Kontsos, PhD *(Rice University)*. Associate Professor. Applied mechanics; probabilistic engineering mechanics; modeling of smart multifunctional materials.

E. Caglan Kumbur, PhD *(Pennsylvania State University)*. Associate Professor. Next generation energy technologies; fuel cell design and development.

Harry G. Kwatny, PhD *(University of Pennsylvania) S. Herbert Raynes Professor of Mechanical Engineering*. Professor. Dynamic systems analysis; stochastic optimal control; control of electric power plants and systems.

John Lacontora, PhD *(New Jersey Institute of Technology)*. Associate Research Professor. Service engineering; industrial engineering.

Leslie Lamberson, PhD *(California Institute of Technology)*. Assistant Professor. Dynamic behavior of materials, dynamic fracture, damage micromechanics, active materials.

Alan Lau, PhD *(Massachusetts Institute of Technology) Associate Department Head for Graduate Affairs, Department of Mechanical Engineering and Mechanics*. Professor. Deformation and fracture of nano-devices and macroscopic structures; damage-tolerant structures and microstructures.

Matthew McCarthy, PhD *(Columbia University)*. Assistant Professor. Micro- and nanoscale thermofluidic systems, bio-inspired cooling, smart materials and structures for self-regulated two-phase cooling, novel architectures for integrated energy conversion and storage.

David L. Miller, PhD *(Louisiana State University) Department Head*. Professor. Gas-phase reaction kinetics; thermodynamics; biofuels.

Hongseok (Moses) Noh, PhD *(Georgia Institute of Technology)*. Associate Professor. MEMS; BioMEMS; lab-on-a-chip; microfabrication; microfluidics.

Paul Y. Oh, PhD *(Columbia University)*. Adjunct Professor. Smart sensors servomechanisms; machine vision and embedded microcomputers for robotics and mechatronics.

Sorin Siegler, PhD *(Drexel University)*. Professor. Orthopedic biomechanics; robotics; dynamics and control of human motion; applied mechanics.

Wei Sun, PhD *(Drexel University) Albert Soffa Chair Professor of Mechanical Engineering*. Professor. Computer-aided tissue engineering; solid freeform fabrication; CAD/CAM; design and modeling of nanodevices.

Ying Sun, PhD *(University of Iowa)*. Associate Professor. Transport processes in multi-component systems with fluid flow; heat and mass transfer; phase change; pattern formation.

Tein-Min Tan, PhD *(Purdue University)*. Associate Professor. Mechanics of composites; computational mechanics and finite-elements methods; structural dynamics.

James Tangorra, PhD *(Massachusetts Institute of Technology) Associate Department Head for Finance and Administration, Department of Mechanical Engineering and Mechanics*. Associate Professor. Analysis of human and (other) animal physiological systems; head-neck dynamics and control; balance, vision, and the vestibular system; animal swimming and flight; robotics; system identification; bio-inspired design.

Christopher Weinberger, PhD *(Stanford University)*. Assistant Professor. Multiscale materials modeling of mechanical properties including DFT, atomistics, mesoscale and microscale FEM modeling.

Ajmal Yousuff, PhD *(Purdue University)*. Associate Professor. Optimal control; flexible structures; model and control simplifications.

Jack G. Zhou, PhD *(New Jersey Institute of Technology)*. Professor. CAD/CAM; computer integrated manufacturing systems; rapid prototyping; system dynamics and automatic control.

## Interdepartmental Faculty

Richard Chiou, PhD *(Georgia Institute of Technology)*. Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Michael Glaser, MFA *(Ohio State University) Program Director for Product Design*. Assistant Professor. Quantifying the designer's intuition; the interplay between digital and physical forms; human desire to shape our surroundings.

Yury Gogotsi, PhD *(Kiev Polytechnic Institute) Director, A. J. Drexel Nanotechnology Institute*. Distinguished University & Trustee Chair Professor. Nanomaterials; carbon nanotubes; nanodiamond; graphene; MXene; materials for energy storage, supercapacitors, and batteries.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Polymeric and cementitioius materials; geosynthetic reliability and durability.

Michele Marcolongo, PhD, PE *(University of Pennsylvania) Department Head*. Professor. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Roger Marino, PhD *(Drexel University)*. Associate Teaching Professor. Fluid Mechanics, Water Resources, Engineering Education, Land Development

Mira S. Olson, PhD *(University of Virginia)*. Associate Professor. Groundwater; environmental fluid mechanics; hydrology.

William C. Regli, PhD *(University of Maryland-College Park)*. Professor. Artificial intelligence; computer graphics; engineering design and Internet computing.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering*. Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces; scanning probe microscopy; laser spectroscopy, including Raman scattering.

## Emeritus Faculty

Leon Y. Bahar, PhD *(Lehigh University)*. Professor Emeritus. Analytical methods in engineering, coupled thermoelasticity, interaction between analytical dynamics and control systems.

Pei C. Chou, ScD *(Aeronautical Engineering from New York University) Billings Professor Emeritus of Mechanical Engineering*. Professor Emeritus. Material response due to impulsive loading, wave propagation in isotropic and composite materials, manufacturing technology.

Gordon D. Moskowitz, PhD *(Princeton University)*. Professor Emeritus. Biomechanics, dynamics, design, applied mathematics.

Donald H. Thomas, PhD *(Case Institute of Technology)*. Professor Emeritus. Biocontrol theory, biomechanics, fluidics and fluid control, vehicle dynamics, engineering design.

Albert S. Wang, PhD *(University of Delaware) Albert and Harriet Soffa Professor*. Professor Emeritus. Treatment of damage evolution processes in multi-phased high-temperature materials, including ceramics and ceramic-matrix composites.

## Courses

**MEM 201 Foundations of Computer Aided Design 3.0 Credits**
Covers application of modern, computer-aided graphics techniques and the use of state-of-the-art, computer-aided design/drafting package(s). Includes topics such as principles of computer-aided design/drafting and interactions with computer-aided manufacturing, rapid prototyping, and other modern manufacturing processes; engineering graphics and graphics languages in computer-aided design and/or drafting; creation of a drawing environment; database and file management, editing, modification, displaying, dimensioning, plotting and printing; special editing techniques; 3-D modeling, solid modeling, shading, and rendering; and file transfer. Students must have Sophomore class standing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman

**MEM 202 Statics 3.0 Credits**
Covers two-and three-dimensional vector representation of forces, moments and couples; static equilibrium of particles, rigid bodies, and engineering structures; analysis of external and internal forces in structures via methods of free body diagrams; and properties of cross-sectional areas.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** PHYS 185 [Min Grade: D] or PHYS 101 [Min Grade: D]

**MEM 220 Basic Fluid Mechanics 4.0 Credits**
Covers general physical properties of a fluid; kinetics of fluid motion; material derivative, vorticity, strain, and dynamics of fluids; and derivation of conservation laws in control volume form with applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** TDEC 114 [Min Grade: D] or MATH 189 [Min Grade: D] or MATH 200 [Min Grade: D]

**MEM 230 Mechanics of Materials I 4.0 Credits**
Covers definitions of stress and strain, uniaxial loading, torsion, bending moments and shear forces in beams, bending stresses and shear stress in beams, and stress transformation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 202 [Min Grade: D]

**MEM 238 Dynamics 4.0 Credits**
Covers kinematics and kinetics in two and three-dimensional space, force and acceleration, linear and angular momentum, and energy methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** (MATH 189 [Min Grade: D] or MATH 200 [Min Grade: D]) and (PHYS 111 [Min Grade: D] or PHYS 185 [Min Grade: D] or PHYS 101 [Min Grade: D])

**MEM 255 Introduction to Controls 4.0 Credits**
Introduces the concepts of modeling of mechanical, electrical, electromechanical, thermal, and hydraulic systems; linearization; state-space model; time-domain analysis; transfer functions; frequency-domain analysis; analysis of systems involving automatic control of position, speed, power, flow, pressure, temperature, and other physical quantities; basic concept of feedback; basic concept of stability; computer-aided analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 238 [Min Grade: D] and (MATH 201 [Min Grade: D] or MATH 261 [Min Grade: D] or ENGR 231 [Min Grade: D]) and (MATH 210 [Min Grade: D] or MATH 262 [Min Grade: D] or ENGR 232 [Min Grade: D])

**MEM 304 Introduction to Biomechanical Engineering 3.0 Credits**
An overview of the application of mechanical engineering to biological systems. Covers basic anatomy and physiology; tissue, joint, cell, and protein mechanics; joint kinematics; biofluid mechanics; biothermodynamics; biotransport; biomimetic controls; and biomanufacturing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATH 200 [Min Grade: D] and PHYS 101 [Min Grade: D] and CHEM 102 [Min Grade: D] and BIO 141 [Min Grade: D]

**MEM 310 Thermodynamic Analysis I 4.0 Credits**
Reviews first and second laws of thermodynamics as applied to closed systems, control volumes, and thermodynamic cycles; covers thermodynamic relations and properties of real fluids, mixtures, and solutions; introduces phase and chemical equilibrium, power and refrigeration cycles, and combustion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ENGR 210 [Min Grade: D] or MEM 210 [Min Grade: D]

**MEM 311 Thermal Fluid Science Laboratory 2.0 Credits**
Introduces modern laboratory techniques, including statistical analysis of experimental data; thermodynamic properties and equations of state; and dynamic and static temperature measurements with potentiometers, bridge circuits, and oscilloscopes. Fall.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 220 [Min Grade: D] and MEM 310 [Min Grade: D]

**MEM 320 Fluid Dynamics I 3.0 Credits**
Covers equation of motion for compressible flow; static, total, and stagnation concepts; one-dimensional isentropic, normal shock, including Fanno and Rayleigh flows and choked flow; two-dimensional supersonic flow, including Prandtl-Meyer flow and oblique shocks; analysis and design of compressible flow devices, including supersonic nozzles, diffusers, wind tunnels, inlets, and combustors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 220 [Min Grade: D]

**MEM 330 Mechanics of Materials II 4.0 Credits**
Reviews mechanics of materials, beam theory, combined loading, stress transformation, shear center, asymmetrical bending, deflection of beams, statically indeterminate beams, energy methods, inelastic bending, and beam column instability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 230 [Min Grade: D]

**MEM 331 Experimental Mechanics I 2.0 Credits**
Covers static testing methods, including strain gages, extensometers, photoelasticity, and model analysis; practical applications of experimental stress analysis; and verification of standard materials tests, including tensile, shear, and buckling. Winter. Some or all pre-requisites may be taken as either a pre-requisite or co-requisite. Please see the department for more information.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 238 [Min Grade: D] (Can be taken Concurrently)MEM 230 [Min Grade: D]

**MEM 333 Mechanical Behavior of Materials 3.0 Credits**
Introduces the deformation and failure of engineering materials;
Emphasizes application of the fundamentals to engineering design to
prevent failure; Covers material damage and failure under multi-axial
stresses, yielding, fracture mechanics, fatigue crack growth, fatigue life
estimation, and deformation and failure of composite materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Pre-Junior or Senior.
**Prerequisites:** MEM 230 [Min Grade: D]

**MEM 345 Heat Transfer 4.0 Credits**
Covers fundamentals of conduction, convection, and radiation; steady
and unsteady heat conduction; fundamentals of boundary layer flows;
introduction to forced and free convection for external and internal flows;
blackbody radiation; and radiation and surface radiation properties.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** ENGR 210 [Min Grade: D] and (MEM 220 [Min Grade: D]
or CIVE 320 [Min Grade: D]) and (MATH 210 [Min Grade: D] or MATH
262 [Min Grade: D] or ENGR 232 [Min Grade: D])

**MEM 351 Dynamic Systems Laboratory I 2.0 Credits**
Includes experiments involving modeling and simulation of linear and non-
linear dynamic systems, including feedback controls. Spring.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 255 [Min Grade: D]

**MEM 355 Performance Enhancement of Dynamic Systems 4.0
Credits**
This course introduces measures of performance of dynamical systems,
means of computing/evaluation-of such measures, and how to design
controllers to improve performance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 255 [Min Grade: D]

**MEM 361 Engineering Reliability 3.0 Credits**
Reviews probability concepts and modeling of random phenomena,
including parameter estimation, empirical determination of distribution
models, catastrophic failure models, material strength and fatigue life
distribution, and reliability improvement.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** MATH 290 [Min Grade: D] or MATH 201 [Min Grade: D] or
MATH 261 [Min Grade: D] or ENGR 231 [Min Grade: D]

**MEM 371 Introduction to Nuclear Engineering I 2.0 Credits**
Introduces the fundamental scientific, technical, social and ethical issues
in nuclear engineering; nuclear reactions and readiation, radiation
protection and control, nuclear energy production and utilization, nuclear
fuel cycle, nuclear fuel cycle, nuclear materials, controlled fusion and
thermonuclear plasma systems, basics of plasma physics and plasma
chemistry, nuclear waste management, nuclear reactor safety, analysis
of severe nuclear accidents, risk assessment and related issues of
engineering ethics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 201 [Min Grade: D] and (ENGR 210 [Min Grade: D]
or CHE 206 [Min Grade: D])

**MEM 373 Space Systems Engineering I 3.0 Credits**
Introduction to space engineering through presentation of two topics that
serve as the foundation of space systems analysis and design: rocket
propulsion and orbital mechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 220 [Min Grade: D] and MEM 238 [Min Grade: D]
and MEM 310 [Min Grade: D]

**MEM 374 Space Systems Engineering II 3.0 Credits**
Introduction to design principles and theory of satellite systems
engineering, including design theories and parameters involved in satellite
development, as well as real life conditions such as applications, product
assurance, assembly, and testing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 373 [Min Grade: D]

**MEM 380 [WI] Special Topics in Mechanical Engineering 12.0 Credits**
Selected topics that meet student interests and faculty capabilities. May
be taken more than one time when the topics vary. Students may enroll in
more than one section of this course in any one term when different topics
are covered in each section. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 395 Hess Undergraduate Scholars Research 0.5-3.0 Credits**
A change for undergraduates to experience independent research as part
of the MEM Hess Honors Program. Weekly group meetings to discuss the
details of the research endeavor are coupled with independent student in
a research laboratory. May be repeated five times for credit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 5 times for 18 credits
**Prerequisites:** MEM 310 [Min Grade: D]

**MEM 399 Independent Study in Mechanical Engineering 0.5-12.0
Credits**
Provides independent study or research on a topic approved by the
department.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Cannot enroll if classification is Freshman

**MEM 400 Internal Combustion Engines 3.0 Credits**
Covers engine types and trends, thermodynamics of engines and engine processes, ideal and actual engine processes and cycles, combustion and emissions, fuel chemistry and properties, detonation and knock, and engine testing and performance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 310 [Min Grade: D]

**MEM 402 Power Plant Design 3.0 Credits**
Covers heat cycle arrangement, equipment selection, analysis of cost demands, and diversity factors. Includes economic studies of plant and cycle arrangements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 310 [Min Grade: D]

**MEM 403 Gas Turbines & Jet Propulsion 3.0 Credits**
Covers fundamentals of thermodynamics and aerothermodynamics, and application to propulsion engines; thermodynamic cycles and performance analysis of gas turbines and air-breathing propulsion systems, turbojet, turboprop, ducted fan, ramjet, and ducted rocket; theory and design of ramjets, liquid and solid rockets, air-augmented rockets, and hybrid rockets; aerodynamics of flames, including the thermodynamics and kinetics of combustion reactions; supersonic combustion technology and zero-g propulsion problems; and propulsion systems comparison and evaluation for space missions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 220 [Min Grade: D] and MEM 310 [Min Grade: D]

**MEM 405 Principles of Combustion I 3.0 Credits**
Covers thermochemistry, the relationship between heats of formation and bond energies, heat capacity and heats of reaction, chemical equilibrium, calculation of flame temperature, and composition of burned gas.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 410 [Min Grade: D]

**MEM 406 Principles of Combustion II 3.0 Credits**
Covers laminar flame propagation in premixed gases, detonation and deflagration, burning of liquid and solid fuels, and diffusion flames.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 405 [Min Grade: D]

**MEM 410 Thermodynamic Analysis II 3.0 Credits**
Covers thermodynamic analysis of ideal and real mixtures and gas phase reacting systems. Introduces equilibrium analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 310 [Min Grade: D]

**MEM 413 HVAC Loads 3.0 Credits**
Human comfort and associated models; state-of-the-art methods of calculating building peak heating and cooling loads; analysis of different psychrometric processes; different types of secondary systems: description, operating principles, modeling, simulation and sizing of secondary systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 345 [Min Grade: D] and (MEM 310 [Min Grade: D] or AE 220 [Min Grade: D])

**MEM 414 HVAC Equipment 3.0 Credits**
Standard and real, single-stage multistage refrigeration cycles; vapor compression components (compressor, expansion devices, condensers, and evaporators); heat pumps; absorption systems; boilers; heat exchangers; cooling coils, cooling towers; part-load energy performance; annual energy; annual energy estimation methods (degree-day, bin method, modified degree-day).
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 345 [Min Grade: D] and (MEM 310 [Min Grade: D] or AE 220 [Min Grade: D])

**MEM 415 Fuel Cell Engines 3.0 Credits**
Introduces fundamental aspects and operating principles of fuel cell systems, including: basic electrochemical principles, thermodynamics required for understanding the operation, components including functions and materials, electrochemical performance characteristics, analysis of system losses and efficiency, various fuel cell types, current state of technology, application areas/implementation, and current technical challenges.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (MEM 220 [Min Grade: D] or CHE 302 [Min Grade: D] or CHE 311 [Min Grade: D] or CIVE 320 [Min Grade: D]) and MEM 310 [Min Grade: D]

**MEM 417 Introduction to Microfabrication 3.0 Credits**
This course focuses on the fundamentals of microfabrication technologies. The materials, principles, and applications of silicon-based microfabrication technologies such as photolithography, wet/dry etching, deposition techniques, surface micromachining, and polymer micromachining are covered. This course also includes two lab sessions through which students have hands-on experiences in microfabrication.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**MEM 419 Microfluidics and Lab-on-a-Chip 3.0 Credits**
This course focuses on design, manufacturing, and application of lab-on-a-chip systems as well as understanding microfluidic phenomena. The lecture covers novel microfluidic phenomena, microsensors, microactuators, and case studies. This course also includes two lab sessions through which student have hands-on experiences in lab-on-a-chip technology.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** MEM 417 [Min Grade: D]

**MEM 420 Aerodynamics 3.0 Credits**
Covers steady and unsteady flow, flow around a body, wing theory, thin airfoil theory, fundamental equation of finite-wing theory, and aerodynamic characteristics of wings. Introduces potential theory and boundary layer phenomena.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 220 [Min Grade: D]

**MEM 423 Mechanics of Vibration 4.0 Credits**
Covers free and forced vibrations of one-, two-, and multiple-degree-of-freedom systems; continuous systems; and transient and random vibration problems. Includes use of digital computer for homework and special class problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 238 [Min Grade: D] and (TDEC 222 [Min Grade: D] or ENGR 232 [Min Grade: D] or MATH 210 [Min Grade: D] or MATH 262 [Min Grade: D])

**MEM 424 Biomechanics 3.0 Credits**
Introduces modeling of dynamics of biomechanical systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 202 [Min Grade: D] and MEM 238 [Min Grade: D]

**MEM 425 Aircraft Design & Performance 3.0 Credits**
Introduces aerodynamics and airfoils; steady flight; power required and power available curves; range and endurance; takeoff, glide, and landing; stick force and control-free stability; moment coefficients and derivatives; and designing to specification. Students must have Junior class standing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**MEM 426 Aerospace Structures 3.0 Credits**
Covers properties of wing and fuselage sections, torsion of thin-walled and skin-stringer multiple-cell sections, non-symmetrical bending of wing and fuselage sections, shear in thin-walled and skin-stringer sections, and buckling. Introduces matrix methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 230 [Min Grade: D]

**MEM 427 Finite Element Methods 3.0 Credits**
Introduces the fundamental theory and formulations of finite element method and its application in structural mechanics and thermal/fluid science. Topics include formulation of 1-D and 2-D elements, isoparametric elements, static and dynamic analysis of trusses, beams, and frames, 2-D plane problems, and heat transfer problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 230 [Min Grade: D]

**MEM 428 Introduction to Composites I 3.0 Credits**
Introduces anisotropic elasticity, lamina stiffness and compliance, plane stress and strain, test methods, and failure criteria.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 330 [Min Grade: D]

**MEM 429 Introduction to Composites II 3.0 Credits**
Covers laminated plate theory, stiffness and compliance of laminated plates, effect of laminated configuration on elastic performance, and strength production.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 428 [Min Grade: D]

**MEM 430 Advanced Stress Analysis 4.0 Credits**
Examines three-dimensional representation of stress and strain, coordinate transformation, stress strain relationships for anisotropic and isotropic materials, equilibrium equations, boundary value problems, governing equations in plane strain and plane stress problems, Airy's stress function, two-dimensional problems in polar coordinates, and selected applications to stress analysis problems in mechanical engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 330 [Min Grade: D]

**MEM 431 Machine Design I 3.0 Credits**
Covers static strength and fatigue theories of failure, fasteners, welded joints, springs, roller bearings, and lubricated spur gears.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Junior or Pre-Junior or Sophomore
**Prerequisites:** MEM 202 [Min Grade: D] and MEM 230 [Min Grade: D] and MEM 238 [Min Grade: D]

**MEM 435 Introduction to Computer-Aided Design and Manufacturing 4.0 Credits**
Covers fundamental use of CAD/CAM systems for geometry definition, finite element applications, and introductory computer graphics concepts.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.
**Prerequisites:** MEM 201 [Min Grade: D]

**MEM 436 Introduction to Computer-Aided Manufacturing 3.0 Credits**
Examination of the basic elements that are used to integrate the design
and manufacturing processes. Robotics computerized-numerical
controlled machine, and CAD/CAM systems. Manufacturability
considerations when integrating unit process elements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 201 [Min Grade: D] and MEM 435 [Min Grade: D]

**MEM 437 Manufacturng Process I 3.0 Credits**
Examines the basic elements used to integrate the design and
manufacturing processes; robotics, computerized-numerical-controlled
machines, and CAD/CAM systems; and manufacturability considerations
when integrating unit process elements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 220 [Min Grade: D] and MEM 230 [Min Grade: D]

**MEM 438 Manufacturing Process II 3.0 Credits**
Covers plastics and reinforced plastics processes, theory of polymer and
plastic process, simple models of polymer flows, and manufacturability of
plastics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 437 [Min Grade: D]

**MEM 440 Thermal Systems Design 3.0 Credits**
This course covers fundamentals of thermal system design; the role of
design in engineering practice; economic analysis used for design of
thermal systems; advanced concepts and analysis of heat exchangers
and distillation equipment; modeling of thermal systems; simulation of
thermal systems; fundamentals of optimization and design of optimized
thermal systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 345 [Min Grade: D]

**MEM 444 Biofluid Mechanics 3.0 Credits**
This course introduces flow-related anatomy and pathophysiology, and
biomedical flow devices and their design challenges. Analysis methods
to solve biological fluid mechanics design problems are introduced
and several interdisciplinary team projects are assigned to apply fluid
mechanics to practical biological or medical problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 220 [Min Grade: D] or BMES 451 [Min Grade: D]

**MEM 445 Solar Energy Fundamentals 3.0 Credits**
This course focuses on basic theories of solar radiation, solar thermal
energy, and photovoltaics. Students will learn basic radiation heat
transfer, solar radiation, solar thermal collection and storage, passive
and active solar heating/cooling, physics of photovoltaic cells, and
characteristics and types of solar cells.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 345 [Min Grade: C] and PHYS 201 [Min Grade: C]

**MEM 446 Fundamentals of Plasmas I 3.0 Credits**
Introduces the fundamentals of plasma science and modern industrial
plasma applications in electronics, fuel conversion, environmental control,
chemistry, biology, and medicine. Topics include quasi-equilibrium and
non-equilibrium thermodynamics, statistics, fluid dynamics and kinetics of
plasma and other modern high temperature and high energy systems and
processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 201 [Min Grade: D] or TDEC 201 [Min Grade: D] or
PHYS 112 [Min Grade: D] or PHYS 187 [Min Grade: D]

**MEM 447 Fundamentals of Plasmas II 3.0 Credits**
Continues the development of the engineering fundamentals of plasma
discharges applied in modern industrial plasma applications in electronics,
fuel conversion, environmental control, chemistry, biology, and medicine.
Topics include quasi-equilibrium and non-equilibrium thermodynamics,
statistics, fluid dynamics of major thermal and non-thermal plasma
discharges, operating at low, moderate and atmospheric pressures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 446 [Min Grade: D]

**MEM 448 Applications of Thermal Plasmas 3.0 Credits**
Introduces applications of modern thermal plasma processes focused
on synthesis of new materials, material treatment, fuel conversion,
environmental control, chemistry, biology, and medicine. Topics Include
thermodynamics and fluid dynamics of high temperature plasma
processes, engineering organization of specific modern thermal plasma
technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 201 [Min Grade: D] or TDEC 201 [Min Grade: D] or
PHYS 112 [Min Grade: D] or PHYS 187 [Min Grade: D]

**MEM 449 Applications of Non-Thermal Plasmas 3.0 Credits**
Application of modern non-thermal plasma processes focused on
synthesis of new materials, material treatment, fuel conversion,
environmental control, chemistry, biology, and medicine. Topics Include
non-equilibrium thermodynamics and fluid dynamics of cold temperature
plasma processes, engineering organization of specific modern non-
thermal plasma technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PHYS 201 [Min Grade: D] or TDEC 201 [Min Grade: D] or
PHYS 112 [Min Grade: D] or PHYS 187 [Min Grade: D]

**MEM 453 Aircraft Flight Dynamics & Control I 3.0 Credits**
Covers general equations of motion for aircraft; linearization based on
small disturbance theory and modal analysis to identify longitudinal
open-loop characteristics; review of classical control theory; state space
analysis; and autopilot design, including classical, pole placement, and
optimal.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 355 [Min Grade: D]

**MEM 454 Aircarft Flight Dynamics & Control II 3.0 Credits**
Covers observers; lateral dynamics; Dutch roll, roll convergence, and spiral modes; autopilot design and evaluations; and inertial cross-coupling computer simulation and analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 453 [Min Grade: D]

**MEM 455 Introduction to Robotics 4.0 Credits**
Introduces basic concepts in robot operation and structure, including actuators, sensors, mechanical components, robot control and robot programming.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 238 [Min Grade: D] and MEM 255 [Min Grade: D]

**MEM 456 Robotics II 3.0 Credits**
Covers homogeneous kinematics of robots; velocities and accelerations; and static forces in manipulators, including iterative Newton-Euler formulation of manipulator dynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 455 [Min Grade: D]

**MEM 457 Robotics III 3.0 Credits**
Covers robotic-based automated manufacturing, including robot work cell configurations, applications of robots in manufacturing, material transfer, assembly, and inspection.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** MEM 456 [Min Grade: D]

**MEM 458 Micro-Based Control Systems I 3.0 Credits**
Provides hands-on experience in real-time control and manipulation of hardware dynamic systems, including microcomputer, architecture, software, and device drivers. Emphasizes real-time interfacing of data acquisition and control systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 355 [Min Grade: D]

**MEM 459 Control Applications of DSP Microprocessors 3.0 Credits**
Continues MEM 458. Provides real-time control and manipulation of hardware dynamic systems. Emphasizes real-time interfacing of data acquisition and control systems. Topics include Code Composer Studio, Microprocessor C programming, Pulse width modulation (PWM), Quadrature encoder pulse (QEP) circuits, DSP system control and interrupts, Digital loop systems, design of PID digital controllers, design of digital controllers in state space, microcomputer controller implementation, sensors and actuators, and implementation of digital controllers in microprocessors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman
**Prerequisites:** MEM 458 [Min Grade: D]

**MEM 462 [WI] Introduction to Engineering Management 3.0 Credits**
Introduces the general theory of management, including the processes of planning, organizing, assembling resources, supervising, and controlling. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Junior or Senior.

**MEM 475 Medical Robotics I 3.0 Credits**
Use of robots in surgery, safety considerations, understanding robot kinematics, analysis of surgeon performance using a robotic devices, inverse kinematics, velocity analysis, acceleration analysis, various types of surgeries case study.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 238 [Min Grade: D]

**MEM 476 Medical Robotics II 3.0 Credits**
Force and movement for robot arms, robot dynamics, computer vision, vision based control, combining haptics, vision and robot dynamics in a cohesive framework for the development of a medical robotic system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 475 [Min Grade: D]

**MEM 477 Haptics for Medical Robotics 3.0 Credits**
Introduction to haptics, physiology of touch, actuators, sensors, non-portable force feedback, portable voice feedback, tactile feedback interfaces, haptic sensing and control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 238 [Min Grade: D]

**MEM 478 Computer-Aided Tissue Engr 3.0 Credits**
Introduction to the engineering aspects of tissue reengineering and integrated CAD/CAE/CAM technology applied to tissue engineering with hands-on experience combing CAD, medical image processing, 3-D reconstruction software, and solid freeform fabrication of tissue scaffolding.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**MEM 491 [WI] Senior Design Project I 3.0 Credits**
Introduces the design process, including information retrieval, problem definition, proposal writing, patents, and design notebooks. Includes presentations on problem areas by experts from industry, government, and education. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** MEM 230 [Min Grade: D] and MEM 238 [Min Grade: D] and MEM 355 [Min Grade: D] and MEM 345 [Min Grade: D]

**MEM 492 [WI] Senior Design Project II 3.0 Credits**
Continues MEM 491. Requires written and oral progress reports. This is a
writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** MEM 491 [Min Grade: D]

**MEM 493 [WI] Senior Design Project III 3.0 Credits**
Continues MEM 492. Requires written and oral final reports, including oral
presentations by each design team at a formal Design Conference open
to the public and conducted in the style of a professional conference. This
is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** MEM 492 [Min Grade: D]

# Minor in Nuclear Engineering

The minor assumes that students will have a background in mathematics
and physics equivalent to that covered in the first two years of the
engineering curriculum. Specifically, students are required to complete
the following pre-requisites: PHYS 101 Fundamentals of Physics I ;
PHYS 102 Fundamentals of Physics II; PHYS 201 Fundamentals of
Physics III; ENGR 210 Introduction to Thermodynamics and ENGR 220
Fundamentals of Materials. Courses taken to meet these prerequisite
requirements will not count toward the minor.

#### Required Courses

| | | |
|---|---|---|
| ECEP 402 | Theory of Nuclear Reactors | 4.0 |
| ECEP 372 | Radiation Detection and Measurement | 3.0 |
| ECEP 404/MEM 371 | Introduction to Nuclear Engineering | 2.0 |
| ECEP 406 | Introduction to Radiation Health Principles | 3.0 |
| MATE 450 | The Nuclear Fuel Cycle & Materials | 3.0 |
| PHYS 330 | Introduction to Nuclear Physics | 2.0 |
| Select 9.0 credits from at least two of the following principal areas | | 9.0 |
| **Industrial Applications Electives** | | |
| ECEP 403 | Nuclear Power Plant Design & Operation | |
| MEM 402 | Power Plant Design | |
| MEM 448 | Applications of Thermal Plasmas | |
| MEM 449 | Applications of Non-Thermal Plasmas | |
| **Power Engineering Electives** | | |
| ECEP 352 | Electric Motor Control Principles | |
| ECEP 354 | Energy Management Principles | |
| ECEP 411 | Power Systems I | |
| ECEP 412 | Power Systems II | |
| **Nuclear & Thermal Engineering & Science Electives** | | |
| MEM 446 | Fundamentals of Plasmas I | |
| MEM 447 | Fundamentals of Plasmas II | |
| **Materials Electives** | | |
| MATE 221 | Introduction to Mechanical Behavior of Materials | |
| MATE 341 | Defects in Solids | |
| MATE 355 | Structure and Characterization of Crystalline Materials | |
| MATE 370 | Mechanical Behavior of Solids | |
| **Transport Phenomena Electives** | | |
| CHE 302 | Process Fluid Mechanics | |
| CHE 303 | Process Heat Transfer | |
| CHE 310 | Transport Phenomena | |
| CHE 311 | Fluid Flow and Transport | |
| CIVE 320 | Introduction to Fluid Flow | |
| MEM 220 | Basic Fluid Mechanics | |
| MEM 345 | Heat Transfer | |
| **Simulation Electives** | | |
| PHYS 105 | Computational Physics I | |
| PHYS 305 | Computational Physics II | |
| PHYS 405 | Advanced Computational Physics | |
| **Total Credits** | | **26.0** |

The Nuclear Engineering minor is open to all engineering majors. The
minor consists of a minimum of six required courses for 17.0 credits and
an additional 9.0 credits of elective courses.

Additional information about the minor is available on the
ECE Department website (http://www.ece.drexel.edu/
Undergraduate_Programs2.html) .

For advising questions, please e-mail advising@ece.drexel.edu
(%20advising@ece.drexel.edu) .

To make an appointment, please call 215.895.2241
Drop-in hours: Please e-mail advising@ece.drexel.edu
(%20advising@ece.drexel.edu) for up-to-date drop-in availability.

# Property Management

*Bachelor of Science Degree: 180.0 quarter credits*

## About the Program

Drexel's Bachelor of Science in Property Management provides
an interdisciplinary education necessary for success in the ever-
expanding and complex field of real estate management. The curriculum
consists of courses that will equip students with a solid foundation in
property management and real estate along with specialized courses
in construction management business and property law; presentation
and promotion; accounting; and finance. In addition, students complete
courses that will lead to a minor in Business Administration. The
curriculum also includes a six-month co-op experience that partners
classroom knowledge with experiential learning to develop the requisite
skills students will need to succeed as professionals.

For additional information, visit the Property Management site.

## Degree Requirements

#### General Education Requirements

| | | |
|---|---|---|
| ANTH 101 | Introduction to Cultural Diversity | 3.0 |
| COM 111 | Principles of Communication | 3.0 |
| COM 230 | Techniques of Speaking | 3.0 |
| COM 280 | Public Relations Principles and Theory | 3.0 |
| or COM 345 | Intercultural Communication | |

| ENGL 101 | Composition and Rhetoric I: Inquiry and Exploratory Research | 3.0 |
|---|---|---|
| ENGL 102 | Composition and Rhetoric II: The Craft of Persuasion | 3.0 |
| ENGL 103 | Composition and Rhetoric III: Thematic Analysis Across Genres | 3.0 |
| Select one of the following sequences: | | 8.0-9.0 |
| MATH 101 & MATH 102 | Introduction to Analysis I and Introduction to Analysis II | |
| MATH 181 & MATH 182 & MATH 183 | Mathematical Analysis I and Mathematical Analysis II and Mathematical Analysis III | |
| PHYS 182 | Applied Physics I | 3.0 |
| Natural Science Electives * | | 6.0 |
| PSY 101 | General Psychology I | 3.0 |
| SOC 101 | Introduction to Sociology | 3.0 |
| UNIV G101 | The Drexel Experience | 2.0 |
| Humanities and Social Science Electives ** | | 9.0 |
| **Minor in Business Administration ***** | | |
| ACCT 115 | Financial Accounting Foundations | 4.0 |
| BLAW 201 | Business Law I | 4.0 |
| FIN 301 | Introduction to Finance | 4.0 |
| MKTG 301 | Introduction to Marketing Management | 4.0 |
| ORGB 300 [WI] | Organizational Behavior | 4.0 |
| STAT 201 | Introduction to Business Statistics | 4.0 |
| **Property Management Core** | | |
| CAT 302 | Customer Service Theory and Practice | 3.0 |
| CMGT 262 | Building Codes | 3.0 |
| CRTV 301 | Foundations in Creativity | 3.0 |
| REAL 310 | Introduction to Real Estate | 3.0 |
| PROJ 301 | Introduction to Project Management | 3.0 |
| PRST 211 | Computer Applications for Professionals | 3.0 |
| PRMT 110 | Introduction to Property Management | 3.0 |
| PRMT 210 | Rental Property & Fair Housing Law | 3.0 |
| PRMT 215 | Building Systems for PRMT I | 3.0 |
| PRMT 216 | Building Systems for PRMT II | 3.0 |
| PRMT 225 | Technical Drawings for Property Managers | 3.0 |
| PRMT 310 | Property Financing & Valuation | 3.0 |
| PRMT 315 | Property Risk Management | 3.0 |
| PRMT 320 | Sustainable Property Management | 3.0 |
| PRMT 325 | Human Resource Strategies - Property Management | 3.0 |
| PRMT 330 | Property Management Technology | 3.0 |
| PRMT 333 | Social Responsibility for Property Managers | 3.0 |
| PRMT 491 | Senior Project in Property Management | 3.0 |
| **Free Electives** | | 32.0 |
| Suggested Electives | | |
| BACS 200 | Foundation of Behavioral Health Care | |
| CAT 201 [WI] | Interpersonal Communication | |
| CAT 360 | Applied Organizational Research | |
| CMGT 263 | Understanding Construction Drawings | |
| CRTV 302 | Tools and Techniques in Creativity | |
| CRTV 303 | Creativity in the Workplace | |

| DSMR 231 | Retail Principles | |
|---|---|---|
| HSAD 316 | Health Care across Cultures | |
| HSAD 323 | Health Services and the Elderly | |
| PHIL 323 | Organizational Ethics | |
| PRMT 340 | Managing and Marketing for Retail Properties | |
| PRMT 345 | Managing & Marketing Housing for an Aging Population | |
| PRMT 350 | Affordable Housing Management | |
| PRMT 356 | Military Housing Management | |
| PRMT 360 | Managing & Marketing for Commercial Properties | |
| PRMT 365 | Commercial Property Appraisal | |
| PRMT 380 | Special Topics in PRMT | |
| PRMT 399 | Independent Study in Property Management | |
| PRST 450 | Creative Leadership for Professionals | |
| SOC 120 | Sociology of the Family | |
| SOC 210 | Race and Ethnic Relations | |
| SOC 240 | Urban Sociology | |
| **Concentration Requirement** | | 15.0-16.0 |
| **Total Credits** | | **180.0-182.0** |

\*    Students select 6.0 credits from the following: ANAT, BIO, CHEM, ENVR, FDSC, NFS, PHEV, PHYS. Courses from other departments may be considered with advisor approval.

\*\*    Anthropology, African-American studies, fine arts (history of architecture, art, film, music, theatre) foreign language, history, linguistics, literature, philosophy, political science, psychology, sociology, women's studies, writing, etc.

\*\*\*    No more than 2 transferred courses may be used to complete the Minor in Business. A grade of C (2.0) or better must be earned in each course in the Minor in Business.

## Concentrations

### Residential Property Management Concentration

| PRMT 335 | Marketing and Leasing for Residential Properties | 3.0 |
|---|---|---|
| Select four of the following: | | 12.0 |
| PRMT 340 | Managing and Marketing for Retail Properties | |
| PRMT 345 | Managing & Marketing Housing for an Aging Population | |
| PRMT 350 | Affordable Housing Management | |
| PRMT 355 | Student Housing Management | |
| PRMT 356 | Military Housing Management | |
| **Total Credits** | | **15.0** |

### Housing for an Aging Population Concentration

| HSAD 323 | Health Services and the Elderly | 3.0 |
|---|---|---|
| NURS 370 | Issues in Aging and Longevity | 4.0 |
| PRMT 335 | Marketing and Leasing for Residential Properties | 3.0 |
| PRMT 345 | Managing & Marketing Housing for an Aging Population | 3.0 |
| SOC 125 | Sociology of Aging | 3.0 |
| **Total Credits** | | **16.0** |

**Affordable Housing Administration Concentration**

| | | |
|---|---|---|
| HSAD 323 | Health Services and the Elderly | 3.0 |
| PRMT 335 | Marketing and Leasing for Residential Properties | 3.0 |
| PRMT 350 | Affordable Housing Management | 3.0 |
| SOC 210 | Race and Ethnic Relations | 3.0 |
| SOC 240 | Urban Sociology | 3.0 |
| **Total Credits** | | **15.0** |

**Commercial Property Management Concentration**

| | | |
|---|---|---|
| PRMT 340 | Managing and Marketing for Retail Properties | 3.0 |
| PRMT 341 | Managing and Marketing Office Buildings | 3.0 |
| PRMT 342 | Managing and Marketing Industrial Properties | 3.0 |
| PRMT 363 | Commercial Property Financial Reports | 3.0 |
| PRMT 365 | Commercial Property Appraisal | 3.0 |
| **Total Credits** | | **15.0** |

# Minor in Property Management

A property management minor is a valuable supplement to a bachelor's degree in just about any field. Drexel's minor in Property Management is designed to provide students with the fundamentals required for real estate management. The program presents an overview of the complex responsibilities of property management — from business intelligence to human resource management to facilities and contract administration to increasing asset value.

### Required Courses

| | | |
|---|---|---|
| PRMT 110 | Introduction to Property Management | 3.0 |
| PRMT 210 | Rental Property & Fair Housing Law | 3.0 |
| PRMT 215 | Building Systems for PRMT I | 3.0 |
| PRMT 310 | Property Financing & Valuation | 3.0 |
| PRMT 315 | Property Risk Management | 3.0 |
| PRMT 325 | Human Resource Strategies - Property Management | 3.0 |
| PRMT 330 | Property Management Technology | 3.0 |
| Select one of the following: | | 3.0 |
| PRMT 216 | Building Systems for PRMT II | |
| PRMT 225 | Technical Drawings for Property Managers | |
| PRMT 335 | Marketing and Leasing for Residential Properties | |
| **Total Credits** | | **24.0** |

# Property Management Faculty

Kimberly Mitchell, PhD *(Virginia Polytechnic Institute and State University) Director, Property Management Program.* Associate Teaching Professor. Multi-family real estate operations, sustainability, affordability, and policy; asset management; real estate development.

# Courses

**PRMT 110 Introduction to Property Management 3.0 Credits**
An introduction to the multidisciplinary world of property management. This course provides an overview of facilities, construction, marketing, leadership, human resource management, finance, law, sociology, and how to interact with a variety of key stakeholders, such as property owners, investors, tenants, and the government.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 210 Rental Property & Fair Housing Law 3.0 Credits**
Rental Property Law including lease essentials, tenancies, implied warranty of habitability, security deposits, tort liability, leasehold improvements, default, eviction, landlord¿s and tenant¿s rights, duties and remedies. The course covers the basics of Fair Housing law, the Americans with Disabilities Act, and anti-discrimination law. Current issues and cases are featured.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 215 Building Systems for PRMT I 3.0 Credits**
The first of a two-course sequence addressing building systems. Covers heating, ventilating, and air-conditioning principles and practices as they relate to property management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 216 Building Systems for PRMT II 3.0 Credits**
The second of a two-course sequence addressing building systems. Covers plumbing, electrical, fire safety, telecommunications, acoustical and roofing system principles and practices as they relate to property management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 215 [Min Grade: D]

**PRMT 225 Technical Drawings for Property Managers 3.0 Credits**
This course covers reading and interpreting a variety of technical drawings and plans that relate to property management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 310 Property Financing & Valuation 3.0 Credits**
This course provides the financial tools to calculate and analyze the cash flows, tax implications and risks of various projects. Decision-making models, lease valuation, and sensitivity analysis are employed in real situations. Alternative financing choices, cost of funds, tax incentive options, capitalization rates, and current market conditions are considered.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** FIN 301 [Min Grade: D]

**PRMT 315 Property Risk Management 3.0 Credits**
This course focuses on strategies managers and owners employ to maximize protection of property and tenants and minimize exposure to liability and costs. The course includes emergency management, security, and insurance protection. Agency duties are explored including fair housing and environmental issues. The essentials of various insurance policies are presented.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 320 Sustainable Property Management 3.0 Credits**
An introduction to the study of sustainable housing where energy issues and environmental resource efficiences are considered in the planning, development, design, renovation, environmental prOtection, waste minimization, and overall management of a property. The impact of Green Property design on property management expecially facility management is featured.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 325 Human Resource Strategies - Property Management 3.0 Credits**
This course focuses on specialized strategies to successfully manage employees and subcontractors involved in property management companies and projects. A variety of areas are covered: recruiting top talent, retention, diversity policies, employee coaching, negotiations, conflict resolution, training and development, outsourcing, and housing law.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 330 Property Management Technology 3.0 Credits**
The focus of this course is the role that technology plays in the management and marketing of property. Important issues discussed include the latest software innovations, auto-pay systems, tenant website systems, software integration, communications strategy, security systems, television and data systems, and incorporating technology into a property's marketing plan.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D]

**PRMT 333 Social Responsibility for Property Managers 3.0 Credits**
The course explores application of ethics and social responsibility concepts, and challenges property managers are likely to face.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 335 Marketing and Leasing for Residential Properties 3.0 Credits**
This course covers the marketing of residential rental properties to acquire new tenants and retain existing ones. Market analysis is used as a foundation to create a marketing plan. Buyer motivation, customer service, and tenant retention strategies are discussed. Students demonstrate successful sales techniques by participating in a sales presentation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 340 Managing and Marketing for Retail Properties 3.0 Credits**
An introducation to managing and marketing retail property using shopping centers as the basis for discussion. Issues include leasing, tenant mix, tenant relations, advertising, and daily and long-term concerns. Mixed-use developments are featured and students review best practice examples and analyze and visit area shopping centers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D]

**PRMT 341 Managing and Marketing Office Buildings 3.0 Credits**
This course covers skills required for successful office building management. Topics include managing, marketing, leasing, and maintaining single office buildings and portfolios of properties. Views management of the office building as a real estate investment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D]

**PRMT 342 Managing and Marketing Industrial Properties 3.0 Credits**
This course covers skills required for successful industrial property management. Topics include managing, marketing, leasing, and maintaining single industrial properties and portfolios of industrial properties.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D]

**PRMT 345 Managing & Marketing Housing for an Aging Population 3.0 Credits**
This course covers the management and marketing of housing for later life starting with a market analysis. Students discover challenges to be overcome and opportunities available in this unique segment of the housing market. The course covers successful management and marketing strategies involving active adult communities and senior living facilities.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D]

**PRMT 350 Affordable Housing Management 3.0 Credits**
An introduction to the challenges of managing affordable housing. Managing affordable housing requires the interaction of important players: legislators, government policymakers, citizen advocacy groups, and citizens/tenants. This course features presentations from industry leaders, visits to affordable developments, and completion of an analysis paper covering the development, marketing and management process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D]

**PRMT 355 Student Housing Management 3.0 Credits**
This course focuses on the effective management of student housing. Successful student housing managers need to have specialized education in a variety of areas including federal laws, emergency management requirements, security and communications planning, marketing to the student population, town-gown relations and awareness of current cases and issues.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D]

**PRMT 356 Military Housing Management 3.0 Credits**
This course focuses on the effective management of military housing. The successful management of military housing requires specialized study in a variety of areas including federal laws, emergency management requirements, security and communications planning, military regulations, Department of Defense initiatives and regulations, and awareness of current cases and issues.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D]

**PRMT 360 Managing & Marketing for Commercial Properties 3.0 Credits**
An introduction to managing and marketing commercial property using office buildings, warehouses, medical buildings, factories and industrial properties as the basis for discussion and analysis. Issues include maintenance, marketing, location analysis, lease provisions, risk management, leasehold improvements, and government and tax incentive programs. Students discuss best practice examples and analyze and visit properties to meet industry leaders.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 110 [Min Grade: D] and FIN 301 [Min Grade: D]

**PRMT 363 Commercial Property Financial Reports 3.0 Credits**
Covers the administration, preparation, and interpretation of operating and capital budgets, profit and loss statements, balance sheets, arrears reports, vacancy reports, and collection reports. Topics include tenant charges for operating costs, calculating a lease commission, and understanding components of net operating income and cash flow.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** FIN 301 [Min Grade: D] and PRMT 110 [Min Grade: D]

**PRMT 365 Commercial Property Appraisal 3.0 Credits**
This course focuses on the fundamental concepts of real estate appraisal with an emphasis on the process of valuing commercial property. The course covers the foundations of property valuation, data collection and analysis, and alternative approaches to estimating the value of commercial properties.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 380 Special Topics in PRMT 0.5-12.0 Credits**
Covers special topics of interest in Property Management. This course may be repeated for credit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**PRMT 399 Independent Study in Property Management 1.0-6.0 Credit**
Provides individual study or research in Property Management under faculty supervision. This course may be repeated for credit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is PRMT.

**PRMT 491 Senior Project in Property Management 3.0 Credits**
In this capstone course students participate in discussions and conduct research of key issues facing property managers. A major part of the class is a community analysis project using guidelines provided by the National Apartment Association and a professional property manager as a mentor through the process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is PRMT and classification is Senior.

# Minor in Real Estate

Designed for students in various disciplines (such as architecture, business, civil engineering, architectural engineering, fashion merchandising and interior design) the minor in real estate provides the necessary knowledge, skills, and perspective to be successful in the real estate development process. Students will explore the knowledge and skill sets required to create and maintain built environments for living, working and entertainment purposes.

**Required Courses**

| | | |
|---|---|---|
| ARCH 432 | The Development Process | 3.0 |
| CMGT 468 | Real Estate | 3.0 |
| REAL 310 | Introduction to Real Estate | 3.0 |
| REAL 320 | Real Estate Law - Principle & Practice | 3.0 |
| REAL 330 | Facilities & Property Management | 3.0 |
| REAL 470 | Real Estate Investments - Market & Feasibility Analysis | 3.0 |
| Select two of the following: | | 6.0 |
| REAL 471 | Advanced Real Estate in Investment & Analysis | |
| REAL 472 | Advanced Market Research & Analysis | |
| REAL 473 | Sales & Marketing of Real Estate | |
| REAL 474 | Real Estate Economics in Urban Markets | |
| REAL 475 | Real Estate Finance | |
| REAL 476 | Real Estate Valuation & Analysis | |
| **Total Credits** | | **24.0** |

# Certificate in Affordable Housing Administration

*Certificate Level: Undergraduate*
*Admission Requirements: One year of college and two years of work experience*
*Certificate Type: Certificate*
*Number of Credits to Completion: 21.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 1 year*
*Financial Aid Eligibility: Not aid eligible*

*Note:* Effective Fall 2014, students are no longer being accepted into this certificate program.

Drexel University offers several different certificate programs in property management. These certificates are designed to provide a professional background in a specified area of property management, and to assist in career goals or prompt additional study in the field.

### Requirements

| | | |
|---|---|---|
| PRMT 110 | Introduction to Property Management | 3.0 |
| HSAD 323 | Health Services and the Elderly | 3.0 |
| PRMT 335 | Marketing and Leasing for Residential Properties | 3.0 |
| PRMT 350 | Affordable Housing Management | 3.0 |
| PRMT 345 | Managing & Marketing Housing for an Aging Population | 3.0 |
| SOC 210 | Race and Ethnic Relations | 3.0 |
| SOC 240 | Urban Sociology | 3.0 |
| **Total Credits** | | **21.0** |

# Certificate in Commercial Property Management

*Certificate Level: Undergraduate*
*Admission Requirements: One year of college and two years of work experience*
*Certificate Type: Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 1 year*
*Financial Aid Eligibility: Not aid eligible*

*Note:* Effective Fall 2014, students are no longer being accepted into this certificate program.

Drexel University offers several different certificate programs in property management. These certificates are designed to provide a professional background in a specified area of property management, and to assist in career goals or prompt additional study in the field. Depending on a student's prior educational background, the total number of credits required may be higher due to prerequisites.

### Requirements

| | | |
|---|---|---|
| PRMT 110 | Introduction to Property Management | 3.0 |
| PRMT 340 | Managing and Marketing for Retail Properties | 3.0 |
| PRMT 341 | Managing and Marketing Office Buildings | 3.0 |
| PRMT 342 | Managing and Marketing Industrial Properties | 3.0 |
| PRMT 363 | Commercial Property Financial Reports | 3.0 |
| PRMT 365 | Commercial Property Appraisal | 3.0 |
| **Total Credits** | | **18.0** |

# Certificate in Construction Management

*Certificate Level: Undergraduate*
*Admission Requirements:*
*Certificate Type: Certificate*
*Number of Credits to Completion: 18.0 - 19.0*

*Instructional Delivery: Campus, Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 1 year*
*Financial Aid Eligibility: Not aid eligible*

## Construction Management I - Fundamentals

*18.0 quarter credits*

The Construction Management I - Fundamentals Certificate introduces students to the basic concepts of the construction industry.

Students interested in continuing their education after certification are able to apply their coursework and credits directly to the Bachelor of Science in Construction Management (http://www.drexel.edu/catalog/ug/goodwin/cmgt-).

### Requirements

| | | |
|---|---|---|
| CMGT 101 | Introduction to Construction Management | 3.0 |
| CMGT 161 | Building Materials and Construction Methods I | 3.0 |
| CMGT 162 | Building Materials and Construction Methods II | 3.0 |
| CMGT 163 | Building Materials and Construction Methods III | 3.0 |
| CMGT 261 | Construction Safety | 3.0 |
| CMGT 263 | Understanding Construction Drawings | 3.0 |
| **Total Credits** | | **18.0** |

## Construction Management II - Construction Science

*18.0 quarter credits*

The Construction Management II - Construction Science Certificate focuses on introducing students to design concepts relating to heating, ventilation, and air conditioning systems and the integration of these systems into the construction process. In addition, the certificate also covers the process of estimating as well as building codes involved in construction projects.

Students interested in continuing their education after certification are able to apply their coursework and credits directly to the Bachelor of Science in Construction Management (http://www.drexel.edu/catalog/ug/goodwin/cmgt-).

### Requirements

| | | |
|---|---|---|
| CMGT 266 | Building Systems I | 3.0 |
| CMGT 267 | Building Systems II | 3.0 |
| CMGT 363 | Estimating I | 3.0 |
| CMGT 364 | Estimating II | 3.0 |
| Select two of the following: | | 6.0 |
| CMGT 262 | Building Codes | |
| CMGT 264 | Construction Management of Field Operations | |
| CMGT 265 | Information Technologies in Construction | |
| **Total Credits** | | **18.0** |

## Construction Management III - Management Concepts

*19.0 quarter credits*

The Construction Management III - Management Concepts Certificate focuses on construction contracts, specifications, and practices with

regard to business law and liability. The certificate also covers value engineering and construction planning, scheduling, network systems, as well as the communications required for project control and claims prevention.

Students interested in continuing their education after certification are able to apply their coursework and credits directly to the Bachelor of Science in Construction Management (http://www.drexel.edu/catalog/ug/goodwin/cmgt-).

**Requirements**

| | | |
|---|---|---|
| CMGT 361 | Contracts And Specifications I | 3.0 |
| CMGT 362 | Contracts and Specifications II | 3.0 |
| CMGT 461 | Construction Management | 3.0 |
| CMGT 463 | Value Engineering | 3.0 |
| CMGT 465 | Marketing Construction Services | 3.0 |
| CMGT 467 | Techniques of Project Control | 4.0 |
| **Total Credits** | | **19.0** |

## Construction Management IV - Customized Independent

*18.0 quarter credits*

The Construction Management IV - Customized Independent Certificate is designed to allow students to choose the higher-level courses that best suit their special needs and interests. Students must select all six of their courses at the start of the Certificate program.

Students interested in continuing their education after certification are able to apply their coursework and credits directly to the Bachelor of Science in Construction Management (http://www.drexel.edu/catalog/ug/goodwin/cmgt-).

**Requirements**

| | |
|---|---|
| A minimum of six (6) 300-level or higher approved CMGT courses * | 18.0 |

\*    CIVE and CAEE majors may not include CMGT 371 or CMGT 372.

## Construction Management Faculty

Jeffrey Beard, PHD, MGTPRO *(Georgia Institute of Technology)*. Associate Clinical Professor. Project delivery methodologies; Systems decomposition for civil and industrial projects; Service Life Predictors for the Built Environment and its Components; Design and Construction Entrepreneurship; History of Urban Engineering and ConstructionHistory of Urban Engineering and Construction.

Douglas Carney, MBA, AIA, LEED, AP *(Eastern University)*. Assistant Clinical Professor. Architecture; Contract management; Master planning; Site analysis; Feasibility and zoning studies; Space needs and program development.

Charles Cook, PhD *(New York University)*. Assistant Clinical Professor. Construction management; project management; leadership and teambuilding; oral and written communication.

Edward Keeter, PhD *(Texas A&M University)*. Associate Clinical Professor. Integrated project management; Construction risk management; Construction management; Management of field operations.

Robert Muir, PhD, PE *(Drexel University) Program Director*. Associate Clinical Professor. Construction management; value engineering; management of field operations; planning and scheduling; project management; heavy and industrial construction.

Richard Sievert, PhD, PMP, CFM *(Northwestern University)*. Assistant Clinical Professor. Project management and construction management; value engineering; cost reduction and waste minimization; facilities planning and management; marketing and selling professional services; quality management, engineering and construction business administration.

# Certificate in the Fundamentals of Property Management

*Certificate Level: Undergraduate*
*Admission Requirements: One year of college and two years of work experience*
*Certificate Type: Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 1 year*
*Financial Aid Eligibility: Aid eligible*

*Note:* Effective Fall 2014, students are no longer being accepted into this certificate program.

The fundamentals of property management certificate is designed to provide students with the basic competencies required for the management of residential and commercial real estate. This certificate presents a comprehensive overview of the multidisciplinary responsibilities of the professional property manager, from leasing a rental unit to maintaining the physical plant.

**Requirements**

| | | |
|---|---|---|
| PRMT 110 | Introduction to Property Management | 3.0 |
| PRMT 210 | Rental Property & Fair Housing Law | 3.0 |
| PRMT 215 | Building Systems for PRMT I | 3.0 |
| PRMT 225 | Technical Drawings for Property Managers | 3.0 |
| PRMT 330 | Property Management Technology | 3.0 |
| Select one of the following: | | 3.0 |
| PRMT 216 | Building Systems for PRMT II | |
| PRMT 335 | Marketing and Leasing for Residential Properties | |
| **Total Credits** | | **18.0** |

# Certificate in Housing for an Aging Population

*Certificate Level: Undergraduate*
*Admissions Requirements: One year of college and two years of work experience*
*Certificate Type: Certificate*
*Number of Credits to Completion: 19.0*
*Instructional Delivery: Campus*
*Calendar Type: Quarter*
*Expected Time to Completion: 1 year*
*Financial Aid Eligibility: Not aid eligible*

*Note:* Effective Fall 2014, students are no longer being accepted into this certificate program.

Drexel University offers several different certificate programs in property management. These certificates are designed to provide a professional background in a specified area of property management, and to assist in career goals or prompt additional study in the field.

**Requirements**

| HSAD 323 | Health Services and the Elderly | 3.0 |
|---|---|---|
| NURS 370 | Issues in Aging and Longevity | 4.0 |
| PRMT 110 | Introduction to Property Management | 3.0 |
| PRMT 335 | Marketing and Leasing for Residential Properties | 3.0 |
| PRMT 345 | Managing & Marketing Housing for an Aging Population | 3.0 |
| SOC 125 | Sociology of Aging | 3.0 |
| **Total Credits** | | **19.0** |

# Certificate in Residential Property Management

*Certificate Level: Undergraduate*
*Admission Requirements: One year of college and two years of work experience*
*Certificate Type: Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 1 year*
*Financial Aid Eligibility: Not aid eligible*

*Note:* Effective Fall 2014, students are no longer being accepted into this certificate program.

Drexel University offers several different certificate programs in property management. These certificates are designed to provide a professional background in a specified area of property management, and to assist in career goals or prompt additional study in the field.

**Requirements**

| PRMT 110 | Introduction to Property Management | 3.0 |
|---|---|---|
| PRMT 335 | Marketing and Leasing for Residential Properties | 3.0 |
| Select four of the following: | | 12.0 |
| PRMT 340 | Managing and Marketing for Retail Properties | |
| PRMT 345 | Managing & Marketing Housing for an Aging Population | |
| PRMT 350 | Affordable Housing Management | |
| PRMT 355 | Student Housing Management | |
| PRMT 356 | Military Housing Management | |
| **Total Credits** | | **18.0** |

# The College of Engineering

## About the College

The College of Engineering prepares a new generation of engineers dedicated to discovery and the application of technology to promote economic development and improve quality of life.

Drexel University's College of Engineering is guided by five core values that shape the curriculum and experience for all students: excellence in academics and research; personal, intellectual and professional development; diversity; innovation and exploration; internal and external collaborations and partnerships. We provide a research agenda for our PhD students that addresses society's most pressing challenges regionally, nationally and globally. Our Master of Science students are trained in strategic leadership and entrepreneurial risk-taking to address the opportunities and challenges of a rapidly changing industry. The graduate programs at Drexel College of Engineering integrate evolving engineering science with the growing fields of engineering applications and processes. As Drexel moves though the 21st century, the College of Engineering will continue to offer students a diverse academic learning and research environment, while continuing to build on its national reputation for excellence in engineering and research.

## Majors

- Architectural Engineering (MS, PhD)
- Chemical Engineering (MS, PhD)
- Civil Engineering (MS, PhD)
- Computer Engineering (MS)
- Construction Management (MS)
- Cybersecurity (MS)
- Electrical Engineering (MS, PhD)
- Engineering (ME)
- Engineering Management (MS) *
- Engineering Technology (MS)
- Environmental Engineering (MS, PhD)
- Materials Science and Engineering (MS, PhD)
- Mechanical Engineering (MS, PhD)
- Project Management (MS)
- Property Management (MS)
- Systems Engineering (MS)
- Telecommunications Engineering (MS)

## Certificates

- Construction Management
- Engineering Management
- Power Engineering Management
- Real Estate
- Sustainability and Green Construction
- Systems Design and Development
- Systems Engineering Analysis
- Systems Engineering Fundamentals

- Systems Engineering Integrated Logistics
- Systems Reliability Engineering

\* Multidisciplinary program, offered in concert with other Drexel University Colleges.

## About Graduate Co-op

Drexel University's long tradition in the field of experiential learning has now been extended into many of its master's programs in science, business, and engineering.

This option, called the Graduate Co-op Program (http://www.drexel.edu/scdc/gcp.asp) (GCP), provides students with the opportunity to gain work experience directly related to their career goals while earning academic credit. Students who have earned a minimum of 24 credits with a GPA of at least 3.0 are eligible to participate. Employment typically lasts six months, during which students enroll in a special 3 credit GCP course coinciding with their term of employment. Students gain work experience while earning salaries. It is important to note that the GCP program does not guarantee a job. It is a market-driven process for the candidates as well as employers. GCP provides the tools and contacts; the student must qualify for the job on the basis of merit, qualifications, and skills.

Further information on the GCP program is available at the Drexel Steinbright Career Development Center. (http://www.drexel.edu/scdc)

# Architectural Engineering

## About the Program

*Master of Science in Architectural Engineering: 45.0 quarter credits*
*Doctor of Philosophy in Architectural Engineering: 90.0 quarter credits*

Architectural Engineering is inherently an interdisciplinary enterprise that is centered on the design, construction, and operation of the built environment. Architectural Engineering MS or PhD graduates may include students with expertise in one or more of the following sub-disciplines (usually housed in civil/environmental engineering and elsewhere in traditional disciplinary constructs or newly developing fields of focus or expertise):

1. Building energy efficiency and alternative energy
2. Indoor environmental quality

Our graduates are engineers and researchers trained in integrated building design and operation practices, who can work on interdisciplinary teams that are able to develop creative solutions combined with technological advances to produce functional, efficient, attractive and sustainable building infrastructure.

## Admission Requirements

Applicants to the MS or PhD in Architectural Engineering must meet the following requirements:

- A BS in Engineering OR
- For students without an Engineering degree, the following courses, or their approved equivalents from other departments, will meet these requirements:
  - Fundamental Fluids – CIVE 320
  - Thermodynamics – ENGR 210
  - Heat Transfer – MEM 345 – for Building Energy students

- Basic Chemistry – CHEM 102 – for Indoor Environmental Quality students

The application package will include:

- undergraduate and graduate transcripts;
- three letters of recommendation from faculty or professionals who can evaluate the applicant's promise as a graduate student;
- GRE scores;
- a written statement of career and educational goals.

Competitive applicants will possess an undergraduate GPA of 3.30 or higher and GRE scores above the 60th percentile.

# Master of Science in Architectural Engineering

## Degree Requirements

*45.0 quarter credits*

The goal of the MS in Architectural Engineering (AE) is to produce graduates who have a solid understanding of the Architectural Engineering discipline as well as an understanding of the interrelationships between the major AE sub-disciplines. Graduates will have demonstrated the ability and capacity to apply that understanding and skill, and the curriculum and project requirements are designed to provide to the students and then ask them to demonstrate the ability to effectively engage in professional-level performance.

**Required Courses**

| Core Courses for all AE students | | |
|---|---|---|
| AE 510 | Intelligent Buildings | 3.0 |
| AE 550 | Comfort Analysis and Indoor Air Quality | 3.0 |
| AE 544 | Building Envelope Systems | 3.0 |
| AE 551 | Building Energy Systems I | 3.0 |
| MEM 591 | Applied Engr Analy Methods I | 3.0 |
| MEM 592 | Applied Engr Analy Methods II | 3.0 |
| **Building Energy Theme** | | |
| Complete three of the following: | | 9.0 |
| AE 552 | Building Energy Systems II | |
| CHE 513 | Chemical Engineering Thermodynamics | |
| CHE 525 | Transport Phenomena I | |
| MEM 611 | Conduction Heat Transfer | |
| MEM 612 | Convection Heat Transfer | |
| MEM 621 | Foundations of Fluid Mechanics | |
| **Indoor Air Quality (IAQ) Theme** | | |
| Complete three of the following: | | 9.0 |
| AE 790 | Special Topics [*] | |
| CHE 525 | Transport Phenomena I | |
| ENVE 560 | Fundamentals of Air Pollution Control | |
| ENVE 660 | Chemical Kinetics in Environmental Engineering | |
| ENVS 501 | Chemistry of the Environment | |
| MEM 621 | Foundations of Fluid Mechanics | |
| Additional Electives [**] | | 9.0 |
| **Total Credits** | | **45.0** |

[*] Indoor Modeling and Field Measurements.

[**] The balance of the required 45.0 credits, a maximum of 18.0 credits, will be electives approved by the student's advisor and the departmental graduate advisor.

# PhD in Architectural Engineering

## Degree Requirements

*90.0 quarter credits*

The following general requirements must be satisfied in order to complete the PhD in Architectural Engineering:

- 90.0 quarter credit hours total (or 45 credit hours post-MS)
- Plan of study established with Advisor
- Qualifying courses
- Candidacy exam
- Approval of dissertation proposal
- Defense of dissertation
- Full-time residency for one continuous academic year is usually desired for the PhD degree to ensure students the opportunity for intellectual association with other scholars.

Students entering with a master's degree may be exempted from some or all of the courses in the breadth requirement; however, they are still required to meet all milestones of the program. Individual courses may also be transferred with approval of the Graduate Advisor. The total credit amount, candidacy exam, and dissertation are University Requirements. Additional requirements are determined by the department offering the degree.

| MSAE coursework plus research and courses defined by the dissertation Committee | 90.0 |
|---|---|

## Qualifying Courses

To satisfy the qualifying requirements, students must earn a grade of B+ or better in the first 6 Architectural Engineering graduate courses taken at Drexel, and must earn an overall GPA of 3.5 or better in these courses. Normally these courses comprise at least 4 "core" courses and either 2 more courses, either "core" or in one of the Architectural Engineering themes taken as part of the PhD program; however, they may in some cases include more advanced courses (e.g., if the student has received transfer credit for a core course).

Undergraduate courses, independent studies, research credits, and courses from other departments cannot be counted toward the qualifying requirements. Student progress toward these requirements will be assessed in the Annual Review following the student's first year in the PhD program. For more information visit the Department's PhD Program Requirements page.

## Candidacy Exam

After approximately one year of study beyond the master's degree, doctoral students take a candidacy examination, consisting of written and oral parts. The Architectural Engineering candidacy examination serves to define the student's research domain and to evaluate the student's knowledge and understanding of various fundamental and seminal results in that domain. At this point the student is expected to be able to read, understand, analyze, and explain advanced technical results in a specialized area of Architectural Engineering at an adequate level of

detail. The candidacy examination will evaluate those abilities using a defined set of published manuscripts. The student will prepare a written summary of the contents of the material, present the summary orally, and answer questions about the material. The examination committee will evaluate the written summary, the oral presentation, and the student's answers.

## Thesis Proposal

After completing the candidacy examination successfully, the PhD candidate must prepare a thesis proposal that outlines, in detail, the specific problems that will be solved in the PhD dissertation. The quality of the research proposal should be at the level of, for example, a peer-reviewed proposal to a federal funding agency, or a publishable scientific paper. The candidate is responsible for sending the research proposal to the PhD committee two weeks before the oral presentation. The PhD committee need not be the same as the candidacy exam committee, but it follows the same requirements and must be approved by the Office of Graduate Studies. The oral presentation involves a 30-40-minute presentation by the candidate followed by an unspecified period during which the committee will ask questions.

After the question and answer period, the candidate will be asked to leave the room and the committee will determine if the research proposal has been accepted. The research proposal can be repeated at most once. A thesis proposal must be approved within two years of becoming a PhD candidate.

After approval of the proposal, the committee meets from time to time to review the progress of the research.

## Thesis Defense

After completing the research proposal successfully, the PhD candidate must conduct the necessary research and publish the results in a PhD dissertation. The dissertation must be submitted to the PhD committee two weeks prior to the oral defense and at least 90 days before the graduation date. The oral presentation involves a 45-minute presentation by the candidate, open to the public, followed by an unspecified period during which the committee will ask questions. The question and answer period is not open to the public.

After the question and answer period, the candidate will be asked to leave the room and the committee will determine if the candidate has passed or failed the examination. The candidate will be granted one more chance to pass the final defense if he or she fails it the first time. Paperwork selecting the thesis committee and indicating the results of the thesis defense must be filed with the Department of Civil, Architectural and Environmental Engineering and the Office of Graduate Studies.

The PhD degree is awarded for original research on a significant Architectural Engineering problem. Graduate students who have an MS degree or have completed work equivalent to that required for of an MS degree will continue to work closely with individual faculty members to purse the PhD degree (see Faculty Research Interests on the department website). PhD dissertation research is usually supported by a research grant from a government agency or an industrial contract.

Many doctoral students take three to five years of full-time graduate study to complete their degrees.

## Indoor Air Quality - Sample Plan of Study

**First Year**

| Term 1 | | Credits |
|---|---|---|
| AE 544 | Building Envelope Systems | 3.0 |
| AE 550 | Comfort Analysis and Indoor Air Quality | 3.0 |
| MEM 591 | Applied Engr Analy Methods I | 3.0 |
| | **Term Credits** | **9.0** |
| **Term 2** | | |
| AE 510 | Intelligent Buildings | 3.0 |
| AE 551 | Building Energy Systems I | 3.0 |
| MEM 592 | Applied Engr Analy Methods II | 3.0 |
| | **Term Credits** | **9.0** |
| **Term 3** | | |
| AE 790 | Special Topics | 3.0 |
| Free Elective | | 3.0 |
| Free Elective | | 3.0 |
| | **Term Credits** | **9.0** |
| **Second Year** | | |
| **Term 1** | | |
| Free Elective | | 3.0 |
| ENVS 501 | Chemistry of the Environment | 3.0 |
| MEM 621 | Foundations of Fluid Mechanics | 3.0 |
| | **Term Credits** | **9.0** |
| **Term 2** | | |
| CHE 525 | Transport Phenomena I | 3.0 |
| ENVE 560 | Fundamentals of Air Pollution Control | 3.0 |
| ENVE 660 | Chemical Kinetics in Environmental Engineering | 3.0 |
| | **Term Credits** | **9.0** |

**Total Credit: 45.0**

**Undergraduate Course Prerequisites for students without an Engineering Degree:**

The following courses, or their approved equivalents from other departments, will meet these requirements:

- CIVE 320 - Fundamental Fluids
- CHEM 102 - Basic Chemistry
- ENGR 210 - Thermodynamics

## Building Energy - Sample Plan of Study

**First Year**

| Term 1 | | Credits |
|---|---|---|
| AE 550 | Comfort Analysis and Indoor Air Quality | 3.0 |
| MEM 591 | Applied Engr Analy Methods I | 3.0 |
| MEM 611 | Conduction Heat Transfer | 3.0 |
| | **Term Credits** | **9.0** |
| **Term 2** | | |
| AE 510 | Intelligent Buildings | 3.0 |
| MEM 592 | Applied Engr Analy Methods II | 3.0 |
| MEM 612 | Convection Heat Transfer | 3.0 |
| | **Term Credits** | **9.0** |
| **Term 3** | | |
| AE 551 | Building Energy Systems I | 3.0 |
| Free Elective | | 3.0 |

| Free Elective | | 3.0 |
|---|---|---|
| | **Term Credits** | **9.0** |
| **Second Year** | | |
| **Term 1** | | |
| AE 544 | Building Envelope Systems | 3.0 |
| CHE 513 | Chemical Engineering Thermodynamics | 3.0 |
| MEM 621 | Foundations of Fluid Mechanics | 3.0 |
| | **Term Credits** | **9.0** |
| **Term 2** | | |
| CHE 525 | Transport Phenomena I | 3.0 |
| ENVE 727 | Risk Assessment | 3.0 |
| AE 552 | Building Energy Systems II | 3.0 |
| | **Term Credits** | **9.0** |

**Total Credit: 45.0**

**Undergraduate Course Prerequisites for students without an Engineering Degree**

The following courses, or their approved equivalents from other departments, will meet these requirements:

- CIVE 320 - Fundamental Fluids
- MEM 345 - Heat Transfer
- ENGR 210 - Thermodynamics

## PhD in Architectural Engineering

Upon entering the PhD program, each student will be assigned an academic advisor, and with the help of the advisor will develop and file a plan of study (which can be brought up to date when necessary). The plan of study should be filed with the Graduate Coordinator no later than the end of the first term.

# Certificate in Construction Management

*Certificate Level: Graduate*
*Admission Requirements: Bachelor's degree*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 2 years*
*Financial Aid Eligibility: Not aid eligible*

The certificate in construction management has been designed for professionals to develop the multidisciplinary skills required of effective construction managers.

Students have the option of completing this 18.0 credit certificate in construction management as a stand-alone professional development credential, or as a step toward the MS in Construction Management program (http://drexel.edu/engmgmt/cmgt/academics/ms) .

The admissions process for this program is the same as for the MS in Construction Management (http://www.drexel.edu/grad/apply/overview) .

Depending on the experience and background of individual students, a prerequisite course of CMGT 501 "Leadership in Construction" may be required, or, at the discretion of the faculty, can be waived.

**Requirements**

| CMGT 510 | Construction Control Techniques | 3.0 |
|---|---|---|
| CMGT 512 | Cost Estimating and Bidding Strategies | 3.0 |
| CMGT 515 | Risk Management in Construction | 3.0 |
| CMGT 525 | Applied Construction Project Management | 3.0 |
| CMGT 528 | Construction Contract Administration | 3.0 |
| CMGT 538 | Strategic Management in Construction | 3.0 |
| **Total Credits** | | **18.0** |

# Certificate in Infrastructure Engineering Management

*Certificate Level: Graduate*
*Admissions Requirements: Bachelor's degree in engineering*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 2 years*
*Financial Aid Eligibility: Not aid eligible*

*Note:* Effective Fall 2014, students are no longer being accepted into this certificate program.

The graduate certificate in infrastructure engineering management is designed to prepare engineers to manage large-scale infrastructure projects and key personal interactions with external stakeholders. The program builds upon the College of Engineering's excellence in areas such as engineering management, civil engineering, and environmental risk analysis. Courses focus on decision making, planning and management and explore the impact of regulations on work with public funding and how contractual relationships dominate its execution.

Upon successful completion of the program, graduates will be skilled at managing the flow of public resources, integrating an array of projects into a long-term program, and incorporating public values and participation in infrastructure decisions. The six-course sequence is an 18-credit graduate certificate students can utilize either as a professional development credential or to apply as electives toward the completion of a Master's in Engineering Management .

**Required Courses**

| EGMT 501 | Engineering Management | 3.0 |
|---|---|---|
| EGMT 515 | Infrastructure Systems & Performance Evaluation | 3.0 |
| EGMT 516 | Infrastructure Project & Program Planning | 3.0 |
| EGMT 517 | Public Value & Participation in Infrastructure Decision | 3.0 |
| EGMT 520 | Infrastructure Capstone | 3.0 |
| Elective chosen from either the MS in Engineering Management or MS in Construction Management programs | | 3.0 |
| **Total Credits** | | **18.0** |

# Certificate in Power Engineering Management

*Certificate Level: Graduate*
*Admissions Requirements: Undergraduate degree in engineering*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 3 years*
*Financial Aid Eligibility: Not aid eligible*

The certificate in power engineering management is oriented toward engineers in power utilities, utility associations, or infrastructure firms interested in power distribution systems. The scope of this graduate-level program includes both program management and enhancement of technical knowledge beyond a bachelor's degree.

Admission to this graduate certificate program requires an undergraduate degree in engineering. Completed credits from the certificate completion can apply toward either a master's in engineering management or a master's in electrical engineering.

### Required Courses

| | | |
|---|---|---|
| ECEP 501 | Power System Analysis | 3.0 |
| ECEP 502 | Computer Analysis of Power Systems | 3.0 |
| ECEP 503 | Synchronous Machine Modeling | 3.0 |
| ECEP 612 | Economic Operation of Power Systems | 3.0 |
| EGMT 501 | Engineering Management | 3.0 |
| EGMT 516 | Infrastructure Project & Program Planning | 3.0 |
| **Total Credits** | | **18.0** |

# Certificate in Real Estate

*Certificate Level: Graduate*
*Admission Requirements: Bachelor's degree*
*Certificate Type: Graduate certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Campus, Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 2 years*
*Financial Aid Eligibility: Not aid eligible*

This graduate certificate seeks to produce professionals with the knowledge, skills, and perspective required to be successful in the real estate development process and the industry as a whole. Students explore the knowledge and skills required to create, maintain, and build environments for living, working and entertainment purposes.

Relevant issues include project finance, real estate as investments, design and construction, operations, development law, environmental remediation, public policy, market analysis, and architecture.

Students wising to complete this certificate in the context of a master's degree should consider the MS in Construction Management (http://www.drexel.edu/catalog/grad/goodwin/ms0cmgt-) with a concentration in Real Estate.

### Requirements

| | | |
|---|---|---|
| REAL 568 | Real Estate Development | 3.0 |
| REAL 571 | Advanced Real Estate Investment & Analysis | 3.0 |
| REAL 572 | Advanced Market Research & Analysis | 3.0 |
| REAL 575 | Real Estate Finance | 3.0 |
| REAL 577 | Legal Issues in Real Estate Development | 3.0 |
| Select one of the following: | | 3.0 |
| REAL 573 | Sales & Marketing of Real Estate | |
| REAL 574 | Real Estate Economics in Urban Markets | |
| REAL 576 | Real Estate Valuation & Analysis | |
| **Total Credits** | | **18.0** |

# Certificate in Sustainability and Green Construction

*Certificate Level: Graduate*
*Admission Requirements: Bachelor's degree*
*Certificate Type: Certificate*
*Number of Credits to Completion: 15.0*
*Instructional Delivery: Online, Campus*
*Calendar Type: Quarter*
*Estimated Time to Completion: 1 year*
*Financial Aid Eligibility: Not aid eligible*

The architectural, engineering, and construction community faces the daunting task of providing a built environment which is in harmony with the natural environment—meeting the current needs of society without jeopardizing the ability of future generations to meet their needs. Sustainable development means integrating the decision-making process across the project team, so that every decision is made with an eye to the greatest long-term benefits.

The certificate in Sustainability and Green Construction is a flexible, part-time post-baccalaureate program, focused on the sustainable aspects of the construction process. Students have the opportunity to complete all requirements within one and a half years.

Currently, in the Leadership in Energy and Environmental Design (LEED) green building rating system, the construction process represents a significant portion of the effort required to achieve high performance building programs.This certificate program is intended to explore these concepts in detail. Credits from this certificate will transfer toward a Master of Science in Construction Management.

### Requirements

| | | |
|---|---|---|
| CMGT 535 | Community Impact Analysis | 3.0 |
| CMGT 545 | Sustainable Principles & Practices | 3.0 |
| CMGT 546 | Sustainable Technologies | 3.0 |
| CMGT 547 | LEED Concepts | 3.0 |
| CMGT 558 | Community Sustainability | 3.0 |
| **Total Credits** | | **15.0** |

# Chemical Engineering

*Master of Science in Chemical Engineering (MSCHE): 45.0 quarter credits*
*Doctor of Philosophy: 90.0 quarter credits*

## About the Program

The graduate program in the Chemical and Biological Engineering Department integrates current chemical engineering science with the

growing fields of engineering applications and processes, emphasizing engineering design and scientific analysis. The department intends to develop broadly educated individuals who are knowledgeable in modern theories, cognizant of the behavior of engineering systems, and aware of current mathematical and engineering tools that are useful for the solution of problems in complex processes and systems, especially those in the fields of chemical, environmental, biochemical, and materials process engineering. Areas of particular strength include biological engineering, energy and the environment, multiscale modeling and process systems engineering, and polymer science and engineering.

Programs are arranged to meet the needs and interests of individual students. The plan of study is initially formulated in consultation with the departmental graduate advisor and subsequently guided by the thesis advisor.

Graduates have pursued a variety of careers, ranging from faculty positions in academia to research and development in industry, in the U.S. and overseas.

## Additional Information

For more information about this program, visit Drexel University's Department of Chemical and Biological Engineering (http://www.chemeng.drexel.edu) web page.

## Admission Requirements

Students should fulfill Drexel University's general requirements for admission to graduate studies. The subjects normally included in an undergraduate program in chemical engineering provide a satisfactory background. Decisions regarding prerequisite qualifications for students who may be deficient in some areas are made after consultation with the departmental graduate advisor.

The core courses are designed for students with undergraduate training in chemical engineering. However, students with a background in biological sciences and engineering can also enroll in the core courses after completing the necessary basic engineering courses and disciplinary chemical engineering courses. Programs for such students are determined on an individual basis after consultation with the departmental graduate advisor.

Graduate study in chemical engineering is offered on a regular full-time basis and on a part-time basis. Details not covered in the following information may be obtained by contacting the departmental graduate advisor. The General (Aptitude) Test of the Graduate Record Examination (GRE) is required for applicants pursuing full-time study.

## Financial Assistance

Financial aid in the form of teaching assistantships, research assistantships, and fellowship grants is available to qualified full-time PhD students. Awards are made annually on a competitive basis.

For additional information on how to apply, visit Drexel's Admissions page for Chemical Engineering (http://www.drexel.edu/grad/programs/coe/chemical-engineering) .

# Master of Science in Chemical Engineering

## Degree Requirements

In general, each program leading to the Master of Science in Chemical Engineering must meet the following requirements: core chemical engineering, 15.0 credits; area of concentration, at least 15.0 credits; electives, at most 6.0 credits; research, at most 15.0 credits. Core courses in the chemical engineering Master's program are listed below. A Master's Thesis is optional.

**Thesis option**: The thesis may be based on either a theoretical or an experimental investigation, or both, of limited scope but involving a significant degree of originality. The nature of the research may involve multidisciplinary areas such as biological engineering, materials processing and engineering, energy and the environment, and other topics. The scope and content of the thesis is guided by the thesis advisor. All students pursuing a Master's with Thesis must complete 9.0 credits of thesis research (CHE 898) and, at the discretion of the research advisor, up to 6.0 credits of independent study (CHE 799). Credits not devoted to independent study may be applied to general (non-concentration) graduate-level electives or to additional credits of thesis research.

**Coursework-only (non-Thesis) option:** Students not pursuing Master's with Thesis may take up to 9.0 credits of independent study (CHE 799) and 6.0 credits of general graduate-level electives. Independent study is **not** required for a non-thesis Master's. Non-thesis students may also take additional concentration electives beyond the required 15.0-credit series. Non-thesis students may **not** register for thesis research.

**Concentration**: All Master's students must complete a 15-credit series of concentration electives. Concentration electives may be chosen from course offerings in chemical engineering, mathematics, science, and other engineering disciplines, and are subject to approval by the departmental graduate advisor. Sample concentration series courses are listed below; there are many other possibilities. Non-concentration electives need only be graduate-level.

Full-time students usually take the core courses in the first year. Other courses may be substituted for the core courses, if equivalent courses are available and if the substitution is approved by the graduate advisor. Full-time students normally require a minimum of one calendar year to complete their study and research. Some courses are offered in the late afternoon or evening for the convenience of part-time students. The current schedule of evening courses for part-time students are available upon request.

**Curriculum**

| CHE 502 | Mathematical Methods in Chemical Engineering | 3.0 |
|---|---|---|
| CHE 513 | Chemical Engineering Thermodynamics | 3.0 |
| CHE 525 | Transport Phenomena I | 3.0 |
| CHE 543 | Kinetics & Catalysis I | 3.0 |
| CHE 554 | Process Systems Engineering | 3.0 |
| Area of Concentration | | 15.0 |
| Thesis/Research | | 9.0 |
| Electives | | 6.0 |
| **Sample Areas of Concentration** | | |
| **Biochemical Engineering** | | |
| **Sample Courses** | | |

| BIO 500 | Biochemistry I |
| BIO 610 | Biochemistry of Metabolism |
| BMES 501 | Medical Sciences I |
| CHE 562 | Bioreactor Engineering |
| CHE 564 | Unit Operations in Bioprocess Systems |

**Computer Science**

**Sample Courses**

| CS 543 | Operating Systems |
| CS 551 | Compiler Construction I |
| CS 552 | Compiler Construction II |
| CS 550 | Programming Languages |

**Engineering Management**

**Sample Courses**

| EGMT 501 | Engineering Management |
| EGMT 502 | Advanced Engineering Management |
| EGMT 504 | Engineering Management Communications |
| EGMT 531 | Engineering Economic Evaluation & Analysis |
| EGMT 581 | Human Relations and Organizational Behavior |

**Environmental Engineering**

**Sample Courses**

| ENVS 501 | Chemistry of the Environment |
| ENVS 608 | Fate of Pollutants in Air and Water |
| ENVE 661 | Env Engr Op-Chem & Phys |
| ENVE 662 | Enviro Engr Unit Oper-Bio |
| ENVE 865 | Spec Topics Envr Engineering |

**Materials Science and Engineering**

**Sample Courses**

| MATE 500 | Structure and Properties of Metals |
| MATE 501 | Structure and Properties of Polymers |
| MATE 502 | Structure and Properties of Ceramic and Electronic Materials |
| MATE 505 | Phase Equilibria |
| MATE 507 | Kinetics |
| **Total Credits** | **45.0** |

# PhD in Chemical Engineering

Superior students with MS or BS degrees will be considered for the doctoral program in chemical engineering. Students joining with a Master's degree may satisfy up to 45.0 credit hours of the PhD course/research credit requirements depending on the courses taken and/or research carried out in their Master's programs, subject to approval by graduate program advisor.

## Requirements

The following general requirements must be satisfied in order to complete the PhD in chemical engineering:

- 90 credit hours total
- Qualifying exam (first year)
- Establishing a plan of study (first term)
- 18 core credits
- 15 credit hours of specialized plan of study
- 57 credit hours of research
- Candidacy exam (5th term)

- Dissertation/Thesis
- Defense of Dissertation/Thesis
- GPA requirements: 3.0 overall; 3.0 in graduate Chemical Engineering (CHE) courses; 3.0 core graduate courses

## Qualifying Exam

The qualifying exam takes place in the first year. The department administers the exam twice a year – in January and June. The objective of the exam is to evaluate proficiency in core undergraduate chemical engineering material. The format is made up of seven problems, each covering a separate core topic from the undergraduate curriculum, including thermodynamics, heat transfer, mass transfer, fluid mechanics, kinetics, control, and separations. Students must display mastery of five out of the seven topics to pass the qualifying exam. Each student will be given two opportunities to pass the qualifying exam.

## Thesis Advisor/Plan of Study

All students must meet with their advisor in their first term to work out a plan of study.

**Core Requirements**

| CHE 502 | Mathematical Methods in Chemical Engineering | 3.0 |
| CHE 513 | Chemical Engineering Thermodynamics | 3.0 |
| CHE 525 | Transport Phenomena I | 3.0 |
| CHE 543 | Kinetics & Catalysis I | 3.0 |
| CHE 614 | Chemical Engineering Thermodynamics II | 3.0 |
| CHE 626 | Transport Phenomena II | 3.0 |
| **Specialized Plan of Study Courses** | | **15.0** |

15.0 credit hours of courses approved by research advisor. All students are expected to develop competence in their area(s) of specialization.

| **Research** | | **57.0** |

57.0 credit hours of research (CHE 998), which may include up to 6.0 credit hours of electives.

| CHE 998 | Ph.D. Dissertation | |
| **Total Credits** | | **90.0** |

## Candidacy Exam

The components of the candidacy exam are as follows::

- Proposal Document (Written): The student is required to write a research proposal of about 15 pages, including background, preliminary results, and a research plan (with his/her advisor's input). The proposal must be submitted to each member of the student's thesis committee and to the Graduate Program Advisor **before 5:00 pm on the first day of the student's 5th term.**
- Proposal Defense (Oral): The student provides a formal defense of his/her proposal to his/her thesis committee **before the end of the student's 5th term.**

## Thesis/Dissertation and Defense

As the culmination of intensive study and independent research, the doctoral dissertation represents a major scholarly endeavor; accordingly, it is recognized as the most important requirement of the degree. All doctoral candidates must present an acceptable dissertation based on significant work. The dissertation must represent a unique contribution to

chemical engineering or biochemical engineering knowledge. A final oral examination is conducted, in part, as a defense of the dissertation.

A preliminary exam is targeted for the student's 12th term, with this scheduling subject to the research advisor's discretion. This preliminary exam is to ensure that the student has made adequate progress in his/her project and that he/she has gained skills to write an independent research proposal.

The requirements of the thesis/dissertation and defense include:

- Proposal Document, a.k.a. "Second Proposal": The student is required to write a research proposal of about 15 pages, including background, summary of results to date, and a plan for completion of the thesis work (with minimal advisor input). The proposal must be submitted to each member of the student's thesis committee well in advance of the oral exam date.
- Preliminary Defense (Oral Examination): The student must defend the second proposal and the thesis work to-date in an oral examination by his/her thesis committee.
- Manuscript Submission: Before taking the preliminary exam, the student is required to submit at least one paper based on his/her PhD research to a refereed journal. This must be an original article, not a review.
- A copy of the written proposal, together with a copy of the submitted paper with acknowledgment of submission from the journal editor, must be submitted to the Graduate Program Advisor before the Preliminary Defense and at least 6 months before the Thesis Defense.
- The student is responsible for scheduling the Preliminary Defense
- Students should submit a copy of the Preliminary Exam Reporting Form (http://www.chemeng.drexel.edu/graduate/phd/Preliminary %20Ex%20Form.doc) no later than three days after the exam.

For more information, visit the Chemical and Biological Engineering Department (http://www.chemeng.drexel.edu) web page.

# Facilities

## Abrams Laboratory (ABRAMS)

## Cat-472 (Server room) and Cat-361 (Student offices)

- High-performance computer clusters
  - lamneth -- 90-core DDR Infiniband
  - narpet -- 40-core DDR Infiniband
- Workstation computers (panacea, maelstrom, cygnus, redstar, syrinx, presto)
- 24TB RAID server (nlgn)

## Access to:

- The University Research Computing Facility (URCF)
- The Draco Cluster (Dept. Physics)
- TeraGrid/XSEDE Allocation (TACC Stampede)

## Nanomaterials for Energy Applications and Technology Laboratory (BAXTER)

## Cat-266

- Amplified Ti:Sapphire laser with time-resolved teraherterz spectroscopy and femtosecond UV/vis/NIR transient absorption spectroscopy (Bossone 106)
- Solar simulator with monochromator and photovoltaic/ photoelectrochemical test station
- Electrochemical impedance spectroscopy
- Layer-by-layer deposition robot
- Dip coater
- Spin coater
- Electrodeposition station
- Continuous flow microreactors

## Biofuels Laboratory (CAIRNCROSS)

## Cat-265

- Bubble column biodiesel reactors
- Recirculating heated oil baths
- Quartz crystal microbalance / heat conduction calorimeter (Masscal G1)
- Maxtek quartz crystal microbalance with phase lock oscillator
- Parr reactor

## Elabd Laboratory (ELABD)

## Cat-262, 263, 264

- Electrochemical Impedance Spectrometer (EIS) (Solartron: 1260 impedance analyzer, 1287 electrochemical interface, Zplot software) with many custom made 4 and 2 electrode cells
- Fuel Cell Test Station (Scribner 850C with fuel cell software) equipped for gas and liquid fuels and PEM and AEM test cells
- FTIR spectrometer (Nicolet Nexus 6700) equipped with multiple multi-bounce ATR flow-through cell attachments (Specac)
- FTIR spectrometer (Nicolet Nexus 6700)
- Golden GateTM diamond single-bounce ATR attachment (Specac)
- Silver GateTM zinc selenide single-bounce ATR attachment (Specac)
- Silver GateTM germanium single-bounce ATR attachment retrofit for electrochemical measurements (Specac)
- Dynamic Vapor Sorption (DVS) (TA Instruments Q5000 SA)
- Dynamic Vapor Sorption (DVS) with Cahn balance (Surface Measurement Systems)
- Differential Scanning Calorimeter (DSC) (TA Instruments Q200) with cooling accessory with temperature range of -180 to $725^{o}$C
- Gel Permeation Chromatography (GPC) (Waters Breeze 2) with 1525 Binary HPLC Pump for two separate columns (columns for THF and DMF), 214 Refractive Index Detector
- Environmental Chamber (Tenney) with high temperature/humidity control ranging from 25-200$^{o}$C and 5-95%RH and integrated with vapor permeation and EIS
- Electrospinning Apparatus with custom-built enclosed chamber, 2 syringe pumps, and high voltage power supply (Glassman High Voltage, Inc. Series EL)
- Multipycnometer (Quantachrome)

- Two Liquid Diffusion Cells (PermeGear) integrated to flow-through ATR cell for detection with temperature control
- Vapor Sorption Apparatus (custom-built) with pressure transducer, temperature-controlled chamber, and quartz springs for the measurement of vapor and vapor mixture diffusion and sorption in polymers. This equipment is also integrated to an FTIR-ATR spectrometer for the measurement of molecular transport of pure vapors and vapor mixtures in polymers
- Gas Permeation and Sorption Apparatus (custom-built) with pressure and sorption cells, pressure transducer, and temperature-controlled chamber for the measurement of gas permeation and sorption in polymers
- Mass Spectrometer (MS) (HP 5989B), Gas Chromatograph (GC) (HP 5890), Liquid Chromatograph (LC) (HP 1090)
- Gravimetric Balances (Precisa XR 125 SM-FR, 10 µg accuracy; Mettler Toledo AB 54-S, 100 µg accuracy; Mettler Toledo B2002-S, 10 mg accuracy)
- Sonicators (QSONICA Q125, Cole-Parmer 8890)
- Heat Press (Carver 3351-0)
- Charged-Coupled Device (CCD) camera (Cognex in-sight 5403 vision sensor with patmax)
- Tube Furnace (Barnstead/Thermolyne 21100)
- Convection Oven
- Three Vacuum Ovens
- Three Vacuum Pumps
- 2x Water Bath (Thermo Scientific Neslab RTE 10)
- Rotary Evaporator (Buchi Rotovapor®)
- Many stir/hot plates and other wet chemistry accessories

## Nanofibers for Energy Storage and Conversion Laboratory (KALRA)

### Cat-471

- Four Electrospinning Staions (with core-shell spinning capability)
- Tube Furnaces/Convection Ovens/Vacumm Ovens
- Mbraun Dual User Glove Box
- Carver Heat Press
- Gamry Ref 3000 Potentiostat
- 32-channel Maccor Battery Cycler

### Access to:

- Drexel's Centralized Research Facilties (SEM, TEM, Ultramicrotome, FTIR, XPS, XRD, Multi-angle x-ray scattering)
- XSEDE Compute Hours Allocation
- Synchrotron at Brookhaven National Lab
- BET Surface are and Porosity Analyzer

## Thin Film and Devices Laboratory (LAU)

### CAT-382

- Chemical Vapor Deposition Thin Film Reactor System I
- Chemical Vapor Deposition Rotating Bed Reactor System
- Gamry Reference 600 Electrochemical Testing Station
- Solar Illuminator
- Nicolet 6700 FTIR Spectrometer

- Laurell Technologies Spin Coater

## Bossone-521

- Chemical Vapor Deposition Thin Film Reactor System II

## Access to:

- Centralized Research Facilities (SEM, TEM, XRD, SAXS, XPS, Raman, Profilometer)
- Thermogravimetric Analyzer
- Differential Scanning Calorimeter
- Dynamic Mechanical Analyzer
- UV-Vis Spectrophotometer

## Biosensor and Bioanalytics Laboratory (MUTHARASAN)

### Cat-466, 469

- Custom-built bio-analytical flow apparatus for conducting in situ surface chemistry and detection assays of pathogens, biomarkers, DNA and RNA
- Impedance Analyzers Agilent 4294A and Agilent HP4192A with bridge circuits for device characterization
- Electrochemical Impedance Spectrometer, Gamry Interface 1000 with three electrode cells, and interfaces to biosensor flow cell; Ag/AgCl and Pt electrodes
- Stanford Research System QCM200 and flow cells
- Signal Recovery 875 Lock-In amplifier (plus computer-interface)
- Function/Arbitrary Waveform Generator, 80 MHz Agilent 33250A
- Agilent precision Giga-ohmmeter
- Bausch & Lomb optical Microscopes interfaced with image acquisition system
- Olympus OM-10 Fluorescence Microscope, coupled to Canon digital imaging and video systems
- PTI SS Fluorescence Spectrometer with PMT 750 detector
- UV-VIS spectrometer – Shimadzu UV-1800
- Denton Desktop high vacuum sputtering system; 6-inch target, one or two cathode configuration, Base vacuum $10^{-6}$
- Harrick RF Plasma Reactor (Model PDC-001, 200 W) modified for conducting plasma-assisted surface reactions
- UVP UV Radiation Oven, Model OG-1. Radiation at 185 and 254 nm
- 1550 nm DFB laser (Anritsu GB5A016) and 1310 nm DFB laser (QPhotonics), and associated power supplies
- High speed micro-centrifuge (200 – 15000 rpm)
- Vacuum ovens
- Incubators, 9 ft$^3$, 20-70$^o$C
- Spectrum analyzer (ANDO AQ-6310B), LabView interface
- Ericsson FSU 975 fusion splicer
- Laminar Flow Hoods, Precision $CO_2$ Incubators, Spinners, bioreactors (0.1L to 1L)

## Access to:

- Bruker Daltonics Autoflex III Smartbeam TOF-MALDI mass spectrometer
- 8 M#, Milli-Q system
- Autoclave

- Hot room 37$^{\circ}$C, 100 ft$^2$
- Refrigerated room 4$^{\circ}$C, 100 ft$^2$

## Polymers and Composites Laboratory (PALMESE)

### Bossone-521

- TA Instruments TGA Q50 Thermogravimetric Analyzer
- KSV Instruments CAM 200 Contact Angle and Surface Tension Meter
- TA Instruments DSC Q2000 Differential Scanning Calorimeter
- Instron 8872
- Thermo Nicolet Nexus 870 FTIR
- TA Instruments DMA Dynamic Mechanical Analysis
- Perkin Elmer DSC7 Differential Scanning Calorimeter
- Waters GPC/HPLC (RI, UV Detectors)
- Electrospinning station
- TA Instruments AR Rheometer
- Thinky planetary centrifugal mixer ARE-250
- Melt Press
- Portable Near Infrared Spectrometer
- Brookfield digital viscometer
- Glove Box
- Supercritical Dryer (2x)
- Dielectric Barrier Discharge (DBD) plasma reactor

## Process Systems Engineering Laboratory (SOROUSH)

- Interacting liquid level tanks
- 2-liter RC1 Calorimeter

## Wrenn Laboratory (WRENN)

### Cat-470

- PTI, Inc. C-71 Time-Resolved Fluorescence Spectrometer (pulsed nitrogen and dye lasers)
- PTI, Inc. A-710 Steady State Fluorescence Spectrometer
- Brookhaven 90Plus Dynamic Light Scattering Apparatus
- Brookhaven Goniometer-based, Static Light Scattering Apparatus
- Perkin-Elmer BUV40XW0 UV-Visible Absorbance Spectrometer
- Zeiss Axioskop2 Fluorescence microscope
- Zeiss Ultraviolet Digital Image Analysis System (contains Orca Camera, Sony 17" monitor, and Axiovision II software)
- Beckman Coulter Allegra64 Centrifuge
- Misonix, Inc. XL2020 Sonicator
- Lipex Biomembranes, Inc. Lipid Extruder (10 mL)

## Chemical and Biological Engineering Faculty

Cameron F. Abrams, PhD *(University of California, Berkeley)*. Professor. Molecular simulations in biophysics and materials; receptors for insulin and growth factors; and HIV-1 envelope structure and function.

Nicholas J. Alvarez, PhD *(Carnegie Mellon University)*. Assistant Professor. Photonic Crystal Defect Chromatography; Extensional rheology of polymer/polymer composites; Surfactant/polymer transport to fluid and solid interfaces; Aqueous lubrication; Interfacial Instabilities.

Jason B. Baxter, PhD *(University of California, Santa Barbara)*. Associate Professor. Solar cells, semiconductor nanomaterials, ultrafast spectroscopy.

Richard A. Cairncross, PhD *(University of Minnesota)*. Associate Professor. Effects of microstructure on transport and properties of polymers; moisture transport and degradation on biodegradation on biodegradable polymers; production of biofuel.

Nily R. Dan, PhD *(University of Minnesota)*. Associate Professor. Design of synthetic gene and drug carriers; design of polymeric drug carriers; metal cluster formation in polymeric matrices; colloidal absorption in patterned surfaces.

Aaron T. Fafarman, PhD *(Stanford University)*. Assistant Professor. Colloidal nanocrystals; solution-processed solar cells; electrical and spectroscopic characterization of nanomaterials.

Vibha Kalra, PhD *(Cornell University)*. Assistant Professor. Electrodes for Energy Storage and Conversion; Supercapacitors, Li-S Batteries, Fuel Cells, Flow Batteries; Electrospinning of Nanofibers; Molecular Dynamics Simulations

Kenneth K.S. Lau, PhD *(Massachusetts Institute of Technology)*. Associate Professor. Surface science; nanotechnology; polymer thin films and coatings; chemical vapor deposition.

Raj Mutharasan, PhD *(Drexel University) Frank A. Fletcher Professor*. Biochemical engineering; cellular metabolism in bioreactors; biosensors.

Giuseppe R. Palmese, PhD *(University of Delaware) Department Head, Chemical and Biological Engineering*. Professor. Reacting polymer systems; nanostructured polymers; radiation processing of materials; composites and interfaces.

George F. Rowell, PhD *(University of Pennsylvania) Undergraduate Laboratory Supervisor*. Associate Teaching Professor. Undergraduate laboratory supervising.

Joshua D. Snyder, PhD *(Johns Hopkins University)*. Assistant Professor. Electrocatalysis (Energy Conversion/Storage) Heterogeneous Catalysis; Corrosion (Dealloying, Nanoporous Metals); Interfacial Electrochemical Phenomena in Nanostructured Materials; Colloidal Synthesis

Masoud Soroush, PhD *(University of Michigan)*. Professor. Modeling, control and optimization of solar cell, fuel cell and power storage systems Probabilistic risk assessment and mitigation; Polymerization reaction engineering; Process systems engineering; Polymer membranes; Multiscale mathematical modeling

John H. Speidel, BSHE, MCHE *(University of Delaware; Illinois Institute of Technology)*. Teaching Professor.

Maureen H. Tang, PhD *(University of California, Berkeley)*. Electrochemistry (batteries, fuel cells, electrolyzers); Catalysis and surface science.

Stephen P. Wrenn, PhD *(University of Delaware)*. Associate Professor. Biomedical engineering; biological colloids; membrane phase behavior and cholesterol transport.

# Emeritus Faculty

Charles B. Weinberger, PhD *(University of Michigan).* Professor Emeritus. Suspension rheology; fluid mechanics of multi-phase systems.

# Courses

**CHE 502 Mathematical Methods in Chemical Engineering 3.0 Credits**
Emphasizes formulation of differential and difference equations, both ordinary and partial, governing chemical engineering operations in the steady and unsteady state.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 513 Chemical Engineering Thermodynamics 3.0 Credits**
Examines thermodynamic principles from a classical viewpoint, including properties of materials, equations of state of mixtures, and chemical and phase equilibria of complex mixtures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 525 Transport Phenomena I 3.0 Credits**
Presents a unified treatment of transport rate theory, with emphasis on analogies among momentum, energy, and mass transfer, and continuum and molecular theories of matter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 531 Fundamentals of Solar Cells 3.0 Credits**
This course focuses on the fundamentals of solar cells. It will cover semiconductor materials, basic semiconductor physics, optical and electronic phenomena, and case studies of crystalline silicon, thin film, and nanostructured photovoltaics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 534 Mass Transfer Operations I 3.0 Credits**
Theory and design of equilibrium stage operations. Separation processes for binary and multicomponent mixtures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 543 Kinetics & Catalysis I 3.0 Credits**
Covers chemical reaction kinetics as applied to chemical engineering. Introduces chemical kinetics and mechanisms and heterogeneous kinetics and catalysis. Includes design of ideal and non-ideal chemical reactors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 502 [Min Grade: C]

**CHE 554 Process Systems Engineering 3.0 Credits**
Covers the basic concepts of the systems engineering approach to the design and operation of processing plants. Includes methods for developing control strategies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 502 [Min Grade: C]

**CHE 556 Process Optimization 3.0 Credits**
Focuses on optimization of processes from the viewpoint of economic return.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 560 Transport Phenomena in Biological Systems 3.0 Credits**
Covers gas-liquid mass transfer in microbial systems, mass transfer in cells and biofilms, membrane transport, fluid mechanics of fermentation broth, power consumption in agitated vessels, heat transfer, and scale-up of mass transfer equipment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 561 Principles of Colloid Science 3.0 Credits**
This course focuses on fundamental principles of colloid science from a biological perspective. It will cover surface active agents, thermodynamics or self-assembly of surfactants, surface chemistry and physics of monolayers and bilayers, microstructures and phase behavior, specific biological colloids (micelles, liposomes, and lipoproteins), and colloidal stability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 562 Bioreactor Engineering 3.0 Credits**
Covers growth and product formation kinetics, batch and continuous stirred tank bioreactors, tower reactors, immobilized-cell reactors, and immobilized-enzyme reactors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 564 Unit Operations in Bioprocess Systems 3.0 Credits**
Covers liquid-liquid extractions, membrane separations, chromatographic separations, filtration, centrifugation, distillation, and leaching.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 566 Dynamics and Control of Biological Process Systems 3.0 Credits**
Dynamics of pH and temperature control systems, dynamics of bioreactors to feed upsets, substrate feed rate control, start-up of bioreactors, dynamics of multiple microbial populations, instrumentation of bioreactors, computer interfacing and control of bioreactors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 614 Chemical Engineering Thermodynamics II 3.0 Credits**
The second in a two-quarter sequence in thermodynamics for graduate students in Chemical and Biological Engineering. Students learn theory and application of statistical mechanics with emphasis on prediction of volumetric and thermal properties of pure fluids and mixtures, as well as phase equilibrium. Modern methods in applied statistical mechanics are covered, including Monte Carlo and molecular-dynamics simulations. Non-equilibrium statistical mechanics in terms of linear response theory applied to chemical kinetics is also covered. Students are evaluated on homework sets, two exams, and a term project.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CHE and program is PHD.
**Prerequisites:** CHE 513 [Min Grade: C]

**CHE 626 Transport Phenomena II 3.0 Credits**
Transport of mass, energy, and momentum of turbulent systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 631 Heat Transfer 3.0 Credits**
Advanced topics in heat conduction, convection, and radiation with application to design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 635 Mass Transfer Operations II 3.0 Credits**
Theory and design of continuous contact operations including fixed-bed and fluid-bed processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 644 Kinetics and Catalysis II 3.0 Credits**
Advanced topics in kinetics and catalysis including: diffusion and catalysis; optimization of chemical reaction systems; analysis and treatment of kinetic data.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 658 Advanced Process Design 3.0 Credits**
Covers flowsheet analysis and synthesis, batch process design and scheduling, project scheduling, and economic considerations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 502 [Min Grade: C]

**CHE 670 Real-Time Microcomputer Applications 3.0 Credits**
Application of microcomputers in monitoring and control of external devices and processes. Topics include: digital input/output, real-time clock, analog-to-digital and digital-to-analog conversion, noise removal, signal processing, and data communications. Includes hands-on computer laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 799 Independent Study in Chemical Engineering 9.0 Credits**
Provides advanced independent study in chemical engineering or related interdisciplinary fields.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CHE 800 Special Topics 0.5-9.0 Credits**
Covers selected advanced-level topics in chemical engineering. May be repeated for credit when topics vary.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CHE 898 Master's Thesis 9.0 Credits**
Requires fundamental research in chemical engineering. Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CHE 998 Ph.D. Dissertation 1.0-9.0 Credit**
Requires dissertation research in chemical engineering. Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Civil Engineering

*Master of Science in Civil Engineering (MSCE): 45.0 quarter credits*
Doctor of Philosophy*: 90.0 quarter credits*

## About the Program
### Objectives

The graduate program in civil engineering offers students the opportunity to develop a more fundamental and complete understanding of the principles that govern their field as well as current design methodology. Students are encouraged to be innovative and imaginative in their quest for recognizing, stating, analyzing, and solving engineering problems.

The goal of the master's program is to develop technical depth of expertise for a professional career in the planning, design, construction, and operation of large-scale infrastructure systems, built facilities, and water resources management. The goal of the PhD program is to develop the abilities to discover, pursue, and apply basic knowledge. PhD recipients are prepared to engage in teaching and research or in an industrial career in the development of new concepts and innovative systems.

## General Information

The civil engineering programs comprise the following areas of specialization: building systems, geotechnical engineering, hydraulic and coastal engineering, structural engineering, and water resources.

For more information, visit the Department of Civil, Architectural and Environmental Engineering (http://www.cae.drexel.edu) web page.

## Admission Requirements

MS admission is based on an academic record demonstrating adequate preparation and potential for successful graduate study. This typically includes a BS from an engineering curriculum accredited by the Accrediting Board for Engineering and Technology (ABET) or the equivalent from a non-U.S. institution. Submission of results from the Graduate Record Exam (GRE) is required. A grade point average (GPA) of 3.0 is usually required. Graduates who do not have a bachelor's degree in either Civil, Architectural or Environmental Engineering may be required to take preparatory undergraduate courses.

For additional information on how to apply, visit Drexel's Admissions page for Civil Engineering (http://www.drexel.edu/grad/programs/coe/civil-engineering) .

## Master of Science in Civil Engineering

The programs of study at the master's level continue the specialization developed at the senior level of the undergraduate program or newly developed interests. The Master of Science in Civil Engineering program may be elected by graduates of ABET-accredited undergraduate programs in civil engineering and related fields. Admission and prerequisites are determined on the basis of a student's undergraduate transcript.

Most MSCE graduates work as professional engineers in consulting firms, industry, or governmental agencies. A number of our graduates have started consulting and construction firms in the Philadelphia area and have been very successful. Other former students hold prominent positions in public utilities, local government agencies, and industry.

The full-time graduate academic program is closely associated with the research efforts of the faculty. Full-time master's degree candidates are encouraged to base their master's thesis on some aspect of faculty research. The one-to-one relationship between student and faculty member provides an invaluable learning experience. The General (Aptitude) Test of the Graduate Record Examination (GRE) is required for applicants pursuing full-time study.

The master's degree requires a total of 45.0 credits, of which 24.0 credits must be in the major field of interest and 6.0 credits are to fulfill math requirements. The remaining credits are taken as electives in related areas. The choice of core and elective courses is made in consultation with the student's graduate advisor.

Areas of concentration include:

- Structural
- Geotechnical/geoenvironmental/geosynthetics
- Water resources
- Building systems/energy

Dual graduate degrees are possible. Among the more popular programs are combining the MS in Civil Engineering with an MS in Environmental Engineering, or Engineering Management. The required credits must meet all civil engineering program requirements and will be determined on the basis of the student's proposed program of study.

# PhD in Civil Engineering

The PhD degree is awarded for original research on a significant civil engineering problem. Graduate students who have completed their MS degrees work closely with individual faculty members (see Faculty Research Interests below). PhD dissertation research is usually supported by a research grant from a government agency or an industrial contract.

The full-time graduate academic program is closely associated with the research efforts of the faculty. The General (Aptitude) Test of the Graduate Record Examination (GRE) is required for applicants pursing full-time study.

Doctoral students normally take at least 45.0 credits, including research credits, beyond the master's degree requirements. Full-time residency for one continuous academic year is required for the PhD degree to ensure students the opportunity for intellectual association with other scholars. Many doctoral students take two, three, or four years of full-time graduate study to complete their degrees. Involvement in the teaching activity of the Civil, Architectural and Environmental Engineering Department is required of all PhD applicants.

After approximately one year of study beyond the master's degree, doctoral students take a candidacy examination, consisting of written and oral parts. Each PhD candidate is supervised by a major professor and a doctoral committee chaired by the major professor.

PhD candidates submit a detailed proposal for dissertation research to the doctoral committee. The students then take a proposal examination; successful completion of this examination is required to become a PhD

candidate. After approval of the proposal, the committee meets from time to time to review the progress of the research. The dissertation must be submitted to the doctoral committee at least 90 days before the graduation date. The committee schedules and conducts a final oral examination before approval of the dissertation.

Areas of research include:

- Structural
- Geotechnical/geoenvironmental/geosynthetics
- Water resources
- Sustainable engineering
- Building systems/energy

# Dual Degree Programs

Civil Engineering students may find it useful to pursue dual MS degrees. Such programs have been pursued in concert with Environmental Engineering/Science, Mechanical Engineering, Information Studies and Engineering Management. A dual degree student must complete the required coursework for each degree. Depending upon the concentration, up to 15.0 credits from another program may count as electives for the MSCE. with the advisor's approval. The student is responsible for obtaining approval of MSCE. courses that apply to the second degree.

# Bachelor's/Master's Dual Degree Program

Exceptional undergraduate students can also pursue a master of science degree in the same period as the bachelor of science. Many students deepen their knowledge with a Master's degree in Civil Engineering, while others have broadened their knowledge with a Master's degree in related areas such as Environmental Science, Engineering Management, Software Engineering and Information Technology.

For more information about this program, visit the Department's BS / MS Dual Degree Program (http://www.drexel.edu/cae/academics/environmental-engineering/Accelerated%20and%20Dual%20Degree%20Programs%20CAEE) web page.

# Facilities

**Construction Materials Laboratory**
This laboratory contains facilities for the study of concrete, asphalt, mortar, soil-cement, and timber materials, and moist cure facilities.

**Geosynthetics Laboratory**
This laboratory contains a complete suite of physical, mechanical, hydraulic, endurance, and environmental test devices for assessing behavior of geotextiles, geogrids, geonets, geomembranes, and geocomposites.

**HVAC and Refrigeration Laboratory**
This laboratory contains complete models of heating, ventilation, air conditioning, refrigeration, and pumping system models.

**Hydromechanics Laboratory**
This laboratory contains a wave channel tilting flume, pipe friction equipment, bench demonstration equipment, and a beach erosion model.

**Soil Mechanics and Geoenvironmental Laboratory**
This laboratory contains triaxial and direct shear equipment, controlled environmental chambers, consolidation tests, flexwall permeameters, and a test bed.

**Structural Testing Laboratory**

This laboratory contains universal testing machines with 150,000- and 300,000-pound capacity and test beds with MTS dynamic load equipment.

# Civil, Architectural and Environmental Engineering Faculty

Abieyuwa Aghayere, PhD, P.Eng *(University of Alberta)*. Professor. Structural design - concrete, steel and wood; Structural failure analysis and retrofitting of existing structures; New structural systems and materials.

Emin A. Aktan, PhD *(University of Illinois at Urbana-Champaign) John Roebling Professor of Infrastructure Studies*. Professor. Structural engineering; infrastructure; evaluation; intelligent systems.

Ivan Bartoli, PhD *(University of California, San Diego)*. Assistant Professor. Non-destructive evaluation and structural health monitoring; dynamic identification, stress wave propagation modeling.

Robert Brehm, PhD, PE, FASCE *(Drexel University)*. Associate Teaching Professor. International infrastructure delivery; response to natural catastrophes; risk assessment and mitigation strategies; project management techniques.

S.C. Jonathan Cheng, PhD *(West Virginia University)*. Associate Professor. Soil mechanics; geosynthetics; probabilistic design; landfill containments.

Peter DeCarlo, PhD *(University of Colorado)*. Assistant Professor. Outdoor air quality, particulate matter size and composition instrumentation and measurements, source apportionment of ambient particulate matter, climate impacts of particulate matter.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute)*. Associate Professor. Soil mechanics; geoenvironmental; ground improvement; sustainability.

Patrick Gurian, PhD *(Carnegie-Mellon University)*. Associate Professor. Risk analysis of environmental and infrastructure systems, novel adsorbent materials, environmental standard setting, Bayesian statistical modeling, community outreach and environmental health.

Charles N. Haas, PhD *(University of Illinois-Urbana) L. D. Betz Professor and Department Head, Civil, Architectural and Environmental Engineering*. Professor. Control of human exposures to and risk assessment of pathogenic organisms; water and waste treatment; homeland security.

Ahmad Hamid, PhD *(McMaster University)*. Professor. Engineered masonry; building; cladding; prestressed concrete.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Polymeric and cementitioius materials; geosynthetic reliability and durability.

Joseph B. Hughes, PhD *(University of Iowa) Dean of the College of Engineering*. Distinguished Professor. Biological processes and applications of nanotechnology in environmental systems.

Roger Marino, PhD *(Drexel University)*. Associate Teaching Professor. Fluid Mechanics, Water Resources, Engineering Education, Land Development

Joseph P. Martin, PhD *(Colorado State University)*. Professor. Geoenvironmental engineering; urban environmental hydrology; transportation.

James E. Mitchell, MArch *(University of Pennsylvania)*. Associate Professor. Architectural engineering design; building systems.

Franco Montalto, PhD *(Cornell University)*. Associate Professor. Effects of built infrastructure on societal water needs, ecohydrologic patterns and processes, ecological restoration, green design, water interventions.

Franklin Moon, PhD *(Georgia Institute of Technology)*. Associate Professor. Full-scale structural testing, structural dynamics, evaluation and rehabilitation of existing structures.

Joseph V. Mullin, PhD *(Pennsylvania State University)*. Senior Lecturer. Structural material behavior, engineering economy and design.

Mira S. Olson, PhD *(University of Virginia)*. Associate Professor. Groundwater; environmental fluid mechanics; hydrology.

Anu Pradhan, PhD *(Carnegie Mellon University)*. Assistant Professor. Infrastructure management, construction engineering, transportation engineering, sensing system, geographic information system, statistical machine learning.

Yared Shifferaw, PhD *(Johns Hopkins University)*. Assistant Professor. Computational and experimental mechanics, structural stability, optimization, health monitoring and hazard mitigation, sustainable structures, emerging materials, thin-walled structures and metallic structures.

Kurt Sjoblom, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Laboratory testing of geomaterials, geotechnical engineering, foundation engineering.

Sabrina Spatari, PhD *(University of Toronto)*. Assistant Professor. Research in industrial ecology; development and application of life cycle assessment (LCA) and material flow analysis (MFA) methods for guiding engineering and policy decisions; specific interest in biomass and bioenergy, biofuels, and urban infrastructure.

Michael Waring, PhD *(University of Texas-Austin)*. Assistant Professor. Indoor air quality and building sustainability; indoor particulate matter fate and transport; indoor chemistry and particle formation; secondary impacts of control technologies and strategies.

Jin Wen, PhD *(University of Iowa)*. Associate Professor. Architectural engineering, building control systems, indoor air quality.

Aspasia Zerva, PhD *(University of Illinois)*. Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

# Interdepartmental Faculty

Eugenia Ellis, PhD *(Virginia Polytechnic State University)*. Associate Professor. Registered architect; interior design, extended-care facilities design, research on spatial visualization, perception and imagination.

Bakhtier Farouk, PhD *(University of Delaware) Billings Professor of Mechanical Engineering*. Professor. Heat transfer; combustion; numerical methods; turbulence modeling; materials processing.

Tony H. Grubesic, PhD *(The Ohio State University) Director of the Center for Spatial Analytics and Geocomputation (CSAG)*. Professor. Geographic information science, spatial analysis, development, telecommunication policy, location modeling.

# Emeritus Faculty

Harry G. Harris, PhD *(Cornell University)*. Professor Emeritus. Structural models, dynamics of structures, plates and shells, industrialized building construction.

Robert M. Koerner, PhD *(Duke University)*. Harry Bownam Professor Emeritus. Geosynthetic engineering; soil mechanics; water resources.

Richard Weggel, PhD *(University of Illinois) Samuel S. Baxter Professor Emeritus; Civil and Environmental Engineering*. Professor Emeritus. Coastal engineering; hydraulics engineering; hydrology.

Richard Woodring, PhD *(University of Illinois) Dean of Engineering Emeritus*. Professor Emeritus. Structural engineering, reinforced concrete.

# Civil Architectural Engineering Courses

## Civil Engineering Courses

### CIVE 501 Model Analysis of Structures 3.0 Credits
Open to advanced undergraduates. Covers application of models for the analysis and design of complex structures, including development of laws of similitude, methods of fabricating, and testing and instrumentation of models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### CIVE 510 Prestressed Concrete 3.0 Credits
Open to advanced undergraduates. Covers definitions and general principles, anchorage systems, and loss of prestress; analysis and design of simple beams for flexure, shear, bond, and bearing; partial prestressed and post-tensioned reinforcement; and continuous beams.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### CIVE 520 Advanced Concrete Technology 3.0 Credits
This course covers the mechanical, physical and chemical properties of concrete: characteristics of concrete in the fresh, setting and hardening states; high performance concrete. Factors influencing the mechanical performance of concrete are discussed as well as field testing methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is CIVE or major is EGEO.

### CIVE 530 Geotechnical Engineering for Highways 3.0 Credits
Covers design if stable right-of-way, USDA classification, frost and swell expansion, capillary moisture retention, subgrade compaction, beam on elastic foundation pavement model, loads and resistance of buried pipes, subdrainage, basic slope stability and retaining structures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### CIVE 531 Advanced Foundation Engineering 3.0 Credits
Covers design of shallow foundations (footing and mats), deep foundations (piles, augered, drilled shafts) and retaining structures for stability and deformation performance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### CIVE 560 Introduction to Coastal & Port Engineering 3.0 Credits
Provides an overview of coastal engineering problems and their solution, including shoreline erosion, ocean waves and wave theories, wave generation, diffraction, refraction, harbor hydraulics, coastal currents, and tidal inlet hydraulics and sedimentation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### CIVE 561 Introduction to Hydrology 3.0 Credits
Covers climate and weather, precipitation, evaporation and transpiration, drainage basins, and hydrographs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGEO 700 [Min Grade: C]

### CIVE 562 Introduction to Groundwater Hydrology 3.0 Credits
Covers the fundamentals of fluid flow in porous media, groundwater supply, pollution problems, well and aquifer hydraulics, and groundwater flow modeling.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### CIVE 563 Coastal Processes 3.0 Credits
This course provides a detailed presentation of hydraulic and sedimentary processes occurring in the coastal zone with a view toward applying knowledge of the processes to coastal erosion and shoreline stabilization problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 560 [Min Grade: C]

### CIVE 564 Sustainable Water Resource Engineering 3.0 Credits
Objective is to enable students to incorporate sustainability concepts into the planning, design, and management of water resources, accomplished through critique of historical agricultural, industrial, and urban water infrastructure in the context of their ecological, social justice, and economic impacts. Global case studies featured and discussed. Also involves a research/design project with an actual "class client".
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Sophomore

### CIVE 565 Urban Ecohydraulics 3.0 Credits
Will enable students to incorporate an understanding of ecohydrologic patterns and processes into the design of built landscapes and engineered infrastructure. Students will be introduced to techniques for analyzing and modeling rainfall-runoff processes and will learn how to develop ecosystem water budgets in urban contexts. Case studies and field trips will expose students to both ecosystem restoration and green infrastructure projects in the mid-atlantic region.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 320 [Min Grade: D] and CIVE 330 [Min Grade: D] and CIVE 430 [Min Grade: D]

**CIVE 567 Watershed Analysis 3.0 Credits**
This course focuses on land use change (LUC) and the hydrologic cycle in agricultural and forest (non-urban) watersheds. Using climate, hydrology, and agricultural models, students will investigate how changes in hydroclimatology and landscape-scale land cover affect surface water flow, runoff, and water quality in selected watersheds. The course will explore emerging topics pertaining to water and energy that course through rural watersheds, with the goal of interpreting data output from models into an environmental life cycle assessment (LCA) framework. LCA is a systems analysis framework that feeds information on life cycle environmental damages/consequences back into design and decision making. In this way, this course focuses specifically on watershed analysis models and how their output feed into desig.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 320 [Min Grade: B-] and CIVE 330 [Min Grade: B-] and CIVE 240 [Min Grade: B-]

**CIVE 585 Transportation Planning and Capacity 3.0 Credits**
Open to undergraduates. Covers prediction of travel demand; principles of highway and transit capacity; level-of-service concepts; uninterrupted and interrupted flow; traffic characterization by volume, speed, and density; operational analysis and design of freeways, highways, and urban streets; intermodal systems, intelligent transportation systems (its), and mass transit.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 586 Geometric Design of Highways 3.0 Credits**
Open to undergraduates. Covers classification of highway and transit systems with relation to function, funding, ownership, and design; characteristics of design vehicles, drivers, and traffic; elements of design including sight distance, horizontal alignment, and vertical alignment; cross-section and roadside design; and at-grade and separated intersections and interchanges.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 605 Advanced Mechanics Of Material 3.0 Credits**
Open to advanced undergraduates. Covers shear flow and shear center, unsymmetrical bending, torsion of non-circular and open sections, bending of curved beams, stress at a point, and failure theories.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**CIVE 615 Infrastructure Condition Evaluation 3.0 Credits**
This course covers the tools necessary for the inspection and evaluation of infrastructure. Non-destructive testing (NDT) techniques are introduced and applications and limitations of NDT techniques for a variety of structures are illustrated. Also covered are the policies for deter-mining the physical condition and maintenance needs for highway bridges.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is CIVE or major is EGEO.
**Prerequisites:** CIVE 250 [Min Grade: D] and CIVE 520 [Min Grade: C]

**CIVE 632 Advanced Soil Mechanics 3.0 Credits**
Consolidation magnitude and time rate of settlement, secondary compression, mitigating settlement problems, shear strength of cohesive and non-cohesive soils, critical state soil mechanics, undrainied pore pressure response, SHANSEP undrained strength.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 635 Slope Stability and Landslides 3.0 Credits**
Slope process and mass wasting; landslide characteristics, features and terminology; limit equilibrium slope stability analysis, including Bishop, Janbu, Spenser, Morgenstern-Price methods; effects of water on slop stability; dynamic (earthquake) stability analysis methods; introduction to rock slopes, slope stability investigations, and design and repair.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 636 Ground Modification 3.0 Credits**
This course covers the improvement of soil properties to meet project requirements, including surface and in situ technologies: compaction, densification, precompression, stabilization with admixtures, grouting and dewatering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 640 Environmental Geotechnics 3.0 Credits**
This course covers the analysis and control of subsurface exploration, groundwater remediation, pollutant-soil interaction and waste containment barriers and drains.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 650 Geosynthetics I 3.0 Credits**
Open to advanced undergraduates. Presents a basic description of the various products, relevant aspects of polymeric materials, and an overview of each category of geosynthetics. Covers geotextile testing and design on the basis of primary application function: separation, reinforcement, filtration, drainage, barrier, and combined.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**CIVE 651 Geosynthetics II 3.0 Credits**
Continues CIVE 650. Covers design and testing of geogrids for reinforcement applications and geonets for drainage applications. Presents geomembrane design and testing from an applications perspective in the areas of environmental, geotechnical, transportation, and hydraulic engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 650 [Min Grade: C]

**CIVE 652 Geosynthetics III 3.0 Credits**
Continues CIVE 651. Covers design and testing of geosynthetic clay liners as a hydraulic/gas barrier and geopipes as drainage materials in numerous application. Presents geocomposites in separation, reinforcement, filtration, drainage, and barrier applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 651 [Min Grade: C]

**CIVE 660 Hydrology-Stream Flow 3.0 Credits**
Covers precipitation, runoff, evaporation and transpiration, streamflow, floodflow, and minimum flow. Pays special attention to factors affecting water supply and quality.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** CIVE 561 [Min Grade: C]

**CIVE 662 Hydrodynamics I 3.0 Credits**
Covers theory of perfect fluids, Euler's equations of motion, continuity equation and energy equation, velocity potential and stream function, sources and sinks, circulation and vorticity, flow-around bodies and flow in channels, and jet flow.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 663 Hydrodynamics II 3.0 Credits**
Extends the theory of perfect fluids to cover fluid forces and moments on bodies, free streamline theory, and extension of vorticity theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 662 [Min Grade: C]

**CIVE 664 Open Channel Hydraulics 3.0 Credits**
Covers principles of flow in open channels, conservation laws, uniform flow, critical flow, gradually varied flow, backwater computations, channel design, and numerical computation of flows having a free surface.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**CIVE 665 Computational Hydraulics I 3.0 Credits**
This course continues CIVE 664 to cover the application of mathematical and numerical techniques to model complex open channel hydraulic processes. At each stage the fundamental hydraulic principles are reviewed to assure proper construction of a modeling algorithm and to assist in interpretation of results.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE.
**Prerequisites:** CIVE 664 [Min Grade: C] and CIVE 330 [Min Grade: D] and CIVE 341 [Min Grade: D] and CIVE 430 [Min Grade: D]

**CIVE 666 Free Surface Flows 3.0 Credits**
This course extends the concepts of one-dimensional open channel flow to cover both the physical under-standing and the application of mathematical and numerical techniques to model very complex open channel hydraulics problems including transients, countercurrent flows and complex boundary conditions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE.
**Prerequisites:** CIVE 664 [Min Grade: C] and CIVE 665 [Min Grade: C]

**CIVE 701 Structural Analysis I 3.0 Credits**
Covers basic principles of structural analysis, including elastic deflection; elastic analysis of statically indeterminate structures by methods of virtual work, Castigliano's theorems, and moment distribution; and the Muller-Breslau principle and application to influence lines for continuous members and frames. Introduces numerical techniques.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 702 Structural Analysis II 3.0 Credits**
Covers matrix analysis of structures using finite elements, including elastic analysis of structures by influence coefficients, Argyris force method, direct stiffness method, and the displacement method. Introduces the finite-element method for planar structures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 701 [Min Grade: C]

**CIVE 703 Structural Analysis III 3.0 Credits**
Covers development of stiffness functions for planar and three-dimensional finite elements, and application to frame, plate, shell, and massive structures. Introduces the general application of finite elements to continuum problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 702 [Min Grade: C]

**CIVE 704 Behavior and Stability of Structural Members I 3.0 Credits**
Covers development of the basic differential equations of member behavior, including second-order effects, in-plane beam-column behavior, column buckling, elastic and inelastic behavior, energy methods, and approximate methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 705 Behavior and Stability of Structural Members II 3.0 Credits**
Covers general torsion of thin-walled open, closed, and combined open-and-closed cross-sections; lateral torsional buckling; biaxial bending; elastic and inelastic behavior; approximate methods; and frame buckling.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 704 [Min Grade: C]

**CIVE 710 Design and Structure of Integrity Building Systems 3.0 Credits**
Covers integration of design and building cycle, building envelope, structural morphology, composite structures, thermal and moisture design, fire and smoke, sound and vibration, building failure, and repair and restoration.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 711 Engineered Masonry I 3.0 Credits**
Covers masonry materials, structural behavior of masonry assemblages, and deformational characteristics of brick and block masonry; performance of load-bearing wall systems and design of unreinforced masonry elements; and special design and construction topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 712 Engineered Masonry II 3.0 Credits**
Covers fundamental concepts of reinforced masonry, reinforced wall design, column and pilaster design, seismic resistance of masonry structures, prestressed masonry, and applied design of low-and high-rise buildings.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 714 Behavior of Concrete Structures I 3.0 Credits**
Covers reinforced concrete members; relationship between results of research and current specifications for design of members subjected to axial loads, flexure, combined axial load and flexure, combined shear and flexure, long columns, bond and anchorage, and limit design; application to design of determinate and indeterminate reinforced concrete frames; and development of current code provisions for design of floor slabs in buildings.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 715 Behavior of Concrete Structures II 3.0 Credits**
Continues CIVE 714.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 714 [Min Grade: C]

**CIVE 717 Behavior of Metal Structures I 3.0 Credits**
Covers load and resistance factor design, including tension, bolted and welded connections, block-shear, compression, built-up compression members, lateral-torsional instability, light-gauge metal buckling and post-buckling strength, and behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 605 [Min Grade: C]

**CIVE 718 Behavior of Metal Structures II 3.0 Credits**
Covers load and resistance factor design, including design and behavior of metal structural members and connections, flexural members including plate girders, bracing and lateral-torsional buckling resistance, torsion and other combined loading, and composite beams and columns.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 717 [Min Grade: C]

**CIVE 719 Behavior of Metal Structures III 3.0 Credits**
Covers load and resistance factor design, including idealization and design of structures and their connections, frame bracing and sway, frame design philosophy, optimization, fatigue, and fracture.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 718 [Min Grade: C]

**CIVE 730 Experimental Soil Mechanics I 3.0 Credits**
Covers methods and techniques of soil testing, including interpretation and evaluation of test data, and fundamentals of soil behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: D]

**CIVE 731 Experimental Soil Mechanics II 3.0 Credits**
Continues CIVE 730.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: C]

**CIVE 732 Experimental Soil Mechanics III 3.0 Credits**
Continues CIVE 731.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 731 [Min Grade: C]

**CIVE 737 Seismic Geotechnics 3.0 Credits**
Introduction to earthquake hazards and seismology; strong ground motion parameters, deterministic and probabilistic seismic hazard analysis, influence of subsurface conditions and topography and ground motion, soil liquefaction, and brief coverage of seismic slop stability, design of retaining structures, and soil-structure interaction.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: C]

**CIVE 752 Coastal Structures 3.0 Credits**
This course briefly reviews the functional design of costal and port structures and deals in detail with forces on those structures. Forces caused by waves and currents, and mooring and vessel impacts are addressed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 563 [Min Grade: C]

**CIVE 754 Properties and Processes of Polymeric Construction Materials 3.0 Credits**
This course focuses on the uses and characteristics of polymeric materials used in civil and architectural engineering infrastructure. Also covered are micro-structure, physical and chemical properties and mechanical behavior. and the effects of manufacturing on the properties of the products.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is CIVE or major is MATE.
**Prerequisites:** CIVE 250 [Min Grade: D] and TDEC 211 [Min Grade: D]

**CIVE 755 Durability of Polymeric Construction Materials 3.0 Credits**
This is a continuation of CIVE 754 and concentrates on protecting and predicting service lifetimes. It covers physical aging, mechanical stabilization and chemical degradation of polymeric materials and the products in which they are incorporated for field use. Covered in this course is the fundamental degradation mechanisms of different polymeric materials commonly used in Civil Engineering practice. Also covered are test methods and extrapolation methodologies for predicting long-term performance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 754 [Min Grade: C]

**CIVE 756 Evaluation of Polymeric Construction Materials 3.0 Credits**
This lab course is designed to integrate and extend the coverage of CIVE 754 and 755 so that students have a full concept of the behavior of polymeric construction materials. A series of thermal analysis and physical, chemical, and mechanical tests are included. The stress relaxation, stress cracking, oxidation, and applications of test results in infrastructure and environ-mental applications are discussed, including problems in comparative analysis of test results and their implications in design and specification.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 754 [Min Grade: D] and CIVE 755 [Min Grade: D]

**CIVE 767 Surface Water Mixing Processes 3.0 Credits**
This course covers hydrodynamic mixing and transport processes in free-surface flows. Basic mixing processes including molecular diffusion, turbulent diffusion, and dispersion are also covered. Emphasis will be on the solution of the advection-diffusion equation with various boundary conditions. Additional topics include boundary exchanges, non-ideal mixing in rivers, and analysis of jets and plumes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE or major is ENVE.
**Prerequisites:** CIVE 664 [Min Grade: C]

**CIVE 768 Sediment and Contaminate Transport 3.0 Credits**
This course covers the transport of sediments and reactive solutes in surface waters. Reviewed is the classic theory for bed-load and suspended sediment transport; interplay of stream flow, frictional resistance and sediment transport. Biogeochemical processes that influence contaminant mobility and integration of physical and chemical processes in contaminant transport models are also discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE or major is ENVE.
**Prerequisites:** ENVE 767 [Min Grade: C] or CIVE 767 [Min Grade: C]

**CIVE 790 Special Topics 9.0 Credits**
Covers selected advanced-level topics in civil engineering. May be repeated for credit if topics vary.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 799 Independent Study 12.0 Credits**
Independent study on a topic selected by the student. Independent study is supervised by a faculty member and guided by a plan of study.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 801 Dynamics of Structures I 3.0 Credits**
Covers formulation of equations of motion, including generalized single-degree-of-freedom systems, free vibration response, undamped and damped systems, harmonic analysis, resonance and vibration isolation, response to periodic loading, impulsive loading, response to general dynamic loading, non-linear structural response, and Rayleigh's method and other variational techniques. Introduces multi-degree-of-freedom systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 802 Dynamics of Structures II 3.0 Credits**
Covers formulation of multi-degree-of-freedom equations of motion, including evaluation of structural property matrices; elastic properties, mass properties, damping, and external loading; geometric stiffness; undamped free vibrations; analysis of dynamic response; practical vibration analysis; Stodola method; Holzer method; reduction of degrees of freedom; matrix iteration and other techniques; analysis of non-linear systems; variational formulation of the equations of motion; partial differential equations of motion; and free vibrations of beams.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 801 [Min Grade: C]

**CIVE 803 Dynamics of Structures III 3.0 Credits**
Covers distributed parameter dynamic systems, equations of motion, free and forced vibrations, analysis of structural response to earthquakes, seismological background, deterministic analysis of single-degree-of-freedom and multi-degree systems, multi-degree-of-freedom and distributive parameter systems, soil-structure interaction, non-linear response to earthquakes and current design code requirements, dynamics of complex structures, modeling, and use of large computer codes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 811 Plates and Shells I 3.0 Credits**
Covers analysis of circular, rectangular, and continuous plates by classical and approximate methods, including the folded plate theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 812 Plates and Shells II 3.0 Credits**
Covers the general theory of thin shells, cylindrical shells, surfaces of revolution, hyperbolic paraboloids, and other shells of double curvature.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 811 [Min Grade: C]

**CIVE 813 Plates and Shells III 3.0 Credits**
Covers buckling and vibration analysis, including application of finite-elements methods and anisotropic behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 812 [Min Grade: C]

**CIVE 831 Deep Foundations 3.0 Credits**
Covers topics including mat foundation design using plate theory, continuous beam design using beam-on-elastic foundation theory, and pile design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 833 Earth Retaining Structures 3.0 Credits**
Covers lateral earth pressure theories, analysis and design of temporary and permanent retaining structures, surcharge load, excavations, and loads on buried conduits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 838 Soil Behavior 3.0 Credits**
Particle-scale behavior of soil and assemblages; clay mineralogy; soil formation, composition, structure and properties; soil water interaction; clay-water-electrolyte systems, adsorption-desorption and ion exchange; conduction phenomena; micromechanics; volume change behavior; strength and deformation behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: C]

**CIVE 839 Geomechanics Modeling 3.0 Credits**
This course covers constitutive laws in goemechanics, including linear elastic, quasi-linear (hyperbolic) elastic, linear elastic-perfectly plastic and elasto-plastic models based on critical state soil mechanics. The finite element method is used to solve geotechnical boundary value problems incorporating different constitutive models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: C]

**CIVE 898 Master's Thesis 0.5-20.0 Credits**
Involves investigation of an approved topic. Required of full-time master's degree students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 997 Research 1.0-12.0 Credit**
Research.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 998 Ph.D. Dissertation 1.0-12.0 Credit**
Involves investigation of an approved topic. Required of Ph.D. students.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

## Civil, Architectural Environmental Engr Courses

# Computer Engineering

*Master of Science in Computer Engineering (MSCPE): 45.0 - 48.0 quarter credits*
*PhD: 90.0 quarter credits*

## About the Program

The computer engineering curriculum is designed to: (1) address the needs of students with a variety of different backgrounds; (2) ensure that graduates will have adequate knowledge and skills in at least one area of specialization; (3) meet the immediate needs of working students as well as to adequately prepare full-time students for a real-world technological environment; and (4) equip students with tools to grasp and develop new technologies and trends.

The Master of Science in Computer Engineering degree requires a minimum of 45.0 approved credits chosen in accordance with a plan of study arranged in consultation with the student's advisor and the departmental graduate advisor. Up to but not exceeding 9.0 research/ thesis credits may be taken by students who choose to write a master's thesis. Students who elect a non-thesis option are also encouraged to engage in research, by registering for supervised research credits (not to exceed 9.0 credits).

For more information, visit the Department of Electrical and Computer Engineering (http://www.ece.drexel.edu) web site.

## Admission Requirements

Applicants should preferably have an undergraduate degree equivalent to a US bachelor's degree in computer engineering, computer science, or electrical engineering. Students holding degrees in other engineering and science disciplines with appropriate coursework or training will also be considered.

Appropriate coursework includes experience with all of the following: Software (advanced programming and operating systems); Computer Architecture (digital systems design, computer organization and architecture); Algorithms and Data Structures; Computer Networks. Students must have a minimum 3.0 GPA (on a 4.0 scale) for the last two years of undergraduate studies, as well as for any subsequent graduate-level work.

The GRE General Test is required of applicants to full-time MS and PhD programs. Students whose native language is not English and who do not hold a degree from a US institution must take the Test of English as a Foreign Language (TOEFL).

For additional information on how to apply, visit Drexel's Admissions page for Computer Engineering (http://www.drexel.edu/grad/programs/coe/ computer-engineering) .

## Master of Science in Computer Engineering

The Master of Science in Computer Engineering curriculum encompasses 45.0 or 48.0 (with the Graduate Co-op option) approved credit hours, chosen in accordance with the following requirements and a plan of study arranged with the departmental graduate advisor in consultation with the student's research advisor, if applicable. Before the end of the first quarter in the Department of Electrical and Computer Engineering, for a full-time student, or by the end of the first year for a part-time student, said plan of study must be filed and approved with the departmental graduate advisor.

A total of at least 30.0 credit hours must be taken from among the graduate course offerings of the Department of Electrical and Computer Engineering. These credits must be taken at Drexel University. No transfer credit may be used to fulfill these requirements, regardless of content equivalency.

The remaining courses needed to reach the minimum credit hour requirement for the degree program are considered elective courses. Elective courses can be chosen from among the graduate course offerings of the Department of Electrical and Computer Engineering; other departments within the College of Engineering; the School of Biomedical Science, Engineering and Health Systems; the Department of Mathematics; the Department of Physics; the Department of Chemistry and the Department of Biology. In order to have courses outside of these departments and schools count towards degree completion, they must be approved by the departmental graduate advisors prior to registration for said courses.

Please note that ECEC 500 (Fundamentals of Computer Hardware) and ECEC 600 (Fundamentals of Computer Networks) do **not** count toward

the credit requirements to complete the MS in Electrical Engineering degree program.

| | |
|---|---|
| Computer Engineering (ECEC) Courses | 21.0 |
| General Electrical and Computer Engineering (ECEC, ECEE, ECEP, ECES, ECET) Courses | 9.0 |
| Elective Courses | 15.0 |
| **Total Credits** | **45.0** |

## Options for Degree Fulfillment

Although not required, students are encouraged to complete a Master's Thesis as part of the MS studies. Those students who choose the thesis option may count up to 9.0 research/thesis credits as part of their required credit hour requirements.

Students may choose to participate in the Graduate Co-Op Program, where 6.0 credit hours can be earned for a six month co-operative education experience in industry, working on curriculum related projects. The total number of required credit hours is increased to 48.0 for those students who choose to pursue the Graduate Co-Op option. This change represents an increase in non-departmental required credit hours to a total of 18.0 credit hours, 6.0 of which are earned from the cooperative education experience.

For more information on curricular requirements, visit the Department of Electrical and Computer Engineering' (http://www.ece.drexel.edu) s web site.

# PhD in Electrical Engineering

## General Requirements

The following general requirements must be satisfied in order to complete the PhD in Electrical Engineering:

- 90.0 credit hours total
- candidacy examination
- research proposal
- dissertation defense

Students entering with a master's degree in electrical or computer engineering or a related field will be considered a post-masters PhD student and will only be required to complete a total of 45.0 credit hours, in accordance with University policy.

## Curriculum

Appropriate coursework is chosen in consultation with the student's research advisor. A plan of study must be developed by the student to encompass the total number of required credit hours. Both the departmental graduate advisor and the student's research advisor must approve this plan.

## Candidacy Examination

The candidacy examination explores the depth of understanding of the student in his/her specialty area. The student is expected to be familiar with, and be able to use, the contemporary tools and techniques of the field and to demonstrate familiarity with the principal results and key findings.

The student, in consultation with his/her research advisor, will declare a principal technical area for the examination. The examination includes the following three parts:

- A self-study of three papers from the archival literature in the student's stated technical area, chosen by the committee in consultation with the student.

- A written report (15 pages or less) on the papers, describing their objectives, key questions and hypotheses, methodology, main results and conclusions. Moreover, the student must show in an appendix independent work he/she has done on at least one of the papers – such as providing a full derivation of a result or showing meaningful examples, simulations or applications.

- An oral examination which takes the following format:

  - A short description of the student's principal area of interest (5 minutes, by student).
  - A review of the self-study papers and report appendix (25-30 minutes, by students).
  - Questions and answers on the report, the appendix and directly related background (40-100 minutes, student and committee).

In most cases, the work produced during the candidacy examination will be a principal reference for the student's PhD dissertation; however, this is not a requirement.

## Research Proposal

Each student, after having attained the status of PhD Candidate, must present a research proposal to a committee of faculty and industry members, chosen with his/her research advisor, who are knowledgeable in the specific area of research. This proposal should outline the specific intended subject of study; i.e., it should present a problem statement, pertinent background, methods of study to be employed, expected difficulties and uncertainties and the anticipated form, substance and significance of the results.

The purpose of this presentation is to verify suitability of the dissertation topic and the candidate's approach, and to obtain the advice and guidance of oversight of mature, experienced investigators. It is not to be construed as an examination, though approval by the committee is required before extensive work is undertaken. The thesis proposal presentation must be open to all; announcements regarding the proposal presentation must be made in advance.

The thesis advisory committee will have the sole responsibility of making any recommendations regarding the research proposal. It is strongly recommended that the proposal presentation be given as soon as possible after the successful completion of the candidacy examination.

## Dissertation Defense

Dissertation Defense procedures are described in the Office of Graduate Studies policies regarding Doctor of Philosophy Program Requirements (http://www.drexel.edu/provost/graduatestudies) . The student must be a PhD candidate for at least one year before he/she can defend his/her doctoral thesis.

## Dual Degree

The ECE Department offers outstanding students the opportunity to receive two diplomas (BS and MS) at the same time. The program requires five (5) years to complete. Participants, who are chosen from

the best undergraduates students, work with a faculty member on a research project and follow a study plan that includes selected graduate classes. This program prepares individuals for careers in research and development; many of its past graduates continued their studies toward a PhD.

For more information on eligibility, academic requirements, and tuition policy visit the Engineering Combined BS/MS (http://www.ece.drexel.edu/undergrad/bsms.html) page.

# Facilities

Drexel University and the Electrical and Computer Engineering Department are nationally recognized for a strong history of developing innovative research. Research programs in the ECE Department prepare students for careers in research and development, and aim to endow graduates with the ability to identify, analyze, and address new technical and scientific challenges. The ECE Department is well equipped with state-of-the-art facilities in each of the following ECE Research laboratories:

## Research Laboratories at the ECE Department

### Adaptive Signal Processing and Information Theory Research Group

The Adaptive Signal Processing and Information Theory Research Group (http://www.ece.drexel.edu/walsh/aspitrg/home.html) conducts research in the area of signal processing and information theory. Our main interests are belief/expectation propagation, turbo decoding and composite adaptive system theory. We are currently doing projects on the following topics:
i) Delay mitigating codes for network coded systems,
ii) Distributed estimation in sensor networks via expectation propagation,
iii) Turbo speaker identification,
iv) Performance and convergence of expectation propagation,
v) Investigating bounds for SINR performance of autocorrelation based channel shorteners.

### Applied Networking Research Lab

Applied Networking Research Lab (ANRL) projects focus on modeling and simulation as well as experimentation in wired, wireless and sensor networks. ANRL is the home of MuTANT, a Multi-Protocol Label Switched Traffic Engineering and Analysis Testbed composed of 10 high-end Cisco routers and several PC-routers, also used to study other protocols in data networks as well as automated network configuration and management. The lab also houses a sensor network testbed.

#### Bioimage Laboratory

Uses computer gaming hardware for enhanced and affordable 3-D visualization, along with techniques from information theory and machine learning to combine the exquisite capabilities of the human visual system with computational sensing techniques for analyzing vast quantities of image sequence data.

### Data Fusion Laboratory

The Data Fusion Laboratory investigates problems in multisensory detection and estimation, with applications in robotics, digital communications, radar, and target tracking. Among the projects in progress: computationally efficient parallel distributed detection architectures, data fusion for robot navigation, modulation recognition and RF scene analysis in time-varying environments, pattern recognition in biological data sequences and large arrays, and hardware realizations of data fusion architectures for target detection and target tracking.

### Drexel Network Modeling Laboratory

The Drexel Network Modeling Laboratory investigates problems in the mathematical modeling of communication networks, with specific focus on wireless ad hoc networks, wireless sensor networks, and supporting guaranteed delivery service models on best effort and multipath routed networks. Typical methodologies employed in our research include mathematical modeling, computer simulation, and performance optimization, often with the end goal of obtaining meaningful insights into network design principles and fundamental performance tradeoffs.

### Drexel Power-Aware Computing Laboratory

The Power-Aware Computing Lab (http://dpac.ece.drexel.edu) investigates methods to increase energy efficiency across the boundaries of circuits, architecture, and systems. Our recent accomplishments include the Sigil profiling tool, scalable modeling infrastructure for accelerator implementations, microarchitecture-aware VDD gating algorithms, an accelerator architecture for ultrasound imaging, evaluation of hardware reference counting, hardware and operating system support for power-agile computing, and memory systems for accelerator-based architectures.

### Drexel University Nuclear Engineering Education Laboratory

The field of nuclear engineering encompasses a wide spectrum of occupations, including nuclear reactor design, medical imaging, homeland security, and oil exploration. The Drexel University Nuclear Engineering Education Laboratory (DUNEEL) provides fundamental hands on understanding for power plant design and radiation detection and analysis. Software based study for power plant design, as well as physical laboratory equipment for radiation detection, strengthen the underlying concepts used in nuclear engineering such that the student will comprehend and appreciate the basic concepts and terminology used in various nuclear engineering professions. Additionally, students use the laboratory to develop methods for delivering remote, live time radiation detection and analysis. The goal of DUNEEL is to prepare students for potential employment in the nuclear engineering arena.

### Drexel VLSI Laboratory

The Drexel VLSI Laboratory (http://ece.drexel.edu/faculty/taskin/wiki/vlsilab/index.php/Main_Page) investigates problems in the design, analysis, optimization and manufacturing of high performance (low power, high throughput) integrated circuits in contemporary CMOS and emerging technologies. Suited with industrial design tools for integrated circuits, simulation tools and measurement beds, the VLSI group is involved with digital and mixed-signal circuit design to verify the functionality of the discovered novel circuit and physical design principles. The Drexel VLSI laboratory develops design methodologies and automation tools in these areas, particularly in novel clocking techniques, featuring resonant clocking, and interconnects, featuring wireless interconnects.

### Drexel Wireless Systems Laboratory

The Drexel Wireless Systems Laboratory (DWSL) contains an extensive suite of equipment for constructing, debugging, and testing prototype wireless communications systems. Major equipment within DWSL includes:

- three software defined radio network testbeds (HYDRA, USRP, and WARP) for rapidly prototyping radio, optical and ultrasonic communications systems,
- a TDK RF anechoic chamber and EMSCAN desktop antenna pattern measurement system,
- a materials printer and printed circuit board milling machine for fabricating conformal antennas and
- wireless protocol conformance testing equipment from Aeroflex.

The lab is also equipped with network analyzers, high speed signal generators, oscilloscopes, and spectrum analyzers as well as several Zigbee development platforms for rapidly prototyping sensor networks.

DWSL personnel also collaborate to create wearable, fabric based transceivers through collaboration with the Shima Seiki Haute Laboratory in the Drexel ExCITe Center. The knitting equipment at Drexel includes sixteen SDS-ONE APEX3 workstations and four state-of-the-art knitting machines. The workstations accurately simulate fabric construction and provide researchers and designers the opportunity to program, create and simulate textile prototypes, import CAD specifications of final products, and produce made-to-measure or mass-produced pieces on Shima Seiki knitting machines. For testing smart textiles for biomedical, DWSL personnel also have collaborators in the Center for Interdisciplinary Clinical Simulation and Practice (CICSP) in the Drexel College of Medicine which provides access to medical mannequin simulators.

## Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (EESI) (http://www.ece.drexel.edu/gailr/EESI) seeks to solve problems in high-throughput genomics and engineer better solutions for biochemical applications. The lab's primary thrust is to enhance the use of high-throughput DNA sequencing technologies with pattern recognition and signal processing techniques. Applications include assessing the organism content of an environmental sample, recognizing/classifying potential and functional genes, inferring environmental factors and inter-species relationships, and inferring microbial evolutionary relationships from short-read DNA/RNA fragments. The lab also investigates higher-level biological systems such as modeling and controlling chemotaxis, the movement of cells.

## Electric Power Engineering Center

This newly established facility makes possible state-of-the-art research in a wide variety of areas, ranging from detailed theoretical model study to experimental investigation in its high voltage laboratories. The mission is to advance and apply scientific and engineering knowledge associated with the generation, transmission, distribution, use, and conservation of electric power. In pursuing these goals, this center works with electric utilities, state and federal agencies, private industries, nonprofit organizations and other universities on a wide spectrum of projects. Research efforts, both theoretical and experimental, focus on the solution of those problems currently faced by the electric power industry. Advanced concepts for electric power generation are also under investigation to ensure that electric power needs will be met at the present and in the future.

## Electronic Design Automation Facility

Industrial-grade electronic design automation software suite and intergrated design environment for digital, analog and mixed-signal systems development. Field Programmable Gate Array (FPGA) development hardware. Most up-to-date FPGA/embedded system development hardware kits. Printed circuit board production facility. Also see Drexel VLSI Laboratory.

## Microwave-Photonics Device Laboratories

The laboratory is equipped with test and measurement equipment for high-speed analog and digital electronics and fiber optic systems. The test equipment includes network analyzers from Agilent (100kHz- 1.3 GHz and 45 Mhz-40 GHz), and Anritsu (45 MHz-6 GHz); spectrum analyzers from Tektronix, HP, and Agilent with measurement capability of DC to 40 GHz and up to 90 GHz using external mixers; signal generators and communication channel modulators from HP, Rhode-Schwartz, Systron Donner, and Agilent; microwave power meter and sensor heads, assortment of passive and active microwave components up to 40 GHz ; data pattern generator and BER tester up to 3Gb/s; optical spectrum analyzer from Anritsu and power meters from HP; single and multimode fiber optic based optical transmitter and receiver boards covering ITU channels at data rates up to 10Gb/s; passive optical components such as isolator, filter, couplers, optical connectors and fusion splicer; LPKF milling machine for fabrication of printed circuit boards; wire-bonding and Cascade probe stations; Intercontinental test fixtures for testing of MMIC circuits and solid-state transistors; state-of-the-art microwave and electromagnetic CAD packages such as Agilent ADS, ANSYS HFSS, and COMSOL multi-physics module.

## Music and Entertainment Technology Laboratory

The Music and Entertainment Technology Laboratory (MET-lab) is devoted to research in digital media technologies that will shape the future of entertainment, especially in the areas of sound and music. We employ digital signal processing and machine learning to pursue novel applications in music information retrieval, music production and processing technology, and new music interfaces. The MET-lab is also heavily involved in outreach programs for K-12 students and hosts the Summer Music Technology program, a one-week learning experience for high school students. Lab facilities include a sound isolation booth for audio and music recording, a digital audio workstation running ProTools, two large multi-touch display interfaces of our own design, and a small computing cluster for distributed processing.

## NanoPhotonics+ Lab (http://drexelnanophotonics.com)

Our research is primarily in the area of nanophotonics with a focus on the nanoscale interaction of light with matter. Interests include: liquid crystal/polymer composites for gratings, lenses and HOEs; liquid crystal interactions with surfaces and in confined nanospaces; alternative energy generation through novel photon interactions; ink-jet printed conducting materials for RF and photonic applications; and the creation and development of smart textiles technologies including soft interconnects, sensors, and wireless implementations.

## Opto-Electro-Mechanical Laboratory

This lab concentrates on the system integration on optics, electronics, and mechanical components and systems, for applications in imaging, communication, and biomedical research. Research areas include: Programmable Imaging with Optical Micro-electrical-mechanical systems (MEMS), in which microscopic mirrors are used to image light into a single photodetector; Pre-Cancerous Detection using White Light Spectroscopy, which performs a cellular size analysis of nuclei in tissue; Free-space Optical Communication using Space Time Coding, which consists of diffused light for computer-to-computer communications, and also tiny lasers and detectors for chip-to-chip communication; Magnetic Particle Locomotion, which showed that particles could swim in a uniform field;

and Transparent Antennas using Polymer, which enables antennas to be printed through an ink-jet printer.

## Plasma and Magnetics Laboratory

Research is focused on applications of electrical and magnetic technologies to biology and medicine. This includes the subjects of non-thermal atmospheric pressure plasma for medicine, magnetic manipulation of particles for drug delivery and bio-separation, development of miniature NMR sensors for cellular imaging and carbon nanotube cellular probes.

## Power Electronics Research Laboratory

The Power Electronics Research Laboratory (PERL) is involved in circuit and design simulation, device modeling and simulation, and experimental testing and fabrication of power electronic circuits. The research and development activities include electrical terminations, power quality, solar photovoltaic systems, GTO modeling, protection and relay coordination, and solid-state circuit breakers. The analysis tools include EMPT, SPICE, and others, which have been modified to incorporate models of such controllable solid-state switches as SCRs, GTOs, and MOSFETs. These programs have a wide variety and range of modeling capabilities used to model electromagnetics and electromechanical transients ranging from microseconds to seconds in duration. The PERL is a fully equipped laboratory with 42 kVA AC and 70 kVA DC power sources and data acquisition systems, which have the ability to display and store data for detailed analysis. Some of the equipment available is a distribution and HV transformer and three phase rectifiers for power sources and digital oscilloscopes for data measuring and experimental analysis. Some of the recent studies performed by the PERL include static VAR compensators, power quality of motor controllers, solid-state circuit breakers, and power device modeling which have been supported by PECO, GE, Gould, and EPRI.

## RE Touch Lab

The RE Touch Lab is investigating the perceptual and mechanical basis of active touch perception, or haptics, and the development of new technologies for stimulating the sense of touch, allowing people to touch, feel, and interact with digital content as seamlessly as we do with objects in the real world. We study the scientific foundations of haptic perception and action, and the neuroscientific and biomechanical basis of touch, with a long-term goal of uncovering the fundamental perceptual and mechanical computations that enable haptic interaction. We also create new technologies for rendering artificial touch sensations that simulate those that are experienced when interacting with real objects, inspired by new findings on haptic perception.

## Testbed for Power-Performance Management of Enterprise Computing Systems

This computing testbed is used to validate techniques and algorithms aimed at managing the performance and power consumption of enterprise computing systems. The testbed comprises a rack of Dell 2950 and Dell 1950 PowerEdge servers, as well as assorted desktop machines, networked via a gigabit switch. Virtualization of this cluster is enabled by VMWare's ESX Server running the Linux RedHat kernel. It also comprises of a rack of ten Apple Xserve machines networked via a gigabit switch. These servers run the OS X Leopard operating systems and have access to a RAID with TBs of total disk capacity.

# Electrical and Computer Engineering Faculty

Suryadevara Basavaiah, PhD *(University of Pennsylvania).* Teaching Professor. Computer engineering; computer engineering education; custom circuit design; VLSI technology; process and silicon fabrication.

Tom Chmielewski, PhD *(Drexel University).* Assistant Teaching Professor. Modeling and simulation of electro-mechanical systems; Optimal, Adaptive and Non-Linear Control; DC Motor Control; System Identification; Kalman Filters (Smoothing Algorithms, tracking); image processing, Robot design; Biometric technology and design of embedded systems for control applications utilizing MATLAB and SIMULINK

Fernand Cohen, PhD *(Brown University).* Professor. Surface modeling; tissue characterization and modeling; face modeling; recognition and tracking.

Andrew Cohen, PhD *(Rensselaer Polytechnic Institute).* Associate Professor. Image processing; multi-target tracking; statistical pattern recognition and machine learning; algorithmic information theory; 5-D visualization.

Kapil Dandekar, PhD *(University of Texas-Austin) Director of the Drexel Wireless Systems Laboratory (DWSL); Associate Dean of Research, College of Engineering.* Professor. Cellular/mobile communications and wireless LAN; smart antenna/MIMO for wireless communications; applied computational electromagnetics; microwave antenna and receiver development; free space optical communication; ultrasonic communication; sensor networks for homeland security; ultrawideband communication.

Afshin Daryoush, PhD *(Drexel University).* Professor. Microwave photonics systems; nonlinear microwave circuits; RFIC and wireless communications; antennas and radiating systems; electromagnetic interaction with biological systems.

Bruce A. Eisenstein, PhD *(University of Pennsylvania) Arthur J. Rowland Professor of Electrical and Computer Engineering; Vice Dean, College of Engineering.* Professor. Pattern recognition; estimation; decision theory; digital signal processing.

Adam K. Fontecchio, PhD *(Brown University) Associate Dean for Undergraduate Affairs; Associate Director, Expressive and Creative Interactive Technologies (EXCITE) Center.* Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park).* Professor. Biological and biomedical applications of nanoscale magnetic systems.

Eli Fromm, PhD *(Jefferson Medical College) Roy A. Brothers University Professor / Director for Center of Educational Research.* Professor. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania) Assistant EDE Department Head; Liason for Evening Programs.* Professor. Computerized instruments and measurements; undergraduate engineering education.

Allon Guez, PhD *(University of Florida).* Professor. Intelligent control systems; robotics, biomedical, automation and manufacturing; business systems engineering.

Mark Hempstead, PhD *(Harvard University) Junior Colehower Chair.* Assistant Professor. Computer engineering; power-aware computing; computer architecture; low power VLSI Design; wireless sensor networks.

Peter R. Herczfeld, PhD *(University of Minnesota) Lester A. Kraus Professor/Director, Center for Microwave/Lightwave Engineering.* Professor. Lightwave technology; microwaves; millimeter waves; fiberoptic and integrated optic devices.

Leonid Hrebien, PhD *(Drexel University).* Professor. Tissue excitability; acceleration effects on physiology; bioinformatics.

Paul R. Kalata, PhD *(Illinois Institute of Technology).* Associate Professor. Stochastic and adaptive control theory; identification and decision theory; Kalman filters.

Nagarajan Kandasamy, PhD *(University of Michigan).* Associate Professor. Embedded systems, self-managing systems, reliable and fault-tolerant computing, distributed systems, computer architecture, and testing and verification of digital systems.

Bruce Katz, PhD *(University of Illinois).* Adjunct Professor. Neural networks; the study of aesthetics; artificial intelligence; music perception.

Youngmoo Kim, PhD *(Massachusetts Institutie of Technology) Director, Expressive and Creative Interaction Technologies (EXCITE) Center.* Associate Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Timothy P. Kurzweg, PhD *(University of Pittsburgh) Associate Department Head for Undergraduate Studies and Director of the BSE Program.* Associate Professor. Optical MEM modeling and simulation; system-level simulation; computer architecture.

Mohammad Madihian, PhD *(Shizuoka University).* Adjunct Professor. Solid-state device-circuit interaction; microwave and millimeter-wave monolithic circuit design and evaluation technology; solid-state power generation/amplification/mixing technology; single/multi-mode wireless RF/IF transceiver technology

Karen Miu, PhD *(Cornell University).* Professor. Power systems; distribution networks; distribution automation; optimization; system analysis.

Bahram Nabet, PhD *(University of Washington).* Professor. Optoelectronics; fabrication and modeling; fiber optic devices; nanoelectronics; nanowires.

Prawat Nagvajara, Ph.D. *(Boston University).* Associate Professor. System on a chip; embedded systems; power grid computation; testing of computer hardware; fault-tolerant computing; VLSI systems; error control coding.

Vasileios Nasis, PhD *(Drexel University).* Associate Teaching Professor. Imaging with MOEMS, Projection systems using MEMS/MOEMS, Wireless communications, Remote monitoring, sensor networks.

Dagmar Niebur, PhD *(Swiss Federal Institute of Technology).* Associate Professor. Intelligent systems; dynamical systems; power system monitoring and control.

Chika Nwankpa, PhD *(Illinois Institute of Technology) Interum Department Head.* Professor. Power system dynamics; power electronic switching systems; optically controlled high power switches.

Christopher Peters, PhD *(University of Michigan, Ann Arbor).* Teaching Professor. Nuclear reactor design; ionizing radiation detection; nuclear forensics; power plant reliability and risk analysis; naval/marine power and propulsion; directed energy/high power microwaves; nonstationary signal processing; radar; electronic survivability/susceptibility to harsh environments; electronic warfare.

Karkal S. Prahbu, PhD *(Harvard University).* Teaching Professor. Computer and software engineering; advanced microprocessors and distributed operating systems.

Gail L. Rosen, PhD *(Georgia Institute of Technology).* Associate Professor. Signal processing, signal processing for biological analysis and modeling, bio-inspired designs, source localization and tracking.

Ioannis Savidis, PhD *(University of Rochester) Director of the Integrated Circuits and Electronics (ICE) Design and Analysis Laboratory.* Assistant Professor. Analysis, modeling, and design methodologies for high performance digital and mixed-signal integrated circuits; Emerging integrated circuit technologies; Electrical and thermal modeling and characterization, signal and power integrity, and power and clock delivery for 3-D IC technologies.

Kevin J. Scoles, PhD *(Dartmouth College).* Associate Professor. Microelectronics; electric vehicles; solar energy; biomedical electronics.

Harish Sethu, PhD *(Lehigh University).* Associate Professor. Protocols, architectures and algorithms in computer networks; computer security; mobile ad hoc networks; large-scale complex adaptive networks and systems.

James Shackleford, PhD *(Drexel University).* Assistant Professor. Medical image processing, high performance computing, embedded systems, computer vision, machine learning.

P. Mohana Shankar, PhD *(Indian Institute of Technology) Allen Rothwarf Professor of Electrical and Computer Engineering.* Professor. Wireless communications; biomedical ultrasonics; fiberoptic bio-sensors.

Matthew Stamm, PhD *(University of Maryland, College Park) Head, Multimedia and Information Security Laboratory (MSL).* Assistant Professor. Information Security; Multimedia Forensics and Anti-Forensics; Information Verification; Adversarial Dynamics; Signal Processing.

Baris Taskin, PhD *(University of Pittsburgh).* Associate Professor. Electronic design automation (EDA) of integrated circuits, high-performance VLSI circuits and systems, sequential circuit timing and synchronization, system-on-chip (SOC) design, operational research, VLSI computer-aided design.

Lazar Trachtenberg, DSc *(Israel Institute of Technology).* Professor. Fault tolerance; multi-level logic synthesis; signal processing; suboptimal filtering.

Yon Visell, PhD *(McGill University).* Assistant Professor. Haptic display engineering, material and biomechanical contact physics, neuroscientific and physical basis of human tactile sensation/perception, haptic human-machine interaction, sensorimotor learning, interaction in virtual reality

John Walsh, PhD *(Cornell University).* Associate Professor. Performance and convergence of belief/expectation propagation and turbo decoding/equalization/synchronization, permeation models for ion channels, composite adaptive systems theory.

Steven Weber, PhD *(University of Texas-Austin) Assistant Department Head for Graduate Affairs, Electrical and Computer Engineering.* Associate Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice Cavalcante de Oliveira, PhD *(Georgia Institute of Technology).* Associate Professor. Next generation Internet; quality of service in computer communication networks; wireless networks.

## Interdepartmental Faculty

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine.* Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Jeremy R. Johnson, PhD *(Ohio State University).* Professor. Computer algebra; parallel computations; algebraic algorithms; scientific computing.

John Lacontora, PhD *(New Jersey Institute of Technology).* Associate Research Professor. Service engineering; industrial engineering.

Ryszard Lec, PhD *(University of Warsaw Engineering College).* Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Spiros Mancoridis, PhD *(University of Toronto) Sr. Associate Dean for Computing and CCI Academic Affairs.* Professor. Software engineering; software security; code analysis; evolutionary computation.

Karen Moxon, PhD *(University of Colorado).* Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Paul Y. Oh, PhD *(Columbia University).* Adjunct Professor. Smart sensors servomechanisms; machine vision and embedded microcomputers for robotics and mechatronics.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems.* Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University).* Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

William C. Regli, PhD *(University of Maryland-College Park).* Professor. Artificial intelligence; computer graphics; engineering design and Internet computing.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering.* Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering.* Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces; scanning probe microscopy; laser spectroscopy, including Raman scattering.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems.* Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Aspasia Zerva, PhD *(University of Illinois).* Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

## Emeritus Faculty

Robert Fischl, PhD *(University of Michigan) John Jarem Professor Emeritus / Founder of the Center for Electric Power Engineering.* Professor Emeritus. Power: systems, networks, controls, computer-aided design, power systems, solar energy.

Vernon L. Newhouse, PhD *(University of Leeds) Disque Professor Emeritus.* Professor Emeritus. Biomedical and electrophysics: ultrasonic flow measurement, imaging and texture analysis in medicine, ultrasonic nondestructive testing and robot sensing, clinical engineering.

Hun H. Sun, PhD *(Cornell University) Ernest O. Lange Professor Emeritus.* Professor Emeritus. Systems and signals in biomedical control systems.

Oleh Tretiak, ScD *(MIT).* Professor Emeritus. Image processing; tomography; image registration; pattern recognition.

## Elec Comp Engr-Computers Courses

### ECEC 500 Fundamentals Of Computer Hardware 3.0 Credits
Covers computer organization and architecture; elements of computer hardware, processors, control units, and memories; hardware for basic mathematical operations; tradeoffs between speed and complexity; examples of embedded systems; microcontrollers; systems modeling.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 501 Computational Principles of Representation and Reasoning 3.0 Credits
This course presents fundamentals of discrete mathematics as applied within the computer engineering and manufacturing environment. Students are given the theoretical background in representation and reasoning for a broad variety of engineering problems solving situations. Entity-relational techniques of representation are demonstrated to evolve into the object-oriented approach. Various search techniques are applied in the cases of representing engineering systems by using theory of automata techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 502 Principles of Data Analysis 3.0 Credits
This course presents theoretical methods and techniques of model development applicable within the computer engineering design and manufacturing environment. Students are given the theoretical background in data analysis (including "data mining"). Emphasis is on hybrid systems and discrete events systems. Various methods of recognizing regularities in data will be presented. Elements of the theory of clustering and classification will be dealt with for the paradigm of software and hardware problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 503 Principles of Decision Making 3.0 Credits**
This course presents theoretical fundamentals and engineering techniques of decision making and problem solving applicable within the computer engineering design and manufacturing environment. Students are given the theoretical background in optimization methods for a broad variety of situation. Elements of the theory of planning and on-line control of systems are presented within the scope of software and hardware computer design and control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 511 Combinational Circuit Design 3.0 Credits**
Representing arithmetic. Logic and syntax data for machine processing. Switching algebra: Boolean and multiple values. Identification and classification of functions. Realizing completely specified and incompletely specified Boolean functions. Issues in designing large communication/control Boolean functions. Fault and testing of Boolean function.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 512 Sequential Circuit Design 3.0 Credits**
Finite automata and their realization by sequential machines, capabilities, transformation, and minimization of finite automata, linear finite automata. Clocked pulsed and level mode sequential circuits. Malfunctions in sequential circuits: hazards, races, lockouts, metastability. Issues of state assignment. Evolution of memory elements design: ROM vs. RAM vs. associative memory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 511 [Min Grade: C]

**ECEC 513 Design for Testability 3.0 Credits**
Economics vs. Complexity vs. Strategy of Testing; Fault Models; Test Generation; Testability Analysis & Designing Testable Circuits; Testing Microprocessors, Memories and Computer Components; Test Data Compression; Fault Tolerant Hardware; Reliably vs. Availability; Redundancy and Error Correcting Codes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 511 [Min Grade: C] and ECEC 512 [Min Grade: C]

**ECEC 520 Dependable Computing 3.0 Credits**
Fundamental design issues involved in building reliable, safety-critical, and highly available systems. Topics include testing and fault-tolerant design of VLSI circuits, hardware and software fault tolerance, information redundancy, and fault-tolerant distributed systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 541 Robotic Computer Interface Controls I 3.0 Credits**
Covers sensors, actuators, mechanical components of robots, kinematics, inverse kinematics, dynamics, and equations of motion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 542 Robotic Computer Interface Controls II 3.0 Credits**
Covers the robot control problem, including PD, PID, position, force and hybrid controllers, resolved rate and acceleration control, and multiprocessor architecture.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 641 [Min Grade: C] and ECES 643 [Min Grade: C] and ECEC 541 [Min Grade: C]

**ECEC 543 Robotic Computer Interface Controls III 3.0 Credits**
Covers non-linear control techniques, FLDT, and advanced topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 542 [Min Grade: C]

**ECEC 571 Introduction to VLSI Design 3.0 Credits**
This is an introductory course where systematic understanding, design and analysis of digital VLSI integrated circuits will be covered. The course will begin with a review of CMOS transistor operation and semiconductor processes. Logic design with CMOS transistor and circuit families will be described. Specifically, layout, design rules, and circuit simulation will be addressed. Performance metrics will be analyzed in design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 572 Custom VLSI Design & Analysis I 3.0 Credits**
This is the first of two courses offered on Custom VLSI circuit and systems design and analysis. An understanding of VLSI integrated circuits is achieved through circuit design and analysis. This course focuses exclusively on high performance digital CMOS VLSI circuit and systems design, although some topics on mixed-signal circuits are also addressed. Design and analysis of VLSI integrated circuits will be covered from the circuits and systems design perspectives. First, a thorough analysis of interconnect networks is presented. The second part of the class focuses on synchronization of high performance ICs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 571 [Min Grade: C]

**ECEC 573 Custom VLSI Design & Analysis II 3.0 Credits**
This is the second of two courses offered on Custom VLSI circuit and systems design and analysis. An understanding of VLSI integrated circuits is achieved through circuit design and analysis. This course focuses exclusively on high performance digital CMOS VLSI circuit and systems design, although some topics on mixed-signal circuits are also addressed. The primary focus is on-chip power management. Power generation techniques are discussed and different power converters are analyzed. Power distribution networks are presented with a focus on the different distribution architectures and output impedance characteristics. Techniques to reduce power supply noise are also provided. A secondary focus examines substrate noise in mixed-signal systems and techniques to reduce substrate noise.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 571 [Min Grade: C]

**ECEC 574 ASIC Design I 3.0 Credits**
This course will focus exclusively on digital CMOS Application Specific Integrated Circuit (ASIC) systems design and automation. The ASIC physical design flow, including logic synthesis, floorplanning, placement, clock tree synthesis, routing and verification will be presented. These back-end physical design flow steps will also be covered through hands-on practice using industrial VLSI CAD tools. Contemporary design practices will be reviewed and presented in experiments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 575 ASIC Design II 3.0 Credits**
Design and analysis of VLSI integrated circuits will be covered from a systems design perspective. System timing, arithmetic building block and memory block design processes will be presented. Design tasks in a quarter-long, small-complexity processor design project will cover the back-end of the IC design flow range, from RTL synthesis to timing and power analysis. Projects will be performed in a hierarchical group, similar to an industrial setting, with other graduate and undergraduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 572 [Min Grade: C]

**ECEC 600 Fundamentals of Computer Networks 3.0 Credits**
Fundamentals design principles of ATM, Internet and local area networks; protocol layers and the Internet Architecture; medium access protocols; application protocols and TCP/IP utilities; basic principles and virtual circuit switching; naming and addressing; flow and congestion control protocols; routing algorithms; Quality-of-Service in computer networks; security issues in networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 621 High Performance Computer Architecture 3.0 Credits**
Maximizing single processor performance. Concepts and techniques for design of computer systems. Processor design, instruction set architecture design and implementation, memory hierarchy, pipelines processors, bus bandwidth, processor/memory interconnections, cache memory, virtual memory, advanced I/O systems, performance evaluation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 622 Parallel Computer Architecture 3.0 Credits**
Advanced techniques of computer design. Use of parallel processing to achieve high performance levels. Fine and coarse grained parallelism. Multiple CPU parallelism, through multiprocessors, array and vector processors. Dataflow architectures and special purpose processors. Design implications of memory latency and bandwidth limitations. Speedup problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 621 [Min Grade: C]

**ECEC 623 Advanced Topics in Computer Architecture 3.0 Credits**
This course teaches advanced concepts of modern computer architecture and introduces the current challenges faced by computer architects. These challenges include power consumption, transistor variability, and processor heterogeneity. Students develop their research skills through a self directed research project with a final presentation and conference style writeup.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 621 [Min Grade: C]

**ECEC 631 Principles of Computer Networking 3.0 Credits**
Principles of circuit switching, packet switching and virtual circuits; protocol layering; application layer protocols for e-mail and web applications; naming and addressing; flow control and congestion avoidance with TCP; Internet Protocol (IP); routing algorithms; router architectures; multicast protocols; local area network technologies and protocols; issues in multimedia transmissions; scheduling and policing; Quality-of-Service and emerging Internet service architectures; principles of cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 632 Performance Analysis of Computer Networks 3.0 Credits**
Covers probability theory and its applications to networks, random variable and random processes; Markov chains, multi-dimensional Markov chains; M/M/1, M/M/m, M/M/m/m, M/G/1 and G/G/1 queueing systems and their applications in computer networks; analysis of networks of queues: Kleinrock Independence Approximation; Time-reversibility and Burke's theorem; Jackson's theorem; the phenomenon of long-range dependence and its implications in network design and traffic engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 631 [Min Grade: C]

**ECEC 633 Advanced Topics in Computer Networking 3.0 Credits**
perspectives in the areas of switch/router architectures, scheduling for best-effort and guaranteed services, QoS mechanisms and architectures, web protocols and applications, network interface design, optical networking, and network economics. The course also includes a research project in computer networking involving literature survey, critical analysis, and finally, an original and novel research contribution.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 631 [Min Grade: C] and ECEC 632 [Min Grade: C]

**ECEC 654 Knowledge Engineering I 3.0 Credits**
Covers conceptual modeling, including an overview of knowledge representation. Includes semantic networks, reduced semantic networks, logic of incomplete knowledge bases, extensional semantic networks, and applications of conceptual models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 655 Knowledge Engineering II 3.0 Credits**
Covers expert systems, including language and tools of knowledge engineering. Includes reasoning about reasoning, design and evaluation, heuristics in expert systems, expert systems for decision support, and expert systems in conceptual design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 654 [Min Grade: C]

**ECEC 656 Knowledge Engineering III 3.0 Credits**
Covers information-intensive systems, including information representation in autonomous systems. Includes clauses and their validation; clustering in linguistic structures; linguistic and pictorial knowledge bases; discovery in mathematics, including am; and methods of new knowledge generation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 655 [Min Grade: C]

**ECEC 661 VLSI Design 3.0 Credits**
Covers CMOS design styles, techniques, and performance; VLSI computer hardware, arithmetic units, and signal processing systems; and cat tools for layout design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 662 VLSI Array Processors I 3.0 Credits**
Covers VLSI testing, including design for testability and parallel computer architectures; signal and image processing algorithms and mapping algorithms onto array structures; and systolic array processors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 661 [Min Grade: C]

**ECEC 663 VLSI Array Processors II 3.0 Credits**
Covers wavefront array processors; matching hardware to arrays; hardware design, systems design, and fault-tolerant design; and implementations and VLSI design projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 662 [Min Grade: C]

**ECEC 671 Electronic Design Automation for VLSI Circuits I 3.0 Credits**
This course focuses on the electronic design automation problems in the design process of VLSI integrated circuits. In this first quarter of the course, algorithms, techniques and heuristics structuring the foundations of contemporary VLSI CAD tools are presented. Boolean algebra, graph theory, logic minimization and satisfiability topics are presented.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 672 Electronic Design Automation for VLSI Circuits II 3.0 Credits**
This course focuses on the electronic design automation problems in the design process of VLSI integrated circuits. In this second quarter of the course, physical VLSI design steps of technology mapping, floor planning, placement, routing and timing and presented individual and team-based small-to-medium scale programming projects are assigned.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 671 [Min Grade: C]

**ECEC 673 Deep Sub-Micron Integrated Circuit Design 3.0 Credits**
This course focuses on the design challenges of digital VLSI integrated circuits in deep sub-micron manufacturing technologies. Automation challenges and high-performance circuit design techniques such as low-power and variation-aware design are presented. The course material is delivered in a lecture format structured on recent presentations, articles, and tutorials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 671 [Min Grade: C]

**ECEC 690 Special Topics Computer Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 697 Research in Computer Engineering 1.0-12.0 Credit**
Research in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 699 Supervised Study in Computer Engineering 9.0 Credits**
Supervised study in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 890 Advanced Special Topics in Computer Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 891 Advanced Topics in Computer Engineering 0.5-9.0 Credits**
Advanced topics in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 898 Master's Thesis in Computer Engineering 1.0-12.0 Credit**
Master's thesis in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 997 Dissertation Research in Computer Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 998 Ph.D. Dissertation in Computer Engineering 1.0-12.0 Credit**
Ph.D. dissertation in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Elec Computer Engr-Electroph Courses

**ECEE 501 Physical Principles of Electrical Engineering I 3.0 Credits**
Core course. Covers classical mechanics, including generalized coordinates, Lagrangian and Hamiltonian formulation, and variational principle. Introduces quantum mechanics, including Schrodinger equation, wave functions, operators, expectation values, and hydrogen atom.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 502 Physical Principles of Electrical Engineering II 3.0 Credits**
Core course. Continues ECEE 501. Covers atomic orbitals, angular momentum, oscillators, time-independent and time-dependent perturbation theories, many-particle wave functions, and optical transitions. Also covers statistical mechanics, including distributions, ensembles, and thermal properties of solids.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 501 [Min Grade: C]

**ECEE 507 Electromagnetic Field Analysis I 3.0 Credits**
Core course. Covers Maxwell's equations; solutions of Laplace's equation, Green's function, and scalar and vector potentials; energy and momentum in electromagnetic fields; and interaction of fields and material media.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 508 Electromagnetic Field Analysis II 3.0 Credits**
Core course. Continues ECEE 507. Covers em waves, including reflection, refraction, polarization, and dispersion. Includes metallic and dielectric guiding structures, guides, and waveguide circuits and applications to stripline, microstrip, and optical fiber transmission systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 507 [Min Grade: C]

**ECEE 510 Scattering & Diffraction of Electromagnetic Waves 3.0 Credits**
Boundary value problems of EM theory. Exact and approximate methods for scattering by spheres, half plane, slit; radar cross-section theory. Quasi-optical theory, scattering, diffraction coefficients. Applications to radio propagation around the earth.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 517 Microwave Networks & Transmission Media 3.0 Credits**
Core course. Atmospheric wave propagation, solution of wave equation without sources in isotropic media, plane-waves, polarization, dispersion surfaces, wave admittance and impedance, wave propagation in free-space and various media, waves at interfaces, solution of wave equation with sources, duality principle, arrays analysis, metallic waveguides, modes in cylindrical waveguides, rectangular and circular, resonant cavities and perturbational methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 518 Microwave Passive Components 3.0 Credits**
Core course. V-I and E-H analogy, Kirchoff's Law, Telegrapher's EQ, voltage and current waves, reflection coefficient and impedance relationship, Smith Chart, impedance matching techniques, Bode-Fano theoretical limit, Broadband Quarter-wave Transformer, N-port linear networks, Z, Y, and S parameters, ABCD and T matrices, signal flow-graph and transfer functions, synthesis of two-port and unitary properties, even-odd mode analysis and dual directional couplers (design and synthesis), periodic structures and Flouke modes, filter design and synthesis using insertion loss and image methods, prototype LO filter and transformation to LP, BP, HP, and BS filters, Richards transform and Kuroda identities.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 519 Microwave Active Subsystems 3.0 Credits**
Core course. Overview of physics of P-N junction and Schottky junctions, pin, varactor, and step recovery diodes and their applications, transistors, MESFET and HEMT, BJT and HBT passive microwave circuits: switches, detectors, attenuators, modulators, and phase shifter, active microwave circuits: LNA, power amplifier, distributed amplifier, oscillators (fixed and VCO) power budget and link performance calculations for telecommunication, radar, and EW systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 520 Solid-State Electronics 3.0 Credits**
This course familiarizes the students with the fundamental properties of semiconductor materials leading to the students of electronic and photonic devices. Covered topics include: atomic structure, crystal structure, theories of electron conduction, scattering, pn junctions, heterojunctions, metal-semiconductor contacts, and junction devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 521 Bipolar and FETs 3.0 Credits**
This is the second course in a sequence of three on electronic and photonic devices. The course covers families of electronic devices. The course covers various families of electronic devices based on silicon and compound semiconductors. Bipolar transistors such as BJTs and HBTs and field-effect devices such as MOSFETs, MESFETs, and MODFETs are studied.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 520 [Min Grade: C]

**ECEE 522 Photonic Devices 3.0 Credits**
Covers fundamentals of absorption, spontaneous, and stimulated emission, photodetectors, light emitting diodes, laser oscillation, semiconductor laser diodes, RIN and phase noise, quantum well lasers, optical receivers, and quantum effect devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 521 [Min Grade: C]

**ECEE 523 Integrated Circuits 3.0 Credits**
Covers growth of single-crystal silicon, growth of oxide and epitaxial layers, photolithography, diffusion of impurities, fabrication of bipolar and unipolar integrated circuits, and interconnections and packaging.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 521 [Min Grade: C]

**ECEE 525 Digital IC and CMOS Technology 3.0 Credits**
Covers digital ICs using CMOS technology. Transistor level building blocks, -NOT, NAND, NOR, XOR, OAI, and AOI ? are designed using industry standard CAD tools, e.g. Cadence. Circuit topologies such as CPL, transmission gates are explored. CMOS technology/fabrication and layout are discussed to optimize speed, power, and area.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 526 Custom VLSI Design 3.0 Credits**
Course covers advanced design styles such as dynamic CMOS circuits, low power circuit concepts, bi-CMOS circuits and the design of VLSI sub-systems. A major category is memory design, both DRAM. VLSI design styles, system integration aspects are discussed. Project design involves a fair amount of layout.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 525 [Min Grade: C]

**ECEE 541 Photonic Systems 3.0 Credits**
Introduction to Optical principles through EM theory. Covers the mathematics of wave motion, as well as the idea of light propagating as particles. The course shows how ray (or geometrical) optics and Gaussian optics are derived from the wave theory. The course also introduces the polarization of light, and how this effects optical propagation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 542 Optical Applications of Diffraction and Interference 3.0 Credits**
Optical Applications of Diffraction and Interference. This course is an introduction to optical principles through EM theory. Covered topics include wave motion and superposition. Introduction to optical interference, or the interaction of light with itself. Topics include interference and interferometers, diffraction, and Fourier Optics. Diffraction topics include, far (Fraunhofer), near (Fresnel), and the near-near field diffraction. The course includes coding of some of the classical diffraction algorithms for the use in a project.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 603 Cooperative Phenomena 3.0 Credits**
Covers dielectrics, ferroelectrics, diamagnetism, paramagnetism, ferromagnetism, and antiferromagnetism; superconductivity, London's equations, BCS theory, and Josephson effect; and flux quantization, hard superconductors, GLAG theory, flux dynamics, and high-temperature superconductors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 502 [Min Grade: C] and ECEE 503 [Min Grade: C]

**ECEE 607 Nanoscale Fields 3.0 Credits**
Course covers essentials of electric and magnetic fields, including thermodynamics of polarizable media. Emphasis is on nano-and micro-scale effects like Van der Waals and double layer interactions, plasmon resonance and others. Examples from colloids and other areas of nanotechnology are used to illustrate main ideas.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 619 Radio Frequency Integrated Circuit Design 3.0 Credits**
This course introduces concepts in design of radio frequency (microwave and millimeter wave) integrated circuits. Optimum transistor technologies based on unipolar (MOS, FET, HEMT) and bipolar (BJT.HBT) are discussed for various RFIC applications. Performance of devices and circuits are evaluated in terms of gain, noise, and linearity. Active circuits and systems used in a variety of communications, imaging, and sensing are discussed in terms of standards and applications. IC design projects are integral to this course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 518 [Min Grade: C]

**ECEE 621 Thin Film Technology I 3.0 Credits**
Covers vacuum technology, plasma processing, VLSI fabrication, and thin film technologies (e.g., plasma etching, thin film deposition, and thin film characterizations).
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 622 Microfabrication Technology 3.0 Credits**
The course provides an overview of basic technological processes typically involved in microfabrication of Micro-Electro-Mechanical Systems (MEMS). The course includes several demonstration laboratories involving basic photolithography, thin film depositions and electroplating.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 623 Thin Film Technology III 3.0 Credits**
Presents speakers on state-of-the-art practice and future applications of thin film deposition and processing technology.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 622 [Min Grade: C]

**ECEE 641 Fiber Optics & Optical Communications I 3.0 Credits**
Covers propagation in guided and unguided media, including step and graded fibers, dispersion, guide deformations, and mode coupling. Involves design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 642 Fiber Optics & Optical Communications II 3.0 Credits**
Covers coupling devices, multimode guides, sources, lasers, and radiation patterns. Includes reliability, detectors, circuit models, and noise.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 641 [Min Grade: C]

**ECEE 671 Seminar in Electro-Physics I 2.0 Credits**
Advanced graduate seminar. Focuses on recent developments in microwaves, electro-optics, and solid-state devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 672 Seminar in Electro-Physics II 2.0 Credits**
Continues ECEE 671.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 673 Seminar in Electro-Physics III 2.0 Credits**
Continues ECEE 672.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 690 Special Topics in Electrophysics 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 697 Research in Electrophysics 1.0-12.0 Credit**
Research in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 699 Supervised Study in Electrophysics 0.5-9.0 Credits**
Supervised study in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 811 Microwave & THZ Photonics I 3.0 Credits**
This course focuses on high speed photonic components for microwave and terahertz fiber-optic links, namely high speed lasers, external modulators and photodetectors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 812 Microwave & THZ Photonics II 3.0 Credits**
This course focuses on high speed analog and digital fiber-optic links including loss and dynamic range calculations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 811 [Min Grade: C]

**ECEE 813 Microwave & THZ Photonics III 3.0 Credits**
This course focuses on the applications of fiber-optic links; antenna remoting, optically fed and controlled phased array antennas and fiber radio.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 811 [Min Grade: C] and ECEE 812 [Min Grade: C]

**ECEE 820 Carrier Transport Fundamentals 3.0 Credits**
This course introduces the fundamentals of carrier transport in semiconductors, beyond the common drift-diffusion description functions and Boltzmann transport equations are covered. Monte Carlo simulations are used for low field and high field transport studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 520 [Min Grade: C]

**ECEE 821 Nanoelectronics 3.0 Credits**
Focus is on current transport when the size of electronic medium reaches nanometer scales, that is, deBrogile wavelength. Topics include: characteristic lengths, magneto-electric subbands, conductance from transmission, resistance in a ballistic conductor, quantum Hall effect, electron scattering in quantum structures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 820 [Min Grade: C]

**ECEE 890 Advanced Special Topics in Electrophysics 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 898 Masters Thesis in Electrophysics 9.0 Credits**
Master's thesis in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 997 Dissertation Research in Electrophysics 1.0-12.0 Credit**
Graded Ph.D. dissertation in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 998 Ph.D. Dissertation in Electrophysics 1.0-12.0 Credit**
Ph.D. dissertation in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

## Elec Computer Engr-Power Eng Courses

**ECEP 501 Power System Analysis 3.0 Credits**
Core course. Covers modeling of power systems, including: symmetrical components, transmission lines, transformers, per-unit values and one-line diagrams. Introduces power flow. Required of first-year power majors; equivalent undergraduate credits may be substituted.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 502 Computer Analysis of Power Systems 3.0 Credits**
Core course. Covers digital computation methods, including load flow, fault, and transient stability problems. Required of first-year power engineering majors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 501 [Min Grade: C]

**ECEP 503 Synchronous Machine Modeling 3.0 Credits**
Core course. Covers two-reaction theory, Park's synchronous machine models, modeling of the synchronous machine excitation and governor systems, and the effects on power system stability. Required of first-year power engineering majors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 502 [Min Grade: C]

**ECEP 601 Modeling & Analysis of Power Distribution Systems 3.0 Credits**
Modeling and Analysis of Power Distribution Systems. Introduction to power distribution system; balanced and unbalanced systems, component and load modeling, radial and weakly meshed topologies; algorithms for unbalanced power flow studies including radial and general structure solver.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Corequisite**: ECEP 501

**ECEP 602 Power Distribution Automation and Control 3.0 Credits**
Power Distribution Automation and Control. Focuses on distribution management systems and their application: including optimizing network operation -capacitor placement and control, network reconfiguration, service restoration. Modern solution technology will be addresses.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Corequisite**: ECEP 502

**ECEP 603 Service and Power Quality in Distribution Systems 3.0 Credits**
Service and Power Quality in Distribution Systems. Focus power distribution systems: service and power quality assessment including stat estimation, voltage quality, trouble call analysis, service restoration, component and system reliability assessment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 610 Power System Dynamics 3.0 Credits**
Covers system parameters and dynamics, swing equation and solutions for two-machine and multimachine systems, equal area criterion, computer solution techniques, system effects due to dynamic behavior of particular system components, and load characteristics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 503 [Min Grade: C]

**ECEP 611 Power System Security 3.0 Credits**
Covers contingency analysis, including operating and security constraints and network sensitivities; corrective dispatch using linear programming; and state estimation, including network observability, detection, and identification of bad data.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 610 [Min Grade: C]

**ECEP 612 Economic Operation of Power Systems 3.0 Credits**
Covers unit characteristics and economic operation, including transmission loss coefficients, general loss formula, and automatic economic load dispatch.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 501 [Min Grade: C]

**ECEP 613 Advanced Power System Design 3.0 Credits**
Covers components, functions, application, and performance; relative cost and scaling parameters; overall planning problem considering present-worth and cost-benefit principles; system reliability; intersystem pooling; and growth.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 641 Protective Relaying 3.0 Credits**
Covers relay principles and types, instrumentation of system parameters, relay characteristics and response, system component protection, solid-state relaying, underfrequency relays, and load shedding.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 503 [Min Grade: C]

**ECEP 642 Protective Relay Laboratory 3.0 Credits**
Covers electromechanical and static relays. Emphasizes application based on observed performance. Includes testing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 641 [Min Grade: C]

**ECEP 643 Solid State Protective Relaying 3.0 Credits**
Covers solid-state protective relays as applied to power system stability and protection, including comparisons with electromechanical relays.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 641 [Min Grade: C]

**ECEP 661 High Voltage High Power Phenomena 3.0 Credits**
Covers corona, corona losses, electromagnetic noise, dielectric strength, lightning, impulse testing and safety practices, elements of high-power circuit interruption, circuit and physical phenomena, and circuit breakers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 671 AC-DC and DC-AC Power Electronic Converters 3.0 Credits**
AC-DC and DC-AC Power Electronic Converters. Study of basic power electronic converter circuits: diode and phase controlled rectifiers and inverters; switch-mode converters. Applications to DC and AC power supplies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 501 [Min Grade: C] or ECEP 601 [Min Grade: C]

**ECEP 672 Power Electronic Experiments: Hardware and Software 3.0 Credits**
Hardware and Software Lab-Intensive course. Additional lectures on: Study of DC-DC switch-mode converters; Study of power electronic circuitry in residential, industrial and electric utility applications; Optimizing utility interfaces with power electronic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 671 [Min Grade: C]

**ECEP 673 Power Electronic Applications 3.0 Credits**
Electric Utility Applications with emphasis on DC Transmission, Optimizing the Utility interface. Resonant converters. Fundamentals of motor drives and their controls: induction, DC, synchronous and specialized motors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 671 [Min Grade: C]

**ECEP 690 Special Topics in Power Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 697 Research in Power Engineering 1.0-12.0 Credit**
Research in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 699 Supervised Study in Power Engineering 9.0 Credits**
Supervised study in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 801 Advanced Topics in Power Systems I 0.5-9.0 Credits**
Discusses the latest innovations, theories, and methodologies for the design, planning, and operation of power systems. Requires students to read and discuss technical articles published in the IEEE Transactions on pas, the Journal of Electric Energy and Systems, and other publications.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 802 Advanced Topics in Power Systems II 3.0 Credits**
Continues ECEP 801.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 803 Advanced Topics in Power Systems III 3.0 Credits**
Continues ECEP 802.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 821 Load Forecasting & Probability Methods 3.0 Credits**
Reviews probability methods. Covers probabilistic generation and load models; forecasting methodologies; load classification and characterization; energy and peak demand forecasting; weather-and non-weather-sensitive forecast; and annual, monthly, weekly, and daily forecast.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 610 [Min Grade: C]

**ECEP 822 Power System Planning 3.0 Credits**
Covers deterministic planning, including automated transmission system expansion planning and network sensitivities, and probabilistic planning, including generation and load models, generation cost analysis, production costing, and energy production cost models for budgeting and planning.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 821 [Min Grade: C]

**ECEP 823 Power System Reliability 3.0 Credits**
Covers basic reliability concepts, including probabilistic generation and load models, loss of load probability (LOLP), static and spinning generating-capacity reliability, transmission system reliability, and composite system and interconnected system reliability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 822 [Min Grade: C]

**ECEP 890 Advanced Special Topics in Power Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 898 Master's Thesis Power Engineering 1.0-12.0 Credit**
Master's thesis in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 997 Dissertation Research in Power Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 998 Ph.D. Dissertation in Power Engineering 1.0-12.0 Credit**
Ph.D. dissertation in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

## Elec Computer Engr-Systems Courses

**ECES 510 Analytical Methods in Systems 3.0 Credits**
This course is intended to provide graduate student in the field of signal and image processing with the necessary mathematical foundation, which is prevalent in contemporary signal and image processing research and practice.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 511 Fundamentals of Systems I 3.0 Credits**
Core course. Covers linear operators, including forms and properties (differential equations, transfer function, state space, causality, linearity, and time invariance); impulse response, including convolution, transition matrices, fundamental matrix, and linear dynamical system; definition, including properties and classification; representation, including block diagrams, signal flow, and analog and digital; properties, including controllability and observability; and eigenstructure, including eigenvalues and eigenvector and similarity transformations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 512 Fundamentals of Systems II 3.0 Credits**
Core course. Covers realization and identification, including minimal realization, reducibility and equivalence of models, and identification of systems; stability, including bounded input-bounded output, polynomial roots, and Lyapunov; and feedback compensation and design, including observers and controllers and multi-input/multi-output systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 511 [Min Grade: C]

**ECES 513 Fundamentals of Systems III 3.0 Credits**
Core course. Covers multivariable systems, numerical aspects of system analysis and design, design of compensators, elements of robustness, and robust stabilization.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 521 Probability & Random Variables 3.0 Credits**
Probability concepts. Single and multiple random variables. Functions of random variables. Moments and characteristic functions. Random number and hypothesis testing. Maximum likelihood estimation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 522 Random Process & Spectral Analysis 3.0 Credits**
Random Process. Poisson Process, Shot Noise. Gaussian Process. Matched Filters. Kalman Filters. Power Spectral Density. Autocorrelation and cross correlation. PSD estimation. Entropy. Markov Processes. Queuing Theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C]

**ECES 523 Detection & Estimation Theory 3.0 Credits**
Detection of signals in noise. Bayes criterion. NP criterion. Binary and M_ary hypotheses. Estimation of signal parameters. MLE and MAP estimation. 1D and 2D signals. ROC Analyses. Decision fusion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C] and ECES 522 [Min Grade: C]

**ECES 558 Digital Signal Processing for Sound & Hearing 3.0 Credits**
Introduction to the computational modeling of sound and the human auditory system. Signal processing issues, such as sampling, aliasing, and quantization, are examined from an audio perspective. Covers applications including audio data compression (mp3), sound synthesis, and audio watermarking.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 559 Processing of the Human Voice 3.0 Credits**
Introduction to the computational modeling of the human voice for analysis, synthesis, and recognition. Topics covered include vocal physiology, voice analysis-synthesis, voice data coding (for digital communications, VoIP), speaker identification, speech synthesis, and automatic speech recognition.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C] and ECES 558 [Min Grade: C]

**ECES 561 Medical Robotics I 3.0 Credits**
This course will introduce the emerging, multidisciplinary field of medical robotics. Topics include: introduction to robot architecture, kinematics, dynamics and control; automation aspects of medical procedures; safety, performance limitations; regulatory and economics and future developments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 562 Medical Robotics II 3.0 Credits**
This course will continue the introduction to the emerging, multidisciplinary field of medical robotics. Topics include: medical procedure automation; robot testing and simulation techniques; This is a project based course that will afford students the opportunity to work with existing medical robotic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 561 [Min Grade: C]

**ECES 604 Optimal Estimation & Stochastic Control 3.0 Credits**
Introduction to control system problems with stochastic disturbances; linear state space filtering, Kalman Filtering, Non-linear systems; extended Kalman Filtering. Robust and H-infinity methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C] and ECES 521 [Min Grade: C]

**ECES 607 Estimation Theory 3.0 Credits**
General characteristics of estimators. Estimators: least squares, mean square, minimum variance, maximum a posteriori, maximum likelihood. Numerical solution. Sequential estimators.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 614 Passive Network Synthesis 3.0 Credits**
An introduction to approximation theory; driving point functions; realizability by lumped-parameter circuits; positive real functions; properties of two and three element driving point functions and their synthesis; transfer function synthesis; all-pass networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 615 Analysis & Design of Linear Active Networks 3.0 Credits**
DC and AC models of bipolar transistors and FETs; design of differential operational amplifiers; optimal design of broad-band IC amplifiers; design of tuned amplifiers; design for optimal power gain, distortion, and efficiency; noise in transistor circuits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 621 Communications I 3.0 Credits**
Covers modulation techniques: baseband PAM, passband PAM, QAM, and PSK; orthogonal signaling: FSK; symbol/vector detection: matched filter and correlation detector; sequence detection: ISI; equalization: adaptive and blind; carrier synchronization; and timing recovery.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 622 Communications II 3.0 Credits**
Covers shot noise, noise in detectors, analog fiberoptic systems, carrier and subcarrier modulation, digital systems bit error rates for NRZ and RZ formats, coherent optical communication systems-heterodyne and homodyne systems, wavelength division multiplexing, system design concepts, power budgets, rise time budgets, and optical switching networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 623 Communications III 3.0 Credits**
Covers fundamentals of information theory: information measure, entropy, and channel capacity; source encoding and decoding; rate distortion theory; linear codes; block codes; convolutional codes, Viterbi algorithm; encryption and decryption; and spread spectrum communications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 631 Fundamentals of Deterministic Digital Signal Processing 3.0 Credits**
Fundamentals of Deterministic Digital Signal Processing. This course introduces the fundamentals of deterministic signal processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 632 Fundamentals of Statistical Digital Signal Processing 3.0 Credits**
Fundamentals of Statistical Deterministic Digital Signal Processing. The course covers topics on statistical signal processing related to data modeling, forecasting and system identification.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 640 Genomic Signal Processing 3.0 Credits**
This course focuses on signal processing applied to analysis and design of biological systems. This is a growing area of interest with many topics ranging from DNA sequence analysis, to gene prediction, sequence alignment, and bio-inspired signal processing for robust system design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 642 Optimal Control 3.0 Credits**
Introduces the concept of optimal control first by static optimization for state space formulated systems. The concept is expanded as the linear quadratic regulator problem for dynamic systems allowing solution of the optimal control and suboptimal control problems for both discrete and continuous time. Additional topics include the Riccati equation, the tracking problem, the minimum time problem, dynamic programming, differential games and reinforcement learning. The course focuses on deriving, understanding, and implementation of the algorithms.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 643 Digital Control Systems Analysis & Design 3.0 Credits**
Covers analysis and design of sampled-data control system using Z-transform and state-variable formulation, sampling, data reconstruction and error analysis, stability of linear and non-linear discrete time systems by classical and Lyapunov's second method, compensator design using classical methods (e.g., rootlocus) and computer-aided techniques for online digital controls, optimal control, discrete-time maximum principle, sensitivity analysis, and multirate sampled-data systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 513 [Min Grade: C]

**ECES 644 Computer Control Systems 3.0 Credits**
Introduction to the fundamentals of real-time controlling electromechanical dynamic systems, including modeling, analysis, simulation, stabilization and controller design. Control design approaches include: pole placement, quadratic and robust control performances.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 651 Intelligent Control 3.0 Credits**
Concepts of Intelligence in Engineering Systems, Learning Automation, Principles of Knowledge Representation. Levels of Resolution and Nestedness. Organization of Planning: Axioms and Self-Evident Principles.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 660 Machine Listening and Music IR 3.0 Credits**
This course introduces methods for the computational analysis, recognition, and understanding of sound and music from the acoustic signal. Covered applications include sound detection and recognition, sound source separation, artist and song identification, music similarity determination, and automatic transcription.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 670 Seminar in Systems I 2.0 Credits**
Involves presentations focused on recent publications and research in systems, including communications, controls, signal processing, robotics, and networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 671 Seminar in Systems II 2.0 Credits**
Continues ECES 670.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 672 Seminar in Systems III 2.0 Credits**
Continues ECES 671.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 681 Fundamentals of Computer Vision 3.0 Credits**
Develops the theoretical and algorithmic tool that enables a machine (computer) to analyze, to make inferences about a "scene" from a scene's "manifestations", which are acquired through sensory data (image, or image sequence), and to perform tasks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 682 Fundamentals of Image Processing 3.0 Credits**
The course introduces the foundation of image processing with hands-on settings. Taught in conjunction with an imaging laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 684 Imaging Modalities 3.0 Credits**
This course is intended to produce students and image processing with a background on image formation in modalities for non-invasive 3D imaging. The goal is to develop models that lead to qualitative measures of image quality and the dependence of quality imaging system parameters.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 685 Image Reconstruction Algorithms 3.0 Credits**
This course is intended to provide graduate students in signal and image processing with an exposure to the design and evaluation of algorithms for tomographic imaging.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 684 [Min Grade: C] and BMES 621 [Min Grade: C]

**ECES 690 Special Topics in Systems Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 697 Research In Systems Engineering 1.0-12.0 Credit**
Research in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 699 Supervised Study in Systems Engineering 9.0 Credits**
Supervised study in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 801 Advanced Topics in Systems I 3.0 Credits**
Familiarizes students with current research results in their field of interest, specifically in works reported in such journals as The IEEE Transactions.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 802 Advanced Topics in Systems II 3.0 Credits**
Continues ECES 801.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 803 Advanced Topics in Systems III 3.0 Credits**
Continues ECES 802.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 811 Optimization Methods for Engineering Design 3.0 Credits**
Applications of mathematical programming and optimization methods in engineering design problems such as networks, control, communication, and power systems optimization. Optimization problem definition in terms of objective function, design variables, and design constraints. Single variable and multivariable search methods for unconstrained and constrained minimization using Fibonacci, gradient, conjugate gradient, Fletcher-Powell methods and penalty function approach. Classical optimization--Lagrange multiplier, Kuhn-Tucker conditions. Emphasis is on developing efficient digital computer algorithms for design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 812 Mathematical Program Engineering Design 3.0 Credits**
Approximation theory projection theorem. Solution of nonlinear equations by Newton-Raphson method. Resource allocation, linear programming, and network flow problems. Integer programming for digital filter design and power system expansion problems. Gamory's algorithm.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 813 Computer-Aided Network Design 3.0 Credits**
Simulation and circuit analysis programs: PCAP, MIMIC, GASP. Data structures. Algorithms. Languages. Interactive I/O. Integration of subroutines for simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 817 Non-Linear Control Systems 3.0 Credits**
Covers key topics of feedback linearization, sliding mode control, model reference adaptive control, self-tuning controllers and on-line parameter estimation. In addition additional no n-linear topics such as Barbalat's Lemma, Kalman-Yakubovich Lemma, passivity, absolute stability, and establishing boundedness of signals are presented. The focus of the course is the understanding each of these algorithms in detail through derivation and their implementation through coding in Matlab and Simulink.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 513 [Min Grade: C]

**ECES 818 Machine Learning & Adaptive Control 3.0 Credits**
System identification and parameter estimation, gradient search, least squares and Neural Networks methods. Closed loop implementation of system learning and self-organizing controllers. Random searching learning systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 821 Reliable Communications & Coding I 3.0 Credits**
Covers fundamentals of information theory, including measures of communication, channel capacity, coding for discrete sources, converse of coding system, noisy-channel coding, rate distortion theory for memoryless sources and for sources with memory, and universal coding.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C] and ECES 522 [Min Grade: C]

**ECES 822 Reliable Communications & Coding II 3.0 Credits**
Introduces algebra of coding, including groups, rings, fields, and vector fields. Covers finite fields, decoding circuitry, techniques for coding and decoding, linear codes, error-correction capabilities of linear codes, dual codes and weight distribution, important linear block codes, perfect codes, and Plotkin's and Varshamov's bounds.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 821 [Min Grade: C]

**ECES 823 Reliable Communications & Coding III 3.0 Credits**
Continues techniques for coding and decoding. Covers convolutional codes; Viterbi algorithm; BCH, cyclic, burst-error-correcting, Reed-Solomon, and Reed-Muller codes; and elements of cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 822 [Min Grade: C]

**ECES 890 Advanced Special Topics in Systems Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 898 Master's Thesis in Systems Engineering 1.0-12.0 Credit**
Master's thesis in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 921 Reliable Communications & Coding I 3.0 Credits**
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 997 Dissertation Research in Systems Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 998 Ph.D. Dissertation in Systems Engineering 1.0-12.0 Credit**
Ph.D. dissertation in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Electrical Computer Engr Courses

**ECE 501 Topics in Circuits and Systems 3.0 Credits**
Circuit laws, transfer functions, convolution, transform techniques, systems engineering. This series of courses may be used to meet the admission prerequisites to ECE graduate program. One credit per term is creditable to the M.S.E.E. degree.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 502 Topics In Communications, Controls and Computers 3.0 Credits**
Modulation theory, noise, feedback theory, stability, computer engineering fundamentals, computers in communication and controls. This series of courses may be used to meet the admission prerequisites to the ECE graduate program. One credit per term is creditable to the M.S.E.E. degree.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 503 Topics in Mathematical Techniques In Electrical and Computer Engineering 3.0 Credits**
Complex variables in communication and control, matrix methods in circuits and systems, vector calculus in fields, two-dimensional image processing. This series of courses may be used to meet the admission prerequisites to the ECE graduate program. One credit per term is creditable to the M.S.E.E. degree.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 571 Introduction to Electrical and Computer Engineering Research 0.0 Credits**
Topics of departmental research. Thesis selection. Required of all full-time graduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 572 Techniques of Electrical and Computer Engineering Research 0.0 Credits**
Techniques for making technical presentations: oral and written modes. Meeting organization, audience awareness. Writer-to-reader communication. Required of all full-time graduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 573 Presentation of Electrical and Computer Engineering Research 0.0 Credits**
Conference attendance and critique. Student presentation and critique. Topics of concern: professional ethics, liability, etc. Required of all full-time graduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 695 Research Rotations in Cybersecurity 1.0-12.0 Credit**
The research rotation course allows students to gain exposure to cybersecurity-related research that cuts across conventional departmental barriers and traditional research groups, prior to identifying and focusing on a specific interdisciplinary project or thesis topic. Students selecting to participate in research rotations would participate in the research activities of two labs for each three credits of research rotation they undertake.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECE 697 Research 1.0-12.0 Credit**
Research in electrical and computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 898 Master's Thesis 1.0-12.0 Credit**
Master's thesis in electrical and computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 997 Dissertation Research 1.0-12.0 Credit**
Graded Ph.D. dissertation research in electrical and computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 998 Ph.D. Dissertation 1.0-12.0 Credit**
Ph.D. dissertation research in electrical and computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

# Electrical Engineering Lab Courses

# Cybersecurity

*Master of Science in Cybersecurity: 45.0 quarter credits (or 48.0 credits for the 6-month graduate co-op option)*

## About the Program

As a greater percentage of people worldwide use computers, there is a marked increase in cybersecurity concerns. Motivated through discussions with the National Security Agency (NSA), Drexel University's MS in Cybersecurity program prepares students with both academic and practical training to be competitive in today's rapidly changing technical landscape. The program provides deeply technical and specialized training and enables graduates to understand, adapt, and develop new techniques to confront emerging threats in cybersecurity.

Administered by the Electrical (http://drexel.edu/engineering/departments/electrical_comp) & Computer Engineering Department (http://drexel.edu/engineering/departments/electrical_comp) in the College of Engineering, this program is interdisciplinary in nature and includes courses from

Drexel University's College of Computing & Informatics. Topics covered include computer networking, probability concepts, techniques for analyzing algorithms, dependable software design, reverse software engineering, intrusion detection, ethics, privacy, confidentiality, authenticity, and social networking.

The program offers multidisciplinary "research rotations" as an independent study component of the degree program, and a graduate co-op option for credit.

## Additional Information

For additional information about this program, please visit the ECE Department's Cybersecurity degree page (http://drexel.edu/engineering/programs/grad/CyberSecurity) .

# Degree Requirements

The Master of Science in Cybersecurity program encompasses a minimum of 45.0 or 48.0 (with the 6-month graduate co-op option) approved credit hours, chosen in accordance with the requirements listed below. A plan of study should be arranged with the departmental graduate advisors, and in consultation with the student's research advisor, if applicable.

The required core courses provide students with a theoretical foundation in the field of cybersecurity and a framework to guide the application of knowledge gained in technical electives to the practice of cybersecurity.

| Core Courses | | |
|---|---|---|
| CST 510 | Ethics, Privacy and Legal Issues | 3.0 |
| INFO 517 | Principles of Cybersecurity | 3.0 |
| INFO 725 | Information Policy | 3.0 |
| Networking Foundation | | 3.0 |
| CS 544 | Computer Networks | |
| or ECEC 631 | Principles of Computer Networking | |
| Mathematical Foundations | | 3.0 |
| CS 521 | Data Structures and Algorithms I | |
| or ECES 521 | Probability & Random Variables | |
| **Cybersecurity Technical Electives** [*] | | 18.0 |
| **General Electives** [**] | | 12.0 |
| **Total Credits** | | **45.0** |

[*]   Cybersecurity technical electives are used to build a deep understanding of one or more areas of technical expertise within the field of cybersecurity. All students are required to take a minimum of 18.0 credits of cybersecurity technical electives from the graduate course offerings of the Department of Computer Science, the Department of Computing and Security Technology, and the Department of Electrical and Computer Engineering.

** General electives are the remaining courses needed to reach the minimum credit hour requirement for the degree program. General electives can be chosen from among the graduate course offerings of the College of Computing & Informatics; the Department of Computer Science; the Department of Computing and Security Technology; the Department of Electrical and Computer Engineering, and the Department of Mathematics. In order to have courses outside of these departments and schools count towards degree completion, they must be approved by the departmental graduate advisors prior to registration for said courses.

# Graduate Co-op/Career Opportunities

## Graduate Co-Op

Students may choose to participate in the graduate co-op program, working on curriculum related projects. Up to 6.0 credit hours can be earned for a six month full-time cooperative education experience in the industry. There are two options. Students participating in a three month full-time co-op experience earn 3.0 credits, which is the equivalent of one general elective course. Students engaging in a six month full-time co-op experience earn 6.0 credits, of which 3.0 credits is be considered equivalent to a general elective course; the other 3 credits are considered an additional course, increasingthe total minimum credit requirement for graduation from the MS program with a six month full-time graduate co-op to 48.0 credits.

Further information on the Graduate Co-Op Program (http://www.drexel.edu/scdc/coop/graduate) is available at the Drexel Steinbright Career Development Center. (http://www.drexel.edu/scdc)

## Career Opportunities

The program was deliberately designed to address needs of the Federal Cyber Service, the Department of Defense, and the National Security Agency. The program strengthens ties between these agencies and Drexel University and will provide professional opportunities for students pursuing this degree.

## Research

Students in the MS in Cybersecurity program have opportunities to perform research-oriented coursework for academic credit. Research-oriented coursework can be divided into three categories: research rotations, master's thesis, and independent research.

A total of 9.0 credits of research-oriented coursework may be counted towards the minimum credit hour requirement of the degree program. These credits are considered general electives.

## Facilities

Drexel University and the Electrical and Computer Engineering Department are nationally recognized for a strong history of developing innovative research. Research programs in the ECE Department prepare students for careers in research and development, and aim to endow graduates with the ability to identify, analyze, and address new technical and scientific challenges. The ECE Department is well equipped with state-of-the-art facilities in each of the following ECE Research laboratories:

# Research Laboratories at the ECE Department

## Adaptive Signal Processing and Information Theory Research Group

The Adaptive Signal Processing and Information Theory Research Group (http://www.ece.drexel.edu/walsh/aspitrg/home.html) conducts research in the area of signal processing and information theory. Our main interests are belief/expectation propagation, turbo decoding and composite adaptive system theory. We are currently doing projects on the following topics:
i) Delay mitigating codes for network coded systems,
ii) Distributed estimation in sensor networks via expectation propagation,
iii) Turbo speaker identification,
iv) Performance and convergence of expectation propagation,
v) Investigating bounds for SINR performance of autocorrelation based channel shorteners.

## Applied Networking Research Lab

Applied Networking Research Lab (ANRL) projects focus on modeling and simulation as well as experimentation in wired, wireless and sensor networks. ANRL is the home of MuTANT, a Multi-Protocol Label Switched Traffic Engineering and Analysis Testbed composed of 10 high-end Cisco routers and several PC-routers, also used to study other protocols in data networks as well as automated network configuration and management. The lab also houses a sensor network testbed.

### Bioimage Laboratory

Uses computer gaming hardware for enhanced and affordable 3-D visualization, along with techniques from information theory and machine learning to combine the exquisite capabilities of the human visual system with computational sensing techniques for analyzing vast quantities of image sequence data.

## Data Fusion Laboratory

The Data Fusion Laboratory investigates problems in multisensory detection and estimation, with applications in robotics, digital communications, radar, and target tracking. Among the projects in progress: computationally efficient parallel distributed detection architectures, data fusion for robot navigation, modulation recognition and RF scene analysis in time-varying environments, pattern recognition in biological data sequences and large arrays, and hardware realizations of data fusion architectures for target detection and target tracking.

## Drexel Network Modeling Laboratory

The Drexel Network Modeling Laboratory investigates problems in the mathematical modeling of communication networks, with specific focus on wireless ad hoc networks, wireless sensor networks, and supporting guaranteed delivery service models on best effort and multipath routed networks. Typical methodologies employed in our research include mathematical modeling, computer simulation, and performance optimization, often with the end goal of obtaining meaningful insights into network design principles and fundamental performance tradeoffs.

## Drexel Power-Aware Computing Laboratory

The Power-Aware Computing Lab (http://dpac.ece.drexel.edu) investigates methods to increase energy efficiency across the boundaries of circuits, architecture, and systems. Our recent accomplishments include the Sigil profiling tool, scalable modeling infrastructure for

accelerator implementations, microarchitecture-aware VDD gating algorithms, an accelerator architecture for ultrasound imaging, evaluation of hardware reference counting, hardware and operating system support for power-agile computing, and memory systems for accelerator-based architectures.

## Drexel University Nuclear Engineering Education Laboratory

The field of nuclear engineering encompasses a wide spectrum of occupations, including nuclear reactor design, medical imaging, homeland security, and oil exploration. The Drexel University Nuclear Engineering Education Laboratory (DUNEEL) provides fundamental hands on understanding for power plant design and radiation detection and analysis. Software based study for power plant design, as well as physical laboratory equipment for radiation detection, strengthen the underlying concepts used in nuclear engineering such that the student will comprehend and appreciate the basic concepts and terminology used in various nuclear engineering professions. Additionally, students use the laboratory to develop methods for delivering remote, live time radiation detection and analysis. The goal of DUNEEL is to prepare students for potential employment in the nuclear engineering arena.

## Drexel VLSI Laboratory

The Drexel VLSI Laboratory (http://ece.drexel.edu/faculty/taskin/wiki/vlsilab/index.php/Main_Page) investigates problems in the design, analysis, optimization and manufacturing of high performance (low power, high throughput) integrated circuits in contemporary CMOS and emerging technologies. Suited with industrial design tools for integrated circuits, simulation tools and measurement beds, the VLSI group is involved with digital and mixed-signal circuit design to verify the functionality of the discovered novel circuit and physical design principles. The Drexel VLSI laboratory develops design methodologies and automation tools in these areas, particularly in novel clocking techniques, featuring resonant clocking, and interconnects, featuring wireless interconnects.

## Drexel Wireless Systems Laboratory

The Drexel Wireless Systems Laboratory (DWSL) contains an extensive suite of equipment for constructing, debugging, and testing prototype wireless communications systems. Major equipment within DWSL includes:

- three software defined radio network testbeds (HYDRA, USRP, and WARP) for rapidly prototyping radio, optical and ultrasonic communications systems,
- a TDK RF anechoic chamber and EMSCAN desktop antenna pattern measurement system,
- a materials printer and printed circuit board milling machine for fabricating conformal antennas and
- wireless protocol conformance testing equipment from Aeroflex.

The lab is also equipped with network analyzers, high speed signal generators, oscilloscopes, and spectrum analyzers as well as several Zigbee development platforms for rapidly prototyping sensor networks.

DWSL personnel also collaborate to create wearable, fabric based transceivers through collaboration with the Shima Seiki Haute Laboratory in the Drexel ExCITe Center. The knitting equipment at Drexel includes sixteen SDS-ONE APEX3 workstations and four state-of-the-art knitting machines. The workstations accurately simulate fabric construction and provide researchers and designers the opportunity to program, create and simulate textile prototypes, import CAD specifications of final products,

and produce made-to-measure or mass-produced pieces on Shima Seiki knitting machines. For testing smart textiles for biomedical, DWSL personnel also have collaborators in the Center for Interdisciplinary Clinical Simulation and Practice (CICSP) in the Drexel College of Medicine which provides access to medical mannequin simulators.

## Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (EESI) (http://www.ece.drexel.edu/gailr/EESI) seeks to solve problems in high-throughput genomics and engineer better solutions for biochemical applications. The lab's primary thrust is to enhance the use of high-throughput DNA sequencing technologies with pattern recognition and signal processing techniques. Applications include assessing the organism content of an environmental sample, recognizing/classifying potential and functional genes, inferring environmental factors and inter-species relationships, and inferring microbial evolutionary relationships from short-read DNA/RNA fragments. The lab also investigates higher-level biological systems such as modeling and controlling chemotaxis, the movement of cells.

## Electric Power Engineering Center

This newly established facility makes possible state-of-the-art research in a wide variety of areas, ranging from detailed theoretical model study to experimental investigation in its high voltage laboratories. The mission is to advance and apply scientific and engineering knowledge associated with the generation, transmission, distribution, use, and conservation of electric power. In pursuing these goals, this center works with electric utilities, state and federal agencies, private industries, nonprofit organizations and other universities on a wide spectrum of projects. Research efforts, both theoretical and experimental, focus on the solution of those problems currently faced by the electric power industry. Advanced concepts for electric power generation are also under investigation to ensure that electric power needs will be met at the present and in the future.

## Electronic Design Automation Facility

Industrial-grade electronic design automation software suite and intergrated design environment for digital, analog and mixed-signal systems development. Field Programmable Gate Array (FPGA) development hardware. Most up-to-date FPGA/embedded system development hardware kits. Printed circuit board production facility. Also see Drexel VLSI Laboratory.

## Microwave-Photonics Device Laboratories

The laboratory is equipped with test and measurement equipment for high-speed analog and digital electronics and fiber optic systems. The test equipment includes network analyzers from Agilent (100kHz- 1.3 GHz and 45 Mhz-40 GHz), and Anritsu (45 MHz-6 GHz); spectrum analyzers from Tektronix, HP, and Agilent with measurement capability of DC to 40 GHz and up to 90 GHz using external mixers; signal generators and communication channel modulators from HP, Rhode-Schwartz, Systron Donner, and Agilent; microwave power meter and sensor heads, assortment of passive and active microwave components up to 40 GHz ; data pattern generator and BER tester up to 3Gb/s; optical spectrum analyzer from Anritsu and power meters from HP; single and multimode fiber optic based optical transmitter and receiver boards covering ITU channels at data rates up to 10Gb/s; passive optical components such as isolator, filter, couplers, optical connectors and fusion splicer; LPKF milling machine for fabrication of printed circuit boards; wire-bonding and Cascade probe stations; Intercontinental test fixtures for testing of

MMIC circuits and solid-state transistors; state-of-the-art microwave and electromagnetic CAD packages such as Agilent ADS, ANSYS HFSS, and COMSOL multi-physics module.

## Music and Entertainment Technology Laboratory

The Music and Entertainment Technology Laboratory (MET-lab) is devoted to research in digital media technologies that will shape the future of entertainment, especially in the areas of sound and music. We employ digital signal processing and machine learning to pursue novel applications in music information retrieval, music production and processing technology, and new music interfaces. The MET-lab is also heavily involved in outreach programs for K-12 students and hosts the Summer Music Technology program, a one-week learning experience for high school students. Lab facilities include a sound isolation booth for audio and music recording, a digital audio workstation running ProTools, two large multi-touch display interfaces of our own design, and a small computing cluster for distributed processing.

## NanoPhotonics+ Lab (http://drexelnanophotonics.com)

Our research is primarily in the area of nanophotonics with a focus on the nanoscale interaction of light with matter. Interests include: liquid crystal/polymer composites for gratings, lenses and HOEs; liquid crystal interactions with surfaces and in confined nanospaces; alternative energy generation through novel photon interactions; ink-jet printed conducting materials for RF and photonic applications; and the creation and development of smart textiles technologies including soft interconnects, sensors, and wireless implementations.

## Opto-Electro-Mechanical Laboratory

This lab concentrates on the system integration on optics, electronics, and mechanical components and systems, for applications in imaging, communication, and biomedical research. Research areas include: Programmable Imaging with Optical Micro-electrical-mechanical systems (MEMS), in which microscopic mirrors are used to image light into a single photodetector; Pre-Cancerous Detection using White Light Spectroscopy, which performs a cellular size analysis of nuclei in tissue; Free-space Optical Communication using Space Time Coding, which consists of diffused light for computer-to-computer communications, and also tiny lasers and detectors for chip-to-chip communication; Magnetic Particle Locomotion, which showed that particles could swim in a uniform field; and Transparent Antennas using Polymer, which enables antennas to be printed through an ink-jet printer.

## Plasma and Magnetics Laboratory

Research is focused on applications of electrical and magnetic technologies to biology and medicine. This includes the subjects of non-thermal atmospheric pressure plasma for medicine, magnetic manipulation of particles for drug delivery and bio-separation, development of miniature NMR sensors for cellular imaging and carbon nanotube cellular probes.

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# Interdepartmental Faculty

Kapil Dandekar, PhD *(University of Texas-Austin) Director of the Drexel Wireless Systems Laboratory (DWSL); Associate Dean of Research, College of Engineering.* Professor. Cellular/mobile communications and wireless LAN; smart antenna/MIMO for wireless communications; applied computational electromagnetics; microwave antenna and receiver development; free space optical communication; ultrasonic communication; sensor networks for homeland security; ultrawideband communication.

Rachel Greenstadt, PhD *(Harvard University).* Assistant Professor. Artificial intelligence, privacy, security, multi-agent systems, economics of electronic privacy and information security.

Constantine Katsinis, PhD *(University of Rhode Island).* Associate Teaching Professor. High-performance computer networks, parallel computer architectures with sustained teraflops performance, computer security, image processing.

Steven Weber, PhD *(University of Texas-Austin) Assistant Department Head for Graduate Affairs, Electrical and Computer Engineering.* Associate Professor. Mathematical modeling of computer and

communication networks, specifically streaming multimedia and ad hoc networks.

# Electrical Engineering

*Master of Science in Electrical Engineering (MSEE): 45.0 - 48.0 quarter credits*
*Doctor of Philosophy: 90.0 quarter credits*

## About the Program

The program in electrical engineering prepares students for careers in research and development, and aims to endow graduates with the ability to identify, analyze and address new technical and scientific challenges. At present, the department offers graduate coursework in six general areas: (1) computer engineering; (2) control, robotics and intelligent systems; (3) electrophysics; (4) image and signal processing and interpretation; (5) power engineering and energy; and (6) telecommunications and networking.

The Master of Science in Electrical Engineering degree requires a minimum of 45.0 approved credits chosen in accordance with a plan of study arranged with the permission of a student's advisor and the departmental graduate advisor. Students who complete a six-month period of internship through Drexel's Graduate Co-op Program (GCP) (http://www.ece.drexel.edu/grad/cie.html) must complete 48.0 credits including 6.0 GCP credits.

The plan must contain a selection of core courses from the department's offerings and may include appropriate graduate courses from other engineering departments or from physics or mathematics. Further information can be obtained from the department office or from the graduate advisor.

All students also are encouraged to engage in thesis research. The combined thesis and research cannot exceed 9.0 credits. The program is organized so that a student may complete the degree requirements in two years of full-time study or three years of part-time study.

For more information about the programs, including information about teaching and research assistantships, visit the Department's Electrical and Computer Engineering (http://drexel.edu/engineering/departments/electrical_comp) web site.

## Admission Requirements

Applicants must satisfy general requirements for graduate admission, including a minimum 3.0 GPA (on a 4.0 scale) for the last two years of undergraduate studies, as well as for any subsequent graduate work, and hold a bachelor's degree or the equivalent in electrical engineering, computer engineering, or the equivalent from an accredited college or university. A degree in science (physics, mathematics, computer science, etc.) is also acceptable. Applicants with degrees in sciences may be required to take a number of undergraduate engineering courses. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's.

Applicants for full-time MS and PhD programs must take the GRE general test. Students whose native language is not English and who do not hold a degree from a US institution must take the TOEFL within two years before application.

For additional information on how to apply, visit Drexel's Admissions page for Electrical Engineering (http://www.drexel.edu/grad/programs/coe/electrical-engineering) .

## Master of Science in Electrical Engineering

The Master of Science in Electrical Engineering curriculum encompasses 45.0 or 48.0 (with the Graduate Co-op option) approved credit hours, chosen in accordance with the following requirements and a plan of study arranged with the departmental graduate advisor in consultation with the student's research advisor, if applicable. Before the end of the first quarter in the Department of Electrical and Computer Engineering, for a full-time student, or by the end of the first year for a part-time student, said plan of study must be filed and approved with the departmental graduate advisor.

A total of at least 30.0 credit hours must be taken from among the graduate course offerings of the Department of Electrical and Computer Engineering. These credits must be taken at Drexel University. No transfer credit may be used to fulfill these requirements, regardless of content equivalency.

The remaining courses needed to reach the minimum credit hour requirement for the degree program are considered elective courses. Elective courses can be chosen from among the graduate course offerings of the Department of Electrical and Computer Engineering; other departments within the College of Engineering; the School of Biomedical Science, Engineering and Health Systems; the Department of Mathematics; the Department of Physics; the Department of Chemistry and the Department of Biology. In order to have courses outside of these departments and schools count towards degree completion, they must be approved by the departmental graduate advisors prior to registration for said courses.

Please note that ECEC 500 (Fundamentals of Computer Hardware) and ECEC 600 (Fundamentals of Computer Networks) do **not** count toward the credit requirements to complete the MS in Electrical Engineering degree program.

**Customizable Specialization**

| Required Courses | |
| --- | --- |
| Electrical Engineering ( ECEE, ECEP, ECES, ECET) Courses | 21.0 |
| General Electrical and Computer Engineering (ECEC, ECEE, ECEP, ECES, ECET) Courses | 9.0 |
| Elective Courses | 15.0 |
| **Total Credits** | **45.0** |

**Electrophysics Specialization**

| Required Courses | |
| --- | --- |
| Electrophysics (ECEE) Courses | 18.0 |
| General Electrical and Computer Engineering (ECEC, ECEE, ECEP, ECES, ECET) Courses | 12.0 |
| Elective Courses | 15.0 |
| **Total Credits** | **45.0** |

**Controls, Robotics, Intelligent Systems Specialization**

| Required Courses | | |
| --- | --- | --- |
| ECES 511 | Fundamentals of Systems I | 3.0 |
| ECES 512 | Fundamentals of Systems II | 3.0 |
| ECES 521 | Probability & Random Variables | 3.0 |

| ECES 522 | Random Process & Spectral Analysis | 3.0 |
|---|---|---|
| Select three of the following: | | 9.0 |
| ECES 604 | Optimal Estimation & Stochastic Control | |
| ECES 642 | Optimal Control | |
| ECES 644 | Computer Control Systems | |
| ECES 651 | Intelligent Control | |
| ECES 817 | Non-Linear Control Systems | |
| ECES 818 | Machine Learning & Adaptive Control | |
| General Electrical and Computer Engineering (ECEC, ECEE, ECEP, ECES, ECET) Courses | | 9.0 |
| Elective Courses | | 15.0 |
| **Total Credits** | | **45.0** |

### Power Engineering Specialization

**Required Courses**

| ECEP 501 | Power System Analysis | 3.0 |
|---|---|---|
| ECEP 502 | Computer Analysis of Power Systems | 3.0 |
| ECEP 503 | Synchronous Machine Modeling | 3.0 |
| Select one of the following sequences: | | 6.0 |
| ECES 511 & ECES 512 | Fundamentals of Systems I and Fundamentals of Systems II | |
| ECES 521 & ECES 522 | Probability & Random Variables and Random Process & Spectral Analysis | |
| General Electrical and Computer Engineering (ECEC, ECEE, ECEP, ECES, ECET) Courses | | 15.0 |
| Elective Courses | | 15.0 |
| **Total Credits** | | **45.0** |

### Signal/Image Processing Specialization

**Required Courses**

| ECES 521 | Probability & Random Variables | 3.0 |
|---|---|---|
| ECES 522 | Random Process & Spectral Analysis | 3.0 |
| ECES 523 | Detection & Estimation Theory | 3.0 |
| ECES 631 | Fundamentals of Deterministic Digital Signal Processing | 3.0 |
| ECES 682 | Fundamentals of Image Processing | 3.0 |
| General Electrical and Computer Engineering (ECEC, ECEE, ECEP, ECES, ECET) Courses | | 15.0 |
| Elective Courses | | 15.0 |
| **Total Credits** | | **45.0** |

## Options for Degree Fulfillment

Although not required, students are encouraged to complete a Master's Thesis as part of the MS studies. Those students who choose the thesis option may count up to 9.0 research/thesis credits as part of their required credit hour requirements.

Students may choose to participate in the Graduate Co-Op Program, where 6.0 credit hours can be earned for a six month cooperative education experience in industry, working on curriculum related projects. The total number of required credit hours is increased to 48.0 for those students who choose to pursue the Graduate Co-op option. This change represents an increase in non-departmental required credit hours to a total of 18.0 credit hours, 6.0 of which are earned from the cooperative education experience.

For more information on curricular requirements, visit the Department of Electrical and Computer Engineering' (http://www.ece.drexel.edu) s web site.

## PhD in Electrical Engineering

**General Requirements**
The following general requirements must be satisfied in order to complete the PhD in Electrical Engineering:

- 90.0 credit hours total
- candidacy examination
- research proposal
- dissertation defense

Students entering with a master's degree in electrical or computer engineering or a related field will be considered a post-masters PhD student and will only be required to complete a total of 45.0 credit hours, in accordance with University policy.

**Curriculum**
Appropriate coursework is chosen in consultation with the student's research advisor. A plan of study must be developed by the student to encompass the total number of required credit hours. Both the departmental graduate advisor and the student's research advisor must approve this plan.

**Candidacy Examination**
The candidacy examination explores the depth of understanding of the student in his/her specialty area. The student is expected to be familiar with, and be able to use, the contemporary tools and techniques of the field and to demonstrate familiarity with the principal results and key findings.

The student, in consultation with his/her research advisor, will declare a principal technical area for the examination. The examination includes the following three parts:

- A self-study of three papers from the archival literature in the student's stated technical area, chosen by the committee in consultation with the student.
- A written report (15 pages or less) on the papers, describing their objectives, key questions and hypotheses, methodology, main results and conclusions. Moreover, the student must show in an appendix independent work he/she has done on at least one of the papers – such as providing a full derivation of a result or showing meaningful examples, simulations or applications.
- An oral examination which takes the following format:
  - A short description of the student's principal area of interest (5 minutes, by student).
  - A review of the self-study papers and report appendix (25-30 minutes, by student).
  - Questions and answers on the report, the appendix and directly related background (40-100 minutes, student and committee).

In most cases, the work produced during the candidacy examination will be a principal reference for the student's PhD dissertation; however, this is not a requirement.

**Research Proposal**
After having attained the status of PhD Candidate, each student must present a research proposal to a committee of faculty and industry members, chosen with his/her research advisor, who are knowledgeable in the specific area of research. This proposal should outline the specific

intended subject of study, i.e., it should present a problem statement, pertinent background, methods of study to be employed, expected difficulties and uncertainties and the anticipated form, substance and significance of the results.

The purpose of this presentation is to verify suitability of the dissertation topic and the candidate's approach, and to obtain the advice and guidance of oversight of mature, experienced investigators. It is not to be construed as an examination, though approval by the committee is required before extensive work is undertaken. The thesis proposal presentation must be open to all; announcements regarding the proposal presentation must be made in advance.

The thesis advisory committee will have the sole responsibility of making any recommendations regarding the research proposal. It is strongly recommended that the proposal presentation be given as soon as possible after the successful completion of the candidacy examination.

**Dissertation Defense**

Dissertation Defense procedures are described in the Office of Graduate Studies policies regarding Doctor of Philosophy Program Requirements (http://www.drexel.edu/provost/graduatestudies) . The student must be a PhD candidate for at least one year before he/she can defend his/her doctoral thesis.

# Dual Degree

The Department of Electrical and Computer Engineering offers outstanding students the opportunity to receive two diplomas (BS and MS) at the same time. The program requires five (5) years to complete. Participants, who are chosen from the best undergraduates students, work with a faculty member on a research project and follow a study plan that includes selected graduate classes. This program prepares individuals for careers in research and development; many of its past graduates continued their studies toward a PhD.

For more information on eligibility, academic requirements, and tuition policy visit the Engineering Combined BS/MS (http://www.ece.drexel.edu/undergrad/bsms.html) page.

# Facilities

Drexel University and the Electrical and Computer Engineering Department are nationally recognized for a strong history of developing innovative research. Research programs in the ECE Department prepare students for careers in research and development, and aim to endow graduates with the ability to identify, analyze, and address new technical and scientific challenges. The ECE Department is well equipped with state-of-the-art facilities in each of the following ECE Research laboratories:

# Research Laboratories at the ECE Department

## Adaptive Signal Processing and Information Theory Research Group

The Adaptive Signal Processing and Information Theory Research Group (http://www.ece.drexel.edu/walsh/aspitrg/home.html) conducts research in the area of signal processing and information theory. Our main interests are belief/expectation propagation, turbo decoding and composite adaptive system theory. We are currently doing projects on the following topics:

i) Delay mitigating codes for network coded systems,
ii) Distributed estimation in sensor networks via expectation propagation,
iii) Turbo speaker identification,
iv) Performance and convergence of expectation propagation,
v) Investigating bounds for SINR performance of autocorrelation based channel shorteners.

# Applied Networking Research Lab

Applied Networking Research Lab (ANRL) projects focus on modeling and simulation as well as experimentation in wired, wireless and sensor networks. ANRL is the home of MuTANT, a Multi-Protocol Label Switched Traffic Engineering and Analysis Testbed composed of 10 high-end Cisco routers and several PC-routers, also used to study other protocols in data networks as well as automated network configuration and management. The lab also houses a sensor network testbed.

### Bioimage Laboratory

Uses computer gaming hardware for enhanced and affordable 3-D visualization, along with techniques from information theory and machine learning to combine the exquisite capabilities of the human visual system with computational sensing techniques for analyzing vast quantities of image sequence data.

# Data Fusion Laboratory

The Data Fusion Laboratory investigates problems in multisensory detection and estimation, with applications in robotics, digital communications, radar, and target tracking. Among the projects in progress: computationally efficient parallel distributed detection architectures, data fusion for robot navigation, modulation recognition and RF scene analysis in time-varying environments, pattern recognition in biological data sequences and large arrays, and hardware realizations of data fusion architectures for target detection and target tracking.

# Drexel Network Modeling Laboratory

The Drexel Network Modeling Laboratory investigates problems in the mathematical modeling of communication networks, with specific focus on wireless ad hoc networks, wireless sensor networks, and supporting guaranteed delivery service models on best effort and multipath routed networks. Typical methodologies employed in our research include mathematical modeling, computer simulation, and performance optimization, often with the end goal of obtaining meaningful insights into network design principles and fundamental performance tradeoffs.

# Drexel Power-Aware Computing Laboratory

The Power-Aware Computing Lab (http://dpac.ece.drexel.edu) investigates methods to increase energy efficiency across the boundaries of circuits, architecture, and systems. Our recent accomplishments include the Sigil profiling tool, scalable modeling infrastructure for accelerator implementations, microarchitecture-aware VDD gating algorithms, an accelerator architecture for ultrasound imaging, evaluation of hardware reference counting, hardware and operating system support for power-agile computing, and memory systems for accelerator-based architectures.

# Drexel University Nuclear Engineering Education Laboratory

The field of nuclear engineering encompasses a wide spectrum of occupations, including nuclear reactor design, medical imaging, homeland security, and oil exploration. The Drexel University Nuclear Engineering Education Laboratory (DUNEEL) provides fundamental hands on understanding for power plant design and radiation detection and analysis. Software based study for power plant design, as well as physical laboratory equipment for radiation detection, strengthen the underlying concepts used in nuclear engineering such that the student will comprehend and appreciate the basic concepts and terminology used in various nuclear engineering professions. Additionally, students use the laboratory to develop methods for delivering remote, live time radiation detection and analysis. The goal of DUNEEL is to prepare students for potential employment in the nuclear engineering arena.

# Drexel VLSI Laboratory

The Drexel VLSI Laboratory (http://ece.drexel.edu/faculty/taskin/wiki/vlsilab/index.php/Main_Page) investigates problems in the design, analysis, optimization and manufacturing of high performance (low power, high throughput) integrated circuits in contemporary CMOS and emerging technologies. Suited with industrial design tools for integrated circuits, simulation tools and measurement beds, the VLSI group is involved with digital and mixed-signal circuit design to verify the functionality of the discovered novel circuit and physical design principles. The Drexel VLSI laboratory develops design methodologies and automation tools in these areas, particularly in novel clocking techniques, featuring resonant clocking, and interconnects, featuring wireless interconnects.

# Drexel Wireless Systems Laboratory

The Drexel Wireless Systems Laboratory (DWSL) contains an extensive suite of equipment for constructing, debugging, and testing prototype wireless communications systems. Major equipment within DWSL includes:

- three software defined radio network testbeds (HYDRA, USRP, and WARP) for rapidly prototyping radio, optical and ultrasonic communications systems,
- a TDK RF anechoic chamber and EMSCAN desktop antenna pattern measurement system,
- a materials printer and printed circuit board milling machine for fabricating conformal antennas and
- wireless protocol conformance testing equipment from Aeroflex.

The lab is also equipped with network analyzers, high speed signal generators, oscilloscopes, and spectrum analyzers as well as several Zigbee development platforms for rapidly prototyping sensor networks.

DWSL personnel also collaborate to create wearable, fabric based transceivers through collaboration with the Shima Seiki Haute Laboratory in the Drexel ExCITe Center. The knitting equipment at Drexel includes sixteen SDS-ONE APEX3 workstations and four state-of-the-art knitting machines. The workstations accurately simulate fabric construction and provide researchers and designers the opportunity to program, create and simulate textile prototypes, import CAD specifications of final products, and produce made-to-measure or mass-produced pieces on Shima Seiki knitting machines. For testing smart textiles for biomedical, DWSL personnel also have collaborators in the Center for Interdisciplinary Clinical Simulation and Practice (CICSP) in the Drexel College of Medicine which provides access to medical mannequin simulators.

# Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (EESI) (http://www.ece.drexel.edu/gailr/EESI) seeks to solve problems in high-throughput genomics and engineer better solutions for biochemical applications. The lab's primary thrust is to enhance the use of high-throughput DNA sequencing technologies with pattern recognition and signal processing techniques. Applications include assessing the organism content of an environmental sample, recognizing/classifying potential and functional genes, inferring environmental factors and inter-species relationships, and inferring microbial evolutionary relationships from short-read DNA/RNA fragments. The lab also investigates higher-level biological systems such as modeling and controlling chemotaxis, the movement of cells.

# Electric Power Engineering Center

This newly established facility makes possible state-of-the-art research in a wide variety of areas, ranging from detailed theoretical model study to experimental investigation in its high voltage laboratories. The mission is to advance and apply scientific and engineering knowledge associated with the generation, transmission, distribution, use, and conservation of electric power. In pursuing these goals, this center works with electric utilities, state and federal agencies, private industries, nonprofit organizations and other universities on a wide spectrum of projects. Research efforts, both theoretical and experimental, focus on the solution of those problems currently faced by the electric power industry. Advanced concepts for electric power generation are also under investigation to ensure that electric power needs will be met at the present and in the future.

# Electronic Design Automation Facility

Industrial-grade electronic design automation software suite and intergrated design environment for digital, analog and mixed-signal systems development. Field Programmable Gate Array (FPGA) development hardware. Most up-to-date FPGA/embedded system development hardware kits. Printed circuit board production facility. Also see Drexel VLSI Laboratory.

# Microwave-Photonics Device Laboratories

The laboratory is equipped with test and measurement equipment for high-speed analog and digital electronics and fiber optic systems. The test equipment includes network analyzers from Agilent (100kHz- 1.3 GHz and 45 Mhz-40 GHz), and Anritsu (45 MHz-6 GHz); spectrum analyzers from Tektronix, HP, and Agilent with measurement capability of DC to 40 GHz and up to 90 GHz using external mixers; signal generators and communication channel modulators from HP, Rhode-Schwartz, Systron Donner, and Agilent; microwave power meter and sensor heads, assortment of passive and active microwave components up to 40 GHz ; data pattern generator and BER tester up to 3Gb/s; optical spectrum analyzer from Anritsu and power meters from HP; single and multimode fiber optic based optical transmitter and receiver boards covering ITU channels at data rates up to 10Gb/s; passive optical components such as isolator, filter, couplers, optical connectors and fusion splicer; LPKF milling machine for fabrication of printed circuit boards; wire-bonding and Cascade probe stations; Intercontinental test fixtures for testing of

MMIC circuits and solid-state transistors; state-of-the-art microwave and electromagnetic CAD packages such as Agilent ADS, ANSYS HFSS, and COMSOL multi-physics module.

## Music and Entertainment Technology Laboratory

The Music and Entertainment Technology Laboratory (MET-lab) is devoted to research in digital media technologies that will shape the future of entertainment, especially in the areas of sound and music. We employ digital signal processing and machine learning to pursue novel applications in music information retrieval, music production and processing technology, and new music interfaces. The MET-lab is also heavily involved in outreach programs for K-12 students and hosts the Summer Music Technology program, a one-week learning experience for high school students. Lab facilities include a sound isolation booth for audio and music recording, a digital audio workstation running ProTools, two large multi-touch display interfaces of our own design, and a small computing cluster for distributed processing.

## NanoPhotonics+ Lab (http://drexelnanophotonics.com)

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# Electrical and Computer Engineering Faculty

Suryadevara Basavaiah, PhD *(University of Pennsylvania)*. Teaching Professor. Computer engineering; computer engineering education; custom circuit design; VLSI technology; process and silicon fabrication.

Tom Chmielewski, PhD *(Drexel University)*. Assistant Teaching Professor. Modeling and simulation of electro-mechanical systems; Optimal, Adaptive and Non-Linear Control; DC Motor Control; System Identification; Kalman Filters (Smoothing Algorithms, tracking); image processing, Robot design; Biometric technology and design of embedded systems for control applications utilizing MATLAB and SIMULINK

Fernand Cohen, PhD *(Brown University)*. Professor. Surface modeling; tissue characterization and modeling; face modeling; recognition and tracking.

Andrew Cohen, PhD *(Rensselaer Polytechnic Institute)*. Associate Professor. Image processing; multi-target tracking; statistical pattern recognition and machine learning; algorithmic information theory; 5-D visualization.

Kapil Dandekar, PhD *(University of Texas-Austin) Director of the Drexel Wireless Systems Laboratory (DWSL); Associate Dean of Research, College of Engineering*. Professor. Cellular/mobile communications and wireless LAN; smart antenna/MIMO for wireless communications; applied computational electromagnetics; microwave antenna and receiver development; free space optical communication; ultrasonic communication; sensor networks for homeland security; ultrawideband communication.

Afshin Daryoush, PhD *(Drexel University)*. Professor. Microwave photonics systems; nonlinear microwave circuits; RFIC and wireless communications; antennas and radiating systems; electromagnetic interaction with biological systems.

Bruce A. Eisenstein, PhD *(University of Pennsylvania) Arthur J. Rowland Professor of Electrical and Computer Engineering; Vice Dean, College of Engineering*. Professor. Pattern recognition; estimation; decision theory; digital signal processing.

Adam K. Fontecchio, PhD *(Brown University) Associate Dean for Undergraduate Affairs; Associate Director, Expressive and Creative Interactive Technologies (EXCITE) Center*. Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park)*. Professor. Biological and biomedical applications of nanoscale magnetic systems.

Eli Fromm, PhD *(Jefferson Medical College) Roy A. Brothers University Professor / Director for Center of Educational Research*. Professor. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania) Assistant EDE Department Head; Liason for Evening Programs*. Professor. Computerized instruments and measurements; undergraduate engineering education.

Allon Guez, PhD *(University of Florida)*. Professor. Intelligent control systems; robotics, biomedical, automation and manufacturing; business systems engineering.

Mark Hempstead, PhD *(Harvard University) Junior Colehower Chair*. Assistant Professor. Computer engineering; power-aware computing; computer architecture; low power VLSI Design; wireless sensor networks.

Peter R. Herczfeld, PhD *(University of Minnesota) Lester A. Kraus Professor/Director, Center for Microwave/Lightwave Engineering*. Professor. Lightwave technology; microwaves; millimeter waves; fiberoptic and integrated optic devices.

Leonid Hrebien, PhD *(Drexel University)*. Professor. Tissue excitability; acceleration effects on physiology; bioinformatics.

Paul R. Kalata, PhD *(Illinois Institute of Technology)*. Associate Professor. Stochastic and adaptive control theory; identification and decision theory; Kalman filters.

Nagarajan Kandasamy, PhD *(University of Michigan)*. Associate Professor. Embedded systems, self-managing systems, reliable and fault-tolerant computing, distributed systems, computer architecture, and testing and verification of digital systems.

Bruce Katz, PhD *(University of Illinois)*. Adjunct Professor. Neural networks; the study of aesthetics; artificial intelligence; music perception.

Youngmoo Kim, PhD *(Massachusetts Institutie of Technology) Director, Expressive and Creative Interaction Technologies (EXCITE) Center*. Associate Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Timothy P. Kurzweg, PhD *(University of Pittsburgh) Associate Department Head for Undergraduate Studies and Director of the BSE Program*. Associate Professor. Optical MEM modeling and simulation; system-level simulation; computer architecture.

Mohammad Madihian, PhD *(Shizuoka University)*. Adjunct Professor. Solid-state device-circuit interaction; microwave and millimeter-wave monolithic circuit design and evaluation technology; solid-state power generation/amplification/mixing technology; single/multi-mode wireless RF/IF transceiver technology

Karen Miu, PhD *(Cornell University)*. Professor. Power systems; distribution networks; distribution automation; optimization; system analysis.

Bahram Nabet, PhD *(University of Washington)*. Professor. Optoelectronics; fabrication and modeling; fiber optic devices; nanoelectronics; nanowires.

Prawat Nagvajara, Ph.D. *(Boston University)*. Associate Professor. System on a chip; embedded systems; power grid computation; testing of computer hardware; fault-tolerant computing; VLSI systems; error control coding.

Vasileios Nasis, PhD *(Drexel University)*. Associate Teaching Professor. Imaging with MOEMS, Projection systems using MEMS/MOEMS, Wireless communications, Remote monitoring, sensor networks.

Dagmar Niebur, PhD *(Swiss Federal Institute of Technology)*. Associate Professor. Intelligent systems; dynamical systems; power system monitoring and control.

Chika Nwankpa, PhD *(Illinois Institute of Technology) Interum Department Head*. Professor. Power system dynamics; power electronic switching systems; optically controlled high power switches.

Christopher Peters, PhD *(University of Michigan, Ann Arbor)*. Teaching Professor. Nuclear reactor design; ionizing radiation detection; nuclear forensics; power plant reliability and risk analysis; naval/marine power and propulsion; directed energy/high power microwaves; nonstationary signal processing; radar; electronic survivability/susceptibility to harsh environments; electronic warfare.

Karkal S. Prahbu, PhD *(Harvard University)*. Teaching Professor. Computer and software engineering; advanced microprocessors and distributed operating systems.

Gail L. Rosen, PhD *(Georgia Institute of Technology)*. Associate Professor. Signal processing, signal processing for biological analysis and modeling, bio-inspired designs, source localization and tracking.

Ioannis Savidis, PhD *(University of Rochester) Director of the Integrated Circuits and Electronics (ICE) Design and Analysis Laboratory*. Assistant Professor. Analysis, modeling, and design methodologies for high performance digital and mixed-signal integrated circuits; Emerging

integrated circuit technologies; Electrical and thermal modeling and characterization, signal and power integrity, and power and clock delivery for 3-D IC technologies.

Kevin J. Scoles, PhD *(Dartmouth College)*. Associate Professor. Microelectronics; electric vehicles; solar energy; biomedical electronics.

Harish Sethu, PhD *(Lehigh University)*. Associate Professor. Protocols, architectures and algorithms in computer networks; computer security; mobile ad hoc networks; large-scale complex adaptive networks and systems.

James Shackleford, PhD *(Drexel University)*. Assistant Professor. Medical image processing, high performance computing, embedded systems, computer vision, machine learning.

P. Mohana Shankar, PhD *(Indian Institute of Technology) Allen Rothwarf Professor of Electrical and Computer Engineering*. Professor. Wireless communications; biomedical ultrasonics; fiberoptic bio-sensors.

Matthew Stamm, PhD *(University of Maryland, College Park) Head, Multimedia and Information Security Laboratory (MSL)*. Assistant Professor. Information Security; Multimedia Forensics and Anti-Forensics; Information Verification; Adversarial Dynamics; Signal Processing.

Baris Taskin, PhD *(University of Pittsburgh)*. Associate Professor. Electronic design automation (EDA) of integrated circuits, high-performance VLSI circuits and systems, sequential circuit timing and synchronization, system-on-chip (SOC) design, operational research, VLSI computer-aided design.

Lazar Trachtenberg, DSc *(Israel Institute of Technology)*. Professor. Fault tolerance; multi-level logic synthesis; signal processing; suboptimal filtering.

Yon Visell, PhD *(McGill University)*. Assistant Professor. Haptic display engineering, material and biomechanical contact physics, neuroscientific and physical basis of human tactile sensation/perception, haptic human-machine interaction, sensorimotor learning, interaction in virtual reality

John Walsh, PhD *(Cornell University)*. Associate Professor. Performance and convergence of belief/expectation propagation and turbo decoding/equalization/synchronization, permeation models for ion channels, composite adaptive systems theory.

Steven Weber, PhD *(University of Texas-Austin) Assistant Department Head for Graduate Affairs, Electrical and Computer Engineering*. Associate Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice Cavalcante de Oliveira, PhD *(Georgia Institute of Technology)*. Associate Professor. Next generation Internet; quality of service in computer communication networks; wireless networks.

## Interdepartmental Faculty

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine*. Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Jeremy R. Johnson, PhD *(Ohio State University)*. Professor. Computer algebra; parallel computations; algebraic algorithms; scientific computing.

John Lacontora, PhD *(New Jersey Institute of Technology)*. Associate Research Professor. Service engineering; industrial engineering.

Ryszard Lec, PhD *(University of Warsaw Engineering College)*. Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Spiros Mancoridis, PhD *(University of Toronto) Sr. Associate Dean for Computing and CCI Academic Affairs*. Professor. Software engineering; software security; code analysis; evolutionary computation.

Karen Moxon, PhD *(University of Colorado)*. Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Paul Y. Oh, PhD *(Columbia University)*. Adjunct Professor. Smart sensors servomechanisms; machine vision and embedded microcomputers for robotics and mechatronics.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems*. Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University)*. Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

William C. Regli, PhD *(University of Maryland-College Park)*. Professor. Artificial intelligence; computer graphics; engineering design and Internet computing.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering*. Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering*. Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces; scanning probe microscopy; laser spectroscopy, including Raman scattering.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems*. Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Aspasia Zerva, PhD *(University of Illinois)*. Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

## Emeritus Faculty

Robert Fischl, PhD *(University of Michigan) John Jarem Professor Emeritus / Founder of the Center for Electric Power Engineering*. Professor Emeritus. Power: systems, networks, controls, computer-aided design, power systems, solar energy.

Vernon L. Newhouse, PhD *(University of Leeds) Disque Professor Emeritus*. Professor Emeritus. Biomedical and electrophysics: ultrasonic flow measurement, imaging and texture analysis in medicine, ultrasonic nondestructive testing and robot sensing, clinical engineering.

Hun H. Sun, PhD *(Cornell University) Ernest O. Lange Professor Emeritus.* Professor Emeritus. Systems and signals in biomedical control systems.

Oleh Tretiak, ScD *(MIT).* Professor Emeritus. Image processing; tomography; image registration; pattern recognition.

# Elec Comp Engr-Computers Courses

### ECEC 500 Fundamentals Of Computer Hardware 3.0 Credits
Covers computer organization and architecture; elements of computer hardware, processors, control units, and memories; hardware for basic mathematical operations; tradeoffs between speed and complexity; examples of embedded systems; microcontrollers; systems modeling.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 501 Computational Principles of Representation and Reasoning 3.0 Credits
This course presents fundamentals of discrete mathematics as applied within the computer engineering and manufacturing environment. Students are given the theoretical background in representation and reasoning for a broad variety of engineering problems solving situations. Entity-relational techniques of representation are demonstrated to evolve into the object-oriented approach. Various search techniques are applied in the cases of representing engineering systems by using theory of automata techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 502 Principles of Data Analysis 3.0 Credits
This course presents theoretical methods and techniques of model development applicable within the computer engineering design and manufacturing environment. Students are given the theoretical background in data analysis (including "data mining"). Emphasis is on hybrid systems and discrete events systems. Various methods of recognizing regularities in data will be presented. Elements of the theory of clustering and classification will be dealt with for the paradigm of software and hardware problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 503 Principles of Decision Making 3.0 Credits
This course presents theoretical fundamentals and engineering techniques of decision making and problem solving applicable within the computer engineering design and manufacturing environment. Students are given the theoretical background in optimization methods for a broad variety of situation. Elements of the theory of planning and on-line control of systems are presented within the scope of software and hardware computer design and control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 511 Combinational Circuit Design 3.0 Credits
Representing arithmetic. Logic and syntax data for machine processing. Switching algebra: Boolean and multiple values. Identification and classification of functions. Realizing completely specified and incompletely specified Boolean functions. Issues in designing large communication/control Boolean functions. Fault and testing of Boolean function.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 512 Sequential Circuit Design 3.0 Credits
Finite automata and their realization by sequential machines, capabilities, transformation, and minimization of finite automata, linear finite automata. Clocked pulsed and level mode sequential circuits. Malfunctions in sequential circuits: hazards, races, lockouts, metastability. Issues of state assignment. Evolution of memory elements design: ROM vs. RAM vs. associative memory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 511 [Min Grade: C]

### ECEC 513 Design for Testability 3.0 Credits
Economics vs. Complexity vs. Strategy of Testing; Fault Models; Test Generation; Testability Analysis & Designing Testable Circuits; Testing Microprocessors, Memories and Computer Components; Test Data Compression; Fault Tolerant Hardware; Reliably vs. Availability; Redundancy and Error Correcting Codes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 511 [Min Grade: C] and ECEC 512 [Min Grade: C]

### ECEC 520 Dependable Computing 3.0 Credits
Fundamental design issues involved in building reliable, safety-critical, and highly available systems. Topics include testing and fault-tolerant design of VLSI circuits, hardware and software fault tolerance, information redundancy, and fault-tolerant distributed systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 541 Robotic Computer Interface Controls I 3.0 Credits
Covers sensors, actuators, mechanical components of robots, kinematics, inverse kinematics, dynamics, and equations of motion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### ECEC 542 Robotic Computer Interface Controls II 3.0 Credits
Covers the robot control problem, including PD, PID, position, force and hybrid controllers, resolved rate and acceleration control, and multiprocessor architecture.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 641 [Min Grade: C] and ECES 643 [Min Grade: C] and ECEC 541 [Min Grade: C]

### ECEC 543 Robotic Computer Interface Controls III 3.0 Credits
Covers non-linear control techniques, FLDT, and advanced topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 542 [Min Grade: C]

### ECEC 571 Introduction to VLSI Design 3.0 Credits
This is an introductory course where systematic understanding, design and analysis of digital VLSI integrated circuits will be covered. The course will begin with a review of CMOS transistor operation and semiconductor processes. Logic design with CMOS transistor and circuit families will be described. Specifically, layout, design rules, and circuit simulation will be addressed. Performance metrics will be analyzed in design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 572 Custom VLSI Design & Analysis I 3.0 Credits**
This is the first of two courses offered on Custom VLSI circuit and systems design and analysis. An understanding of VLSI integrated circuits is achieved through circuit design and analysis. This course focuses exclusively on high performance digital CMOS VLSI circuit and systems design, although some topics on mixed-signal circuits are also addressed. Design and analysis of VLSI integrated circuits will be covered from the circuits and systems design perspectives. First, a thorough analysis of interconnect networks is presented. The second part of the class focuses on synchronization of high performance ICs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 571 [Min Grade: C]

**ECEC 573 Custom VLSI Design & Analysis II 3.0 Credits**
This is the second of two courses offered on Custom VLSI circuit and systems design and analysis. An understanding of VLSI integrated circuits is achieved through circuit design and analysis. This course focuses exclusively on high performance digital CMOS VLSI circuit and systems design, although some topics on mixed-signal circuits are also addressed. The primary focus is on-chip power management. Power generation techniques are discussed and different power converters are analyzed. Power distribution networks are presented with a focus on the different distribution architectures and output impedance characteristics. Techniques to reduce power supply noise are also provided. A secondary focus examines substrate noise in mixed-signal systems and techniques to reduce substrate noise.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 571 [Min Grade: C]

**ECEC 574 ASIC Design I 3.0 Credits**
This course will focus exclusively on digital CMOS Application Specific Integrated Circuit (ASIC) systems design and automation. The ASIC physical design flow, including logic synthesis, floorplanning, placement, clock tree synthesis, routing and verification will be presented. These back-end physical design flow steps will also be covered through hands-on practice using industrial VLSI CAD tools. Contemporary design practices will be reviewed and presented in experiments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 575 ASIC Design II 3.0 Credits**
Design and analysis of VLSI integrated circuits will be covered from a systems design perspective. System timing, arithmetic building block and memory block design processes will be presented. Design tasks in a quarter-long, small-complexity processor design project will cover the back-end of the IC design flow range, from RTL synthesis to timing and power analysis. Projects will be performed in a hierarchical group, similar to an industrial setting, with other graduate and undergraduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 572 [Min Grade: C]

**ECEC 600 Fundamentals of Computer Networks 3.0 Credits**
Fundamentals design principles of ATM, Internet and local area networks; protocol layers and the Internet Architecture; medium access protocols; application protocols and TCP/IP utilities; basic principles and virtual circuit switching; naming and addressing; flow and congestion control protocols; routing algorithms; Quality-of-Service in computer networks; security issues in networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 621 High Performance Computer Architecture 3.0 Credits**
Maximizing single processor performance. Concepts and techniques for design of computer systems. Processor design, instruction set architecture design and implementation, memory hierarchy, pipelines processors, bus bandwidth, processor/memory interconnections, cache memory, virtual memory, advanced I/O systems, performance evaluation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 622 Parallel Computer Architecture 3.0 Credits**
Advanced techniques of computer design. Use of parallel processing to achieve high performance levels. Fine and coarse grained parallelism. Multiple CPU parallelism, through multiprocessors, array and vector processors. Dataflow architectures and special purpose processors. Design implications of memory latency and bandwidth limitations. Speedup problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 621 [Min Grade: C]

**ECEC 623 Advanced Topics in Computer Architecture 3.0 Credits**
This course teaches advanced concepts of modern computer architecture and introduces the current challenges faced by computer architects. These challenges include power consumption, transistor variability, and processor heterogeneity. Students develop their research skills through a self directed research project with a final presentation and conference style writeup.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 621 [Min Grade: C]

**ECEC 631 Principles of Computer Networking 3.0 Credits**
Principles of circuit switching, packet switching and virtual circuits; protocol layering; application layer protocols for e-mail and web applications; naming and addressing; flow control and congestion avoidance with TCP; Internet Protocol (IP); routing algorithms; router architectures; multicast protocols; local area network technologies and protocols; issues in multimedia transmissions; scheduling and policing; Quality-of-Service and emerging Internet service architectures; principles of cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 632 Performance Analysis of Computer Networks 3.0 Credits**
Covers probability theory and its applications to networks, random variable and random processes; Markov chains, multi-dimensional Markov chains; M/M/1, M/M/m, M/M/m/m, M/G/1 and G/G/1 queueing systems and their applications in computer networks; analysis of networks of queues: Kleinrock Independence Approximation; Time-reversibility and Burke's theorem; Jackson's theorem; the phenomenon of long-range dependence and its implications in network design and traffic engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 631 [Min Grade: C]

**ECEC 633 Advanced Topics in Computer Networking 3.0 Credits**
perspectives in the areas of switch/router architectures, scheduling for best-effort and guaranteed services, QoS mechanisms and architectures, web protocols and applications, network interface design, optical networking, and network economics. The course also includes a research project in computer networking involving literature survey, critical analysis, and finally, an original and novel research contribution.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 631 [Min Grade: C] and ECEC 632 [Min Grade: C]

**ECEC 654 Knowledge Engineering I 3.0 Credits**
Covers conceptual modeling, including an overview of knowledge representation. Includes semantic networks, reduced semantic networks, logic of incomplete knowledge bases, extensional semantic networks, and applications of conceptual models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 655 Knowledge Engineering II 3.0 Credits**
Covers expert systems, including language and tools of knowledge engineering. Includes reasoning about reasoning, design and evaluation, heuristics in expert systems, expert systems for decision support, and expert systems in conceptual design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 654 [Min Grade: C]

**ECEC 656 Knowledge Engineering III 3.0 Credits**
Covers information-intensive systems, including information representation in autonomous systems. Includes clauses and their validation; clustering in linguistic structures; linguistic and pictorial knowledge bases; discovery in mathematics, including am; and methods of new knowledge generation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 655 [Min Grade: C]

**ECEC 661 VLSI Design 3.0 Credits**
Covers CMOS design styles, techniques, and performance; VLSI computer hardware, arithmetic units, and signal processing systems; and cat tools for layout design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 662 VLSI Array Processors I 3.0 Credits**
Covers VLSI testing, including design for testability and parallel computer architectures; signal and image processing algorithms and mapping algorithms onto array structures; and systolic array processors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 661 [Min Grade: C]

**ECEC 663 VLSI Array Processors II 3.0 Credits**
Covers wavefront array processors; matching hardware to arrays; hardware design, systems design, and fault-tolerant design; and implementations and VLSI design projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 662 [Min Grade: C]

**ECEC 671 Electronic Design Automation for VLSI Circuits I 3.0 Credits**
This course focuses on the electronic design automation problems in the design process of VLSI integrated circuits. In this first quarter of the course, algorithms, techniques and heuristics structuring the foundations of contemporary VLSI CAD tools are presented. Boolean algebra, graph theory, logic minimization and satisfiability topics are presented.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 672 Electronic Design Automation for VLSI Circuits II 3.0 Credits**
This course focuses on the electronic design automation problems in the design process of VLSI integrated circuits. In this second quarter of the course, physical VLSI design steps of technology mapping, floor planning, placement, routing and timing and presented individual and team-based small-to-medium scale programming projects are assigned.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 671 [Min Grade: C]

**ECEC 673 Deep Sub-Micron Integrated Circuit Design 3.0 Credits**
This course focuses on the design challenges of digital VLSI integrated circuits in deep sub-micron manufacturing technologies. Automation challenges and high-performance circuit design techniques such as low-power and variation-aware design are presented. The course material is delivered in a lecture format structured on recent presentations, articles, and tutorials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 671 [Min Grade: C]

**ECEC 690 Special Topics Computer Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 697 Research in Computer Engineering 1.0-12.0 Credit**
Research in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 699 Supervised Study in Computer Engineering 9.0 Credits**
Supervised study in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 890 Advanced Special Topics in Computer Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 891 Advanced Topics in Computer Engineering 0.5-9.0 Credits**
Advanced topics in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 898 Master's Thesis in Computer Engineering 1.0-12.0 Credit**
Master's thesis in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 997 Dissertation Research in Computer Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 998 Ph.D. Dissertation in Computer Engineering 1.0-12.0 Credit**
Ph.D. dissertation in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Elec Computer Engr-Electroph Courses

**ECEE 501 Physical Principles of Electrical Engineering I 3.0 Credits**
Core course. Covers classical mechanics, including generalized coordinates, Lagrangian and Hamiltonian formulation, and variational principle. Introduces quantum mechanics, including Schrodinger equation, wave functions, operators, expectation values, and hydrogen atom.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 502 Physical Principles of Electrical Engineering II 3.0 Credits**
Core course. Continues ECEE 501. Covers atomic orbitals, angular momentum, oscillators, time-independent and time-dependent perturbation theories, many-particle wave functions, and optical transitions. Also covers statistical mechanics, including distributions, ensembles, and thermal properties of solids.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 501 [Min Grade: C]

**ECEE 507 Electromagnetic Field Analysis I 3.0 Credits**
Core course. Covers Maxwell's equations; solutions of Laplace's equation, Green's function, and scalar and vector potentials; energy and momentum in electromagnetic fields; and interaction of fields and material media.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 508 Electromagnetic Field Analysis II 3.0 Credits**
Core course. Continues ECEE 507. Covers em waves, including reflection, refraction, polarization, and dispersion. Includes metallic and dielectric guiding structures, guides, and waveguide circuits and applications to stripline, microstrip, and optical fiber transmission systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 507 [Min Grade: C]

**ECEE 510 Scattering & Diffraction of Electromagnetic Waves 3.0 Credits**
Boundary value problems of EM theory. Exact and approximate methods for scattering by spheres, half plane, slit; radar cross-section theory. Quasi-optical theory, scattering, diffraction coefficients. Applications to radio propagation around the earth.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 517 Microwave Networks & Transmission Media 3.0 Credits**
Core course. Atmospheric wave propagation, solution of wave equation without sources in isotropic media, plane-waves, polarization, dispersion surfaces, wave admittance and impedance, wave propagation in free-space and various media, waves at interfaces, solution of wave equation with sources, duality principle, arrays analysis, metallic waveguides, modes in cylindrical waveguides, rectangular and circular, resonant cavities and perturbational methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 518 Microwave Passive Components 3.0 Credits**
Core course. V-I and E-H analogy, Kirchoff's Law, Telegrapher's EQ, voltage and current waves, reflection coefficient and impedance relationship, Smith Chart, impedance matching techniques, Bode-Fano theoretical limit, Broadband Quarter-wave Transformer, N-port linear networks, Z, Y, and S parameters, ABCD and T matrices, signal flow-graph and transfer functions, synthesis of two-port and unitary properties, even-odd mode analysis and dual directional couplers (design and synthesis), periodic structures and Flouke modes, filter design and synthesis using insertion loss and image methods, prototype LO filter and transformation to LP, BP, HP, and BS filters, Richards transform and Kuroda identities.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 519 Microwave Active Subsystems 3.0 Credits**
Core course. Overview of physics of P-N junction and Schottky junctions, pin, varactor, and step recovery diodes and their applications, transistors, MESFET and HEMT, BJT and HBT passive microwave circuits: switches, detectors, attenuators, modulators, and phase shifter, active microwave circuits: LNA, power amplifier, distributed amplifier, oscillators (fixed and VCO) power budget and link performance calculations for telecommunication, radar, and EW systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 520 Solid-State Electronics 3.0 Credits**
This course familiarizes the students with the fundamental properties of semiconductor materials leading to the students of electronic and photonic devices. Covered topics include: atomic structure, crystal structure, theories of electron conduction, scattering, pn junctions, heterojunctions, metal-semiconductor contacts, and junction devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 521 Bipolar and FETs 3.0 Credits**
This is the second course in a sequence of three on electronic and photonic devices. The course covers families of electronic devices. The course covers various families of electronic devices based on silicon and compound semiconductors. Bipolar transistors such as BJTs and HBTs and field-effect devices such as MOSFETs, MESFETs, and MODFETs are studied.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 520 [Min Grade: C]

**ECEE 522 Photonic Devices 3.0 Credits**
Covers fundamentals of absorption, spontaneous, and stimulated emission, photodetectors, light emitting diodes, laser oscillation, semiconductor laser diodes, RIN and phase noise, quantum well lasers, optical receivers, and quantum effect devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 521 [Min Grade: C]

**ECEE 523 Integrated Circuits 3.0 Credits**
Covers growth of single-crystal silicon, growth of oxide and epitaxial layers, photolithography, diffusion of impurities, fabrication of bipolar and unipolar integrated circuits, and interconnections and packaging.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 521 [Min Grade: C]

**ECEE 525 Digital IC and CMOS Technology 3.0 Credits**
Covers digital ICs using CMOS technology. Transistor level building blocks, -NOT, NAND, NOR, XOR, OAI, and AOI ? are designed using industry standard CAD tools, e.g. Cadence. Circuit topologies such as CPL, transmission gates are explored. CMOS technology/fabrication and layout are discussed to optimize speed, power, and area.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 526 Custom VLSI Design 3.0 Credits**
Course covers advanced design styles such as dynamic CMOS circuits, low power circuit concepts, bi-CMOS circuits and the design of VLSI sub-systems. A major category is memory design, both DRAM. VLSI design styles, system integration aspects are discussed. Project design involves a fair amount of layout.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 525 [Min Grade: C]

**ECEE 541 Photonic Systems 3.0 Credits**
Introduction to Optical principles through EM theory. Covers the mathematics of wave motion, as well as the idea of light propagating as particles. The course shows how ray (or geometrical) optics and Gaussian optics are derived from the wave theory. The course also introduces the polarization of light, and how this effects optical propagation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 542 Optical Applications of Diffraction and Interference 3.0 Credits**
Optical Applications of Diffraction and Interference. This course is an introduction to optical principles through EM theory. Covered topics include wave motion and superposition. Introduction to optical interference, or the interaction of light with itself. Topics include interference and interferometers, diffraction, and Fourier Optics. Diffraction topics include, far (Fraunhofer), near (Fresnel), and the near-near field diffraction. The course includes coding of some of the classical diffraction algorithms for the use in a project.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 603 Cooperative Phenomena 3.0 Credits**
Covers dielectrics, ferroelectrics, diamagnetism, paramagnetism, ferromagnetism, and antiferromagnetism; superconductivity, London's equations, BCS theory, and Josephson effect; and flux quantization, hard superconductors, GLAG theory, flux dynamics, and high-temperature superconductors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 502 [Min Grade: C] and ECEE 503 [Min Grade: C]

**ECEE 607 Nanoscale Fields 3.0 Credits**
Course covers essentials of electric and magnetic fields, including thermodynamics of polarizable media. Emphasis is on nano-and micro-scale effects like Van der Waals and double layer interactions, plasmon resonance and others. Examples from colloids and other areas of nanotechnology are used to illustrate main ideas.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 619 Radio Frequency Integrated Circuit Design 3.0 Credits**
This course introduces concepts in design of radio frequency (microwave and millimeter wave) integrated circuits. Optimum transistor technologies based on unipolar (MOS, FET, HEMT) and bipolar (BJT.HBT) are discussed for various RFIC applications. Performance of devices and circuits are evaluated in terms of gain, noise, and linearity. Active circuits and systems used in a variety of communications, imaging, and sensing are discussed in terms of standards and applications. IC design projects are integral to this course.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 518 [Min Grade: C]

**ECEE 621 Thin Film Technology I 3.0 Credits**
Covers vacuum technology, plasma processing, VLSI fabrication, and thin film technologies (e.g., plasma etching, thin film deposition, and thin film characterizations).
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 622 Microfabrication Technology 3.0 Credits**
The course provides an overview of basic technological processes
typically involved in microfabrication of Micro-Electro-Mechanical Systems
(MEMS). The course includes several demonstration laboratories
involving basic photolithography, thin film depositions and electroplating.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 623 Thin Film Technology III 3.0 Credits**
Presents speakers on state-of-the-art practice and future applications of
thin film deposition and processing technology.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 622 [Min Grade: C]

**ECEE 641 Fiber Optics & Optical Communications I 3.0 Credits**
Covers propagation in guided and unguided media, including step and
graded fibers, dispersion, guide deformations, and mode coupling.
Involves design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 642 Fiber Optics & Optical Communications II 3.0 Credits**
Covers coupling devices, multimode guides, sources, lasers, and radiation
patterns. Includes reliability, detectors, circuit models, and noise.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 641 [Min Grade: C]

**ECEE 671 Seminar in Electro-Physics I 2.0 Credits**
Advanced graduate seminar. Focuses on recent developments in
microwaves, electro-optics, and solid-state devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 672 Seminar in Electro-Physics II 2.0 Credits**
Continues ECEE 671.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 673 Seminar in Electro-Physics III 2.0 Credits**
Continues ECEE 672.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 690 Special Topics in Electrophysics 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 697 Research in Electrophysics 1.0-12.0 Credit**
Research in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 699 Supervised Study in Electrophysics 0.5-9.0 Credits**
Supervised study in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 811 Microwave & THZ Photonics I 3.0 Credits**
This course focuses on high speed photonic components for microwave
and terahertz fiber-optic links, namely high speed lasers, external
modulators and photodetectors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEE 812 Microwave & THZ Photonics II 3.0 Credits**
This course focuses on high speed analog and digital fiber-optic links
including loss and dynamic range calculations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 811 [Min Grade: C]

**ECEE 813 Microwave & THZ Photonics III 3.0 Credits**
This course focuses on the applications of fiber-optic links; antenna
remoting, optically fed and controlled phased array antennas and fiber
radio.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 811 [Min Grade: C] and ECEE 812 [Min Grade: C]

**ECEE 820 Carrier Transport Fundamentals 3.0 Credits**
This course introduces the fundamentals of carrier transport in
semiconductors, beyond the common drift-diffusion description functions
and Boltzmann transport equations are covered. Monte Carlo simulations
are used for low field and high field transport studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 520 [Min Grade: C]

**ECEE 821 Nanoelectronics 3.0 Credits**
Focus is on current transport when the size of electronic medium
reaches nanometer scales, that is, deBrogile wavelength. Topics include:
characteristic lengths, magneto-electric subbands, conductance from
transmission, resistance in a ballistic conductor, quantum Hall effect,
electron scattering in quantum structures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEE 820 [Min Grade: C]

**ECEE 890 Advanced Special Topics in Electrophysics 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 898 Masters Thesis in Electrophysics 9.0 Credits**
Master's thesis in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 997 Dissertation Research in Electrophysics 1.0-12.0 Credit**
Graded Ph.D. dissertation in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEE 998 Ph.D. Dissertation in Electrophysics 1.0-12.0 Credit**
Ph.D. dissertation in electrophysics.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Elec Computer Engr-Power Eng Courses

**ECEP 501 Power System Analysis 3.0 Credits**
Core course. Covers modeling of power systems, including: symmetrical components, transmission lines, transformers, per-unit values and one-line diagrams. Introduces power flow. Required of first-year power majors; equivalent undergraduate credits may be substituted.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 502 Computer Analysis of Power Systems 3.0 Credits**
Core course. Covers digital computation methods, including load flow, fault, and transient stability problems. Required of first-year power engineering majors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 501 [Min Grade: C]

**ECEP 503 Synchronous Machine Modeling 3.0 Credits**
Core course. Covers two-reaction theory, Park's synchronous machine models, modeling of the synchronous machine excitation and governor systems, and the effects on power system stability. Required of first-year power engineering majors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 502 [Min Grade: C]

**ECEP 601 Modeling & Analysis of Power Distribution Systems 3.0 Credits**
Modeling and Analysis of Power Distribution Systems. Introduction to power distribution system; balanced and unbalanced systems, component and load modeling, radial and weakly meshed topologies; algorithms for unbalanced power flow studies including radial and general structure solver.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Corequisite**: ECEP 501

**ECEP 602 Power Distribution Automation and Control 3.0 Credits**
Power Distribution Automation and Control. Focuses on distribution management systems and their application: including optimizing network operation -capacitor placement and control, network reconfiguration, service restoration. Modern solution technology will be addresses.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Corequisite**: ECEP 502

**ECEP 603 Service and Power Quality in Distribution Systems 3.0 Credits**
Service and Power Quality in Distribution Systems. Focus power distribution systems: service and power quality assessment including stat estimation, voltage quality, trouble call analysis, service restoration, component and system reliability assessment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 610 Power System Dynamics 3.0 Credits**
Covers system parameters and dynamics, swing equation and solutions for two-machine and multimachine systems, equal area criterion, computer solution techniques, system effects due to dynamic behavior of particular system components, and load characteristics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 503 [Min Grade: C]

**ECEP 611 Power System Security 3.0 Credits**
Covers contingency analysis, including operating and security constraints and network sensitivities; corrective dispatch using linear programming; and state estimation, including network observability, detection, and identification of bad data.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 610 [Min Grade: C]

**ECEP 612 Economic Operation of Power Systems 3.0 Credits**
Covers unit characteristics and economic operation, including transmission loss coefficients, general loss formula, and automatic economic load dispatch.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 501 [Min Grade: C]

**ECEP 613 Advanced Power System Design 3.0 Credits**
Covers components, functions, application, and performance; relative cost and scaling parameters; overall planning problem considering present-worth and cost-benefit principles; system reliability; intersystem pooling; and growth.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 641 Protective Relaying 3.0 Credits**
Covers relay principles and types, instrumentation of system parameters, relay characteristics and response, system component protection, solid-state relaying, underfrequency relays, and load shedding.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 503 [Min Grade: C]

**ECEP 642 Protective Relay Laboratory 3.0 Credits**
Covers electromechanical and static relays. Emphasizes application based on observed performance. Includes testing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 641 [Min Grade: C]

**ECEP 643 Solid State Protective Relaying 3.0 Credits**
Covers solid-state protective relays as applied to power system stability and protection, including comparisons with electromechanical relays.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 641 [Min Grade: C]

**ECEP 661 High Voltage High Power Phenomena 3.0 Credits**
Covers corona, corona losses, electromagnetic noise, dielectric strength, lightning, impulse testing and safety practices, elements of high-power circuit interruption, circuit and physical phenomena, and circuit breakers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 671 AC-DC and DC-AC Power Electronic Converters 3.0 Credits**
AC-DC and DC-AC Power Electronic Converters. Study of basic power electronic converter circuits: diode and phase controlled rectifiers and inverters; switch-mode converters. Applications to DC and AC power supplies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 501 [Min Grade: C] or ECEP 601 [Min Grade: C]

**ECEP 672 Power Electronic Experiments: Hardware and Software 3.0 Credits**
Hardware and Software Lab-Intensive course. Additional lectures on: Study of DC-DC switch-mode converters; Study of power electronic circuitry in residential, industrial and electric utility applications; Optimizing utility interfaces with power electronic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 671 [Min Grade: C]

**ECEP 673 Power Electronic Applications 3.0 Credits**
Electric Utility Applications with emphasis on DC Transmission, Optimizing the Utility interface. Resonant converters. Fundamentals of motor drives and their controls: induction, DC, synchronous and specialized motors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 671 [Min Grade: C]

**ECEP 690 Special Topics in Power Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 697 Research in Power Engineering 1.0-12.0 Credit**
Research in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 699 Supervised Study in Power Engineering 9.0 Credits**
Supervised study in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 801 Advanced Topics in Power Systems I 0.5-9.0 Credits**
Discusses the latest innovations, theories, and methodologies for the design, planning, and operation of power systems. Requires students to read and discuss technical articles published in the IEEE Transactions on pas, the Journal of Electric Energy and Systems, and other publications.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 802 Advanced Topics in Power Systems II 3.0 Credits**
Continues ECEP 801.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 803 Advanced Topics in Power Systems III 3.0 Credits**
Continues ECEP 802.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEP 821 Load Forecasting & Probability Methods 3.0 Credits**
Reviews probability methods. Covers probabilistic generation and load models; forecasting methodologies; load classification and characterization; energy and peak demand forecasting; weather-and non-weather-sensitive forecast; and annual, monthly, weekly, and daily forecast.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 610 [Min Grade: C]

**ECEP 822 Power System Planning 3.0 Credits**
Covers deterministic planning, including automated transmission system expansion planning and network sensitivities, and probabilistic planning, including generation and load models, generation cost analysis, production costing, and energy production cost models for budgeting and planning.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 821 [Min Grade: C]

**ECEP 823 Power System Reliability 3.0 Credits**
Covers basic reliability concepts, including probabilistic generation and load models, loss of load probability (LOLP), static and spinning generating-capacity reliability, transmission system reliability, and composite system and interconnected system reliability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEP 822 [Min Grade: C]

**ECEP 890 Advanced Special Topics in Power Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 898 Master's Thesis Power Engineering 1.0-12.0 Credit**
Master's thesis in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 997 Dissertation Research in Power Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEP 998 Ph.D. Dissertation in Power Engineering 1.0-12.0 Credit**
Ph.D. dissertation in power engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Elec Computer Engr-Systems Courses

**ECES 510 Analytical Methods in Systems 3.0 Credits**
This course is intended to provide graduate student in the field of signal and image processing with the necessary mathematical foundation, which is prevalent in contemporary signal and image processing research and practice.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 511 Fundamentals of Systems I 3.0 Credits**
Core course. Covers linear operators, including forms and properties (differential equations, transfer function, state space, causality, linearity, and time invariance); impulse response, including convolution, transition matrices, fundamental matrix, and linear dynamical system; definition, including properties and classification; representation, including block diagrams, signal flow, and analog and digital; properties, including controllability and observability; and eigenstructure, including eigenvalues and eigenvector and similarity transformations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 512 Fundamentals of Systems II 3.0 Credits**
Core course. Covers realization and identification, including minimal realization, reducibility and equivalence of models, and identification of systems; stability, including bounded input-bounded output, polynomial roots, and Lyapunov; and feedback compensation and design, including observers and controllers and multi-input/multi-output systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 511 [Min Grade: C]

**ECES 513 Fundamentals of Systems III 3.0 Credits**
Core course. Covers multivariable systems, numerical aspects of system analysis and design, design of compensators, elements of robustness, and robust stabilization.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 521 Probability & Random Variables 3.0 Credits**
Probability concepts. Single and multiple random variables. Functions of random variables. Moments and characteristic functions. Random number and hypothesis testing. Maximum likelihood estimation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 522 Random Process & Spectral Analysis 3.0 Credits**
Random Process. Poisson Process, Shot Noise. Gaussian Process. Matched Filters. Kalman Filters. Power Spectral Density. Autocorrelation and cross correlation. PSD estimation. Entropy. Markov Processes. Queuing Theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C]

**ECES 523 Detection & Estimation Theory 3.0 Credits**
Detection of signals in noise. Bayes criterion. NP criterion. Binary and M_ary hypotheses. Estimation of signal parameters. MLE and MAP estimation. 1D and 2D signals. ROC Analyses. Decision fusion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C] and ECES 522 [Min Grade: C]

**ECES 558 Digital Signal Processing for Sound & Hearing 3.0 Credits**
Introduction to the computational modeling of sound and the human auditory system. Signal processing issues, such as sampling, aliasing, and quantization, are examined from an audio perspective. Covers applications including audio data compression (mp3), sound synthesis, and audio watermarking.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 559 Processing of the Human Voice 3.0 Credits**
Introduction to the computational modeling of the human voice for analysis, synthesis, and recognition. Topics covered include vocal physiology, voice analysis-synthesis, voice data coding (for digital communications, VoIP), speaker identification, speech synthesis, and automatic speech recognition.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C] and ECES 558 [Min Grade: C]

**ECES 561 Medical Robotics I 3.0 Credits**
This course will introduce the emerging, multidisciplinary field of medical robotics. Topics include: introduction to robot architecture, kinematics, dynamics and control; automation aspects of medical procedures; safety, performance limitations; regulatory and economics and future developments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 562 Medical Robotics II 3.0 Credits**
This course will continue the introduction to the emerging, multidisciplinary field of medical robotics. Topics include: medical procedure automation; robot testing and simulation techniques; This is a project based course that will afford students the opportunity to work with existing medical robotic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 561 [Min Grade: C]

**ECES 604 Optimal Estimation & Stochastic Control 3.0 Credits**
Introduction to control system problems with stochastic disturbances; linear state space filtering, Kalman Filtering, Non-linear systems; extended Kalman Filtering. Robust and H-infinity methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C] and ECES 521 [Min Grade: C]

**ECES 607 Estimation Theory 3.0 Credits**
General characteristics of estimators. Estimators: least squares, mean square, minimum variance, maximum a posteriori, maximum likelihood. Numerical solution. Sequential estimators.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 614 Passive Network Synthesis 3.0 Credits**
An introduction to approximation theory; driving point functions; realizability by lumped-parameter circuits; positive real functions; properties of two and three element driving point functions and their synthesis; transfer function synthesis; all-pass networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 615 Analysis & Design of Linear Active Networks 3.0 Credits**
DC and AC models of bipolar transistors and FETs; design of differential operational amplifiers; optimal design of broad-band IC amplifiers; design of tuned amplifiers; design for optimal power gain, distortion, and efficiency; noise in transistor circuits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 621 Communications I 3.0 Credits**
Covers modulation techniques: baseband PAM, passband PAM, QAM, and PSK; orthogonal signaling: FSK; symbol/vector detection: matched filter and correlation detector; sequence detection: ISI; equalization: adaptive and blind; carrier synchronization; and timing recovery.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 622 Communications II 3.0 Credits**
Covers shot noise, noise in detectors, analog fiberoptic systems, carrier and subcarrier modulation, digital systems bit error rates for NRZ and RZ formats, coherent optical communication systems-heterodyne and homodyne systems, wavelength division multiplexing, system design concepts, power budgets, rise time budgets, and optical switching networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 623 Communications III 3.0 Credits**
Covers fundamentals of information theory: information measure, entropy, and channel capacity; source encoding and decoding; rate distortion theory; linear codes; block codes; convolutional codes, Viterbi algorithm; encryption and decryption; and spread spectrum communications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 631 Fundamentals of Deterministic Digital Signal Processing 3.0 Credits**
Fundamentals of Deterministic Digital Signal Processing. This course introduces the fundamentals of deterministic signal processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 632 Fundamentals of Statistical Digital Signal Processing 3.0 Credits**
Fundamentals of Statistical Deterministic Digital Signal Processing. The course covers topics on statistical signal processing related to data modeling, forecasting and system identification.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 640 Genomic Signal Processing 3.0 Credits**
This course focuses on signal processing applied to analysis and design of biological systems. This is a growing area of interest with many topics ranging from DNA sequence analysis, to gene prediction, sequence alignment, and bio-inspired signal processing for robust system design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 642 Optimal Control 3.0 Credits**
Introduces the concept of optimal control first by static optimization for state space formulated systems. The concept is expanded as the linear quadratic regulator problem for dynamic systems allowing solution of the optimal control and suboptimal control problems for both discrete and continuous time. Additional topics include the Riccati equation, the tracking problem, the minimum time problem, dynamic programming, differential games and reinforcement learning. The course focuses on deriving, understanding, and implementation of the algorithms.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 643 Digital Control Systems Analysis & Design 3.0 Credits**
Covers analysis and design of sampled-data control system using Z-transform and state-variable formulation, sampling, data reconstruction and error analysis, stability of linear and non-linear discrete time systems by classical and Lyapunov's second method, compensator design using classical methods (e.g., rootlocus) and computer-aided techniques for online digital controls, optimal control, discrete-time maximum principle, sensitivity analysis, and multirate sampled-data systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 513 [Min Grade: C]

**ECES 644 Computer Control Systems 3.0 Credits**
Introduction to the fundamentals of real-time controlling electromechanical dynamic systems, including modeling, analysis, simulation, stabilization and controller design. Control design approaches include: pole placement, quadratic and robust control performances.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 651 Intelligent Control 3.0 Credits**
Concepts of Intelligence in Engineering Systems, Learning Automation, Principles of Knowledge Representation. Levels of Resolution and Nestedness. Organization of Planning: Axioms and Self-Evident Principles.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 660 Machine Listening and Music IR 3.0 Credits**
This course introduces methods for the computational analysis, recognition, and understanding of sound and music from the acoustic signal. Covered applications include sound detection and recognition, sound source separation, artist and song identification, music similarity determination, and automatic transcription.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 670 Seminar in Systems I 2.0 Credits**
Involves presentations focused on recent publications and research in systems, including communications, controls, signal processing, robotics, and networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 671 Seminar in Systems II 2.0 Credits**
Continues ECES 670.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 672 Seminar in Systems III 2.0 Credits**
Continues ECES 671.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 681 Fundamentals of Computer Vision 3.0 Credits**
Develops the theoretical and algorithmic tool that enables a machine (computer) to analyze, to make inferences about a "scene" from a scene's "manifestations", which are acquired through sensory data (image, or image sequence), and to perform tasks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 682 Fundamentals of Image Processing 3.0 Credits**
The course introduces the foundation of image processing with hands-on settings. Taught in conjunction with an imaging laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 684 Imaging Modalities 3.0 Credits**
This course is intended to produce students and image processing with a background on image formation in modalities for non-invasive 3D imaging. The goal is to develop models that lead to qualitative measures of image quality and the dependence of quality imaging system parameters.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 685 Image Reconstruction Algorithms 3.0 Credits**
This course is intended to provide graduate students in signal and image processing with an exposure to the design and evaluation of algorithms for tomographic imaging.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 684 [Min Grade: C] and BMES 621 [Min Grade: C]

**ECES 690 Special Topics in Systems Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 697 Research In Systems Engineering 1.0-12.0 Credit**
Research in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 699 Supervised Study in Systems Engineering 9.0 Credits**
Supervised study in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 801 Advanced Topics in Systems I 3.0 Credits**
Familiarizes students with current research results in their field of interest, specifically in works reported in such journals as The IEEE Transactions.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 802 Advanced Topics in Systems II 3.0 Credits**
Continues ECES 801.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 803 Advanced Topics in Systems III 3.0 Credits**
Continues ECES 802.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 811 Optimization Methods for Engineering Design 3.0 Credits**
Applications of mathematical programming and optimization methods in engineering design problems such as networks, control, communication, and power systems optimization. Optimization problem definition in terms of objective function, design variables, and design constraints. Single variable and multivariable search methods for unconstrained and constrained minimization using Fibonacci, gradient, conjugate gradient, Fletcher-Powell methods and penalty function approach. Classical optimization--Lagrange multiplier, Kuhn-Tucker conditions. Emphasis is on developing efficient digital computer algorithms for design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 812 Mathematical Program Engineering Design 3.0 Credits**
Approximation theory projection theorem. Solution of nonlinear equations by Newton-Raphson method. Resource allocation, linear programming, and network flow problems. Integer programming for digital filter design and power system expansion problems. Gamory's algorithm.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 813 Computer-Aided Network Design 3.0 Credits**
Simulation and circuit analysis programs: PCAP, MIMIC, GASP. Data structures. Algorithms. Languages. Interactive I/O. Integration of subroutines for simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 817 Non-Linear Control Systems 3.0 Credits**
Covers key topics of feedback linearization, sliding mode control, model reference adaptive control, self-tuning controllers and on-line parameter estimation. In addition additional no n-linear topics such as Barbalat's Lemma, Kalman-Yakubovich Lemma, passivity, absolute stability, and establishing boundedness of signals are presented. The focus of the course is the understanding each of these algorithms in detail through derivation and their implementation through coding in Matlab and Simulink.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 513 [Min Grade: C]

**ECES 818 Machine Learning & Adaptive Control 3.0 Credits**
System identification and parameter estimation, gradient search, least squares and Neural Networks methods. Closed loop implementation of system learning and self-organizing controllers. Random searching learning systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 821 Reliable Communications & Coding I 3.0 Credits**
Covers fundamentals of information theory, including measures of communication, channel capacity, coding for discrete sources, converse of coding system, noisy-channel coding, rate distortion theory for memoryless sources and for sources with memory, and universal coding.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C] and ECES 522 [Min Grade: C]

**ECES 822 Reliable Communications & Coding II 3.0 Credits**
Introduces algebra of coding, including groups, rings, fields, and vector fields. Covers finite fields, decoding circuitry, techniques for coding and decoding, linear codes, error-correction capabilities of linear codes, dual codes and weight distribution, important linear block codes, perfect codes, and Plotkin's and Varshamov's bounds.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 821 [Min Grade: C]

**ECES 823 Reliable Communications & Coding III 3.0 Credits**
Continues techniques for coding and decoding. Covers convolutional codes; Viterbi algorithm; BCH, cyclic, burst-error-correcting, Reed-Solomon, and Reed-Muller codes; and elements of cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 822 [Min Grade: C]

**ECES 890 Advanced Special Topics in Systems Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 898 Master's Thesis in Systems Engineering 1.0-12.0 Credit**
Master's thesis in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 921 Reliable Communications & Coding I 3.0 Credits**
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 997 Dissertation Research in Systems Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 998 Ph.D. Dissertation in Systems Engineering 1.0-12.0 Credit**
Ph.D. dissertation in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Electrical Computer Engr Courses

**ECE 501 Topics in Circuits and Systems 3.0 Credits**
Circuit laws, transfer functions, convolution, transform techniques, systems engineering. This series of courses may be used to meet the admission prerequisites to ECE graduate program. One credit per term is creditable to the M.S.E.E. degree.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 502 Topics In Communications, Controls and Computers 3.0 Credits**
Modulation theory, noise, feedback theory, stability, computer engineering fundamentals, computers in communication and controls. This series of courses may be used to meet the admission prerequisites to the ECE graduate program. One credit per term is creditable to the M.S.E.E. degree.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 503 Topics in Mathematical Techniques In Electrical and Computer Engineering 3.0 Credits**
Complex variables in communication and control, matrix methods in circuits and systems, vector calculus in fields, two-dimensional image processing. This series of courses may be used to meet the admission prerequisites to the ECE graduate program. One credit per term is creditable to the M.S.E.E. degree.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 571 Introduction to Electrical and Computer Engineering Research 0.0 Credits**
Topics of departmental research. Thesis selection. Required of all full-time graduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 572 Techniques of Electrical and Computer Engineering Research 0.0 Credits**
Techniques for making technical presentations: oral and written modes. Meeting organization, audience awareness. Writer-to-reader communication. Required of all full-time graduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 573 Presentation of Electrical and Computer Engineering Research 0.0 Credits**
Conference attendance and critique. Student presentation and critique. Topics of concern: professional ethics, liability, etc. Required of all full-time graduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 695 Research Rotations in Cybersecurity 1.0-12.0 Credit**
The research rotation course allows students to gain exposure to cybersecurity-related research that cuts across conventional departmental barriers and traditional research groups, prior to identifying and focusing on a specific interdisciplinary project or thesis topic. Students selecting to participate in research rotations would participate in the research activities of two labs for each three credits of research rotation they undertake.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECE 697 Research 1.0-12.0 Credit**
Research in electrical and computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 898 Master's Thesis 1.0-12.0 Credit**
Master's thesis in electrical and computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 997 Dissertation Research 1.0-12.0 Credit**
Graded Ph.D. dissertation research in electrical and computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECE 998 Ph.D. Dissertation 1.0-12.0 Credit**
Ph.D. dissertation research in electrical and computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

# Electrical Engineering Lab Courses

# Electrical Engineering/ Telecommunications Engineering

*Master of Science in Electrical/Telecommunications Engineering (MSEET): 45.0 - 48.0 quarter credits*
*Doctor of Philosophy: 90.0 quarter credits*

## About the Program

Fueled by the rapid spread of technologies such as electronic mail, cellular and mobile phone systems, interactive cable television, and the information superhighway, Drexel's program in Telecommunications Engineering responds to the growing demand for engineers with telecommunications expertise. The program combines a strong foundation in telecommunications engineering with training in other important issues such as global concerns, business, and information transfer and processing.

Drexel University's program in Telecommunications Engineering combines the expertise of its faculty in electrical and computer engineering, business, information systems, and humanities. Through its interdisciplinary approach, Drexel's Telecommunications Engineering program trains and nurtures the complete telecommunications engineer. The MS in Electrical Engineering/Telecommunications Engineering degree is awarded to students who demonstrate in-depth knowledge of the field. The average time required to complete the master's degree is two year of full-time or three years of part-time study.

For more information, visit the Department of Electrical and Computer Engineering' (http://www.ece.drexel.edu) s web site.

## Admission Requirements

Applicants must meet the general requirements for graduate admission, which include at least a 3.0 GPA for the last two years of undergraduate study and for any graduate level study undertaken, and are required to hold a bachelor of science degree in electrical engineering or a related field. Applicants whose undergraduate degrees are not in the field of electrical engineering may be required to take a number of undergraduate courses. The GRE General Test is required of applicants for full-time MS and PhD programs. Applicants whose native language is not English and who do not have a previous degree from a US institution are required to take the Test of English as a Foreign Language (TOEFL).

For additional information on how to apply, visit Drexel's Admissions page for Electrical-Telecommunications Engineering (http://www.drexel.edu/grad/programs/coe/electrical-telecommunications) .

## MS in Electrical and Telecommunications Engineering

The Master of Science in Electrical and Telecommunications Engineering curriculum encompasses 45.0 or 48.0 (with the Graduate Co-Op) approved credit hours, chosen in accordance with the following requirements and a plan of study arranged with the departmental graduate advisor in consultation with the student's research advisor (if applicable). This plan of study must be filed in the Department of Electrical and Computer Engineering and approved with the departmental graduate advisor before the end of the first quarter for a full-time student, or by the end of the first year for a part-time student.

## Degree Requirements

A total of at least 30.0 credit hours must be taken from among the graduate course offerings of the Department of Electrical and Computer Engineering. These credits must be taken at Drexel University. No transfer credit may be used to fulfill these requirements, regardless of content equivalency.

| | |
|---|---|
| Telecommunications Engineering (ECET) Courses | 6.0 |
| Telecommunications Engineering Elective (ECEC, ECEE, ECES, ECET) Courses | 15.0 |
| General Electrical and Computer Engineering (ECEC, ECEE, ECEP, ECES, ECET) Courses | 9.0 |
| Elective Courses | 15.0 |
| **Total Credits** | **45.0** |

With the remaining required 15.0 credit hours, students may take graduate coursework, subject to the approval of the departmental

graduate advisor, in electrical and computer engineering, mathematics, physics or other engineering disciplines.

In addition, students pursuing an MS in Electrical and Telecommunications Engineering are allowed and strongly encouraged to take the following course as part of their required 15.0 credit hours:

- COM 650 Telecommunications Policy in the Information Age

Although not required, students are encouraged to complete a master's thesis as part of the MS studies. Those students who choose the thesis option may count up to 9.0 research/thesis credits as part of their required credit hour requirements.

## Graduate Co-Op Program

Students may choose to participate in the Graduate Co-Op Program, where 6.0 credit hours can be earned for a six month cooperative education experience in industry, working on curriculum related projects. The total number of required credit hours is increased to 48 for those students who choose to pursue the Graduate Co-Op option. This change represents an increase in non-departmental required credit hours to a total of 18.0 credit hours, 6.0 of which are earned from the cooperative education experience.

Please note that ECEC 500 (Fundamentals of Computer Hardware) and ECEC 600 (Fundamentals of Computer Networks) do **not** count toward the credit requirements to complete the MS in Electrical Engineering degree program.

For more information on curricular requirements, visit the Department of Electrical and Computer Engineering (http://www.ece.drexel.edu) 's web site.

## PhD in Electrical Engineering

### General Requirements
The following general requirements must be satisfied in order to complete the PhD in Electrical Engineering:

- 90.0 credit hours total
- candidacy examination
- research proposal
- dissertation defense

Students entering with a master's degree in electrical or computer engineering or a related field will be considered a post-masters PhD student and will only be required to complete a total of 45.0 credit hours, in accordance with University policy.

### Curriculum
Appropriate coursework is chosen in consultation with the student's research advisor. A plan of study must be developed by the student to encompass the total number of required credit hours. Both the departmental graduate advisor and the student's research advisor must approve this plan.

### Candidacy Examination
The candidacy examination explores the depth of understanding of the student in his/her specialty area. The student is expected to be familiar with, and be able to use, the contemporary tools and techniques of the field and to demonstrate familiarity with the principal results and key findings.

The student, in consultation with his/her research advisor, will declare a principal technical area for the examination. The examination includes the following three parts:

- A self-study of three papers from the archival literature in the student's stated technical area, chosen by the committee in consultation with the student.
- A written report (15 pages or less) on the papers, describing their objectives, key questions and hypotheses, methodology, main results and conclusions. Moreover, the student must show in an appendix independent work he/she has done on at least one of the papers – such as providing a full derivation of a result or showing meaningful examples, simulations or applications.
- An oral examination which takes the following format:
  - A short description of the student's principal area of interest (5 minutes, by student).
  - A review of the self-study papers and report appendix (25-30 minutes, by student).
  - Questions and answers on the report, the appendix and directly related background (40-100 minutes, student and committee).

In most cases, the work produced during the candidacy examination will be a principal reference for the student's PhD dissertation; however, this is not a requirement.

### Research Proposal
After having attained the status of PhD Candidate, each student must present a research proposal to a committee of faculty and industry members, chosen with his/her research advisor, who are knowledgeable in the specific area of research. This proposal should outline the specific intended subject of study, i.e., it should present a problem statement, pertinent background, methods of study to be employed, expected difficulties and uncertainties and the anticipated form, substance and significance of the results.

The purpose of this presentation is to verify suitability of the dissertation topic and the candidate's approach, and to obtain the advice and guidance of oversight of mature, experienced investigators. It is not to be construed as an examination, though approval by the committee is required before extensive work is undertaken. The thesis proposal presentation must be open to all; announcements regarding the proposal presentation must be made in advance.

The thesis advisory committee will have the sole responsibility of making any recommendations regarding the research proposal. It is strongly recommended that the proposal presentation be given as soon as possible after the successful completion of the candidacy examination. The student must be a PhD candidate for at least one year before he/she can defend his/her doctoral thesis.

### Dissertation Defense
Dissertation Defense procedures are described in the Office of Graduate Studies policies regarding Doctor of Philosophy Program Requirements (http://www.drexel.edu/provost/graduatestudies) . The student must be a PhD candidate for at least one year before he/she can defend his/her doctoral thesis.

## Dual Degree

The ECE Department offers outstanding students the opportunity to receive two diplomas (BS and MS) at the same time. The program requires five (5) years to complete. Participants, who are chosen from the best undergraduates students, work with a faculty member on a

research project and follow a study plan that includes selected graduate classes. This program prepares individuals for careers in research and development; many of its past graduates continued their studies toward a PhD.

For more information on eligibility, academic requirements, and tuition policy visit the Engineering Combined BS/MS (http://www.ece.drexel.edu/undergrad/bsms.html) page.

# Facilities

Drexel University and the Electrical and Computer Engineering Department are nationally recognized for a strong history of developing innovative research. Research programs in the ECE Department prepare students for careers in research and development, and aim to endow graduates with the ability to identify, analyze, and address new technical and scientific challenges. The ECE Department is well equipped with state-of-the-art facilities in each of the following ECE Research laboratories:

## Research Laboratories at the ECE Department

### Adaptive Signal Processing and Information Theory Research Group

The Adaptive Signal Processing and Information Theory Research Group (http://www.ece.drexel.edu/walsh/aspitrg/home.html) conducts research in the area of signal processing and information theory. Our main interests are belief/expectation propagation, turbo decoding and composite adaptive system theory. We are currently doing projects on the following topics:
i) Delay mitigating codes for network coded systems,
ii) Distributed estimation in sensor networks via expectation propagation,
iii) Turbo speaker identification,
iv) Performance and convergence of expectation propagation,
v) Investigating bounds for SINR performance of autocorrelation based channel shorteners.

### Applied Networking Research Lab

Applied Networking Research Lab (ANRL) projects focus on modeling and simulation as well as experimentation in wired, wireless and sensor networks. ANRL is the home of MuTANT, a Multi-Protocol Label Switched Traffic Engineering and Analysis Testbed composed of 10 high-end Cisco routers and several PC-routers, also used to study other protocols in data networks as well as automated network configuration and management. The lab also houses a sensor network testbed.

#### Bioimage Laboratory

Uses computer gaming hardware for enhanced and affordable 3-D visualization, along with techniques from information theory and machine learning to combine the exquisite capabilities of the human visual system with computational sensing techniques for analyzing vast quantities of image sequence data.

### Data Fusion Laboratory

The Data Fusion Laboratory investigates problems in multisensory detection and estimation, with applications in robotics, digital communications, radar, and target tracking. Among the projects in progress: computationally efficient parallel distributed detection architectures, data fusion for robot navigation, modulation recognition and RF scene analysis in time-varying environments, pattern recognition in biological data sequences and large arrays, and hardware realizations of data fusion architectures for target detection and target tracking.

### Drexel Network Modeling Laboratory

The Drexel Network Modeling Laboratory investigates problems in the mathematical modeling of communication networks, with specific focus on wireless ad hoc networks, wireless sensor networks, and supporting guaranteed delivery service models on best effort and multipath routed networks. Typical methodologies employed in our research include mathematical modeling, computer simulation, and performance optimization, often with the end goal of obtaining meaningful insights into network design principles and fundamental performance tradeoffs.

### Drexel Power-Aware Computing Laboratory

The Power-Aware Computing Lab (http://dpac.ece.drexel.edu) investigates methods to increase energy efficiency across the boundaries of circuits, architecture, and systems. Our recent accomplishments include the Sigil profiling tool, scalable modeling infrastructure for accelerator implementations, microarchitecture-aware VDD gating algorithms, an accelerator architecture for ultrasound imaging, evaluation of hardware reference counting, hardware and operating system support for power-agile computing, and memory systems for accelerator-based architectures.

### Drexel University Nuclear Engineering Education Laboratory

The field of nuclear engineering encompasses a wide spectrum of occupations, including nuclear reactor design, medical imaging, homeland security, and oil exploration. The Drexel University Nuclear Engineering Education Laboratory (DUNEEL) provides fundamental hands on understanding for power plant design and radiation detection and analysis. Software based study for power plant design, as well as physical laboratory equipment for radiation detection, strengthen the underlying concepts used in nuclear engineering such that the student will comprehend and appreciate the basic concepts and terminology used in various nuclear engineering professions. Additionally, students use the laboratory to develop methods for delivering remote, live time radiation detection and analysis. The goal of DUNEEL is to prepare students for potential employment in the nuclear engineering arena.

### Drexel VLSI Laboratory

The Drexel VLSI Laboratory (http://ece.drexel.edu/faculty/taskin/wiki/vlsilab/index.php/Main_Page) investigates problems in the design, analysis, optimization and manufacturing of high performance (low power, high throughput) integrated circuits in contemporary CMOS and emerging technologies. Suited with industrial design tools for integrated circuits, simulation tools and measurement beds, the VLSI group is involved with digital and mixed-signal circuit design to verify the functionality of the discovered novel circuit and physical design principles. The Drexel VLSI laboratory develops design methodologies and automation tools in these areas, particularly in novel clocking techniques, featuring resonant clocking, and interconnects, featuring wireless interconnects.

### Drexel Wireless Systems Laboratory

The Drexel Wireless Systems Laboratory (DWSL) contains an extensive suite of equipment for constructing, debugging, and testing prototype wireless communications systems. Major equipment within DWSL includes:

- three software defined radio network testbeds (HYDRA, USRP, and WARP) for rapidly prototyping radio, optical and ultrasonic communications systems,
- a TDK RF anechoic chamber and EMSCAN desktop antenna pattern measurement system,
- a materials printer and printed circuit board milling machine for fabricating conformal antennas and
- wireless protocol conformance testing equipment from Aeroflex.

The lab is also equipped with network analyzers, high speed signal generators, oscilloscopes, and spectrum analyzers as well as several Zigbee development platforms for rapidly prototyping sensor networks.

DWSL personnel also collaborate to create wearable, fabric based transceivers through collaboration with the Shima Seiki Haute Laboratory in the Drexel ExCITe Center. The knitting equipment at Drexel includes sixteen SDS-ONE APEX3 workstations and four state-of-the-art knitting machines. The workstations accurately simulate fabric construction and provide researchers and designers the opportunity to program, create and simulate textile prototypes, import CAD specifications of final products, and produce made-to-measure or mass-produced pieces on Shima Seiki knitting machines. For testing smart textiles for biomedical, DWSL personnel also have collaborators in the Center for Interdisciplinary Clinical Simulation and Practice (CICSP) in the Drexel College of Medicine which provides access to medical mannequin simulators.

## Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (EESI) (http://www.ece.drexel.edu/gailr/EESI) seeks to solve problems in high-throughput genomics and engineer better solutions for biochemical applications. The lab's primary thrust is to enhance the use of high-throughput DNA sequencing technologies with pattern recognition and signal processing techniques. Applications include assessing the organism content of an environmental sample, recognizing/classifying potential and functional genes, inferring environmental factors and inter-species relationships, and inferring microbial evolutionary relationships from short-read DNA/RNA fragments. The lab also investigates higher-level biological systems such as modeling and controlling chemotaxis, the movement of cells.

## Electric Power Engineering Center

This newly established facility makes possible state-of-the-art research in a wide variety of areas, ranging from detailed theoretical model study to experimental investigation in its high voltage laboratories. The mission is to advance and apply scientific and engineering knowledge associated with the generation, transmission, distribution, use, and conservation of electric power. In pursuing these goals, this center works with electric utilities, state and federal agencies, private industries, nonprofit organizations and other universities on a wide spectrum of projects. Research efforts, both theoretical and experimental, focus on the solution of those problems currently faced by the electric power industry. Advanced concepts for electric power generation are also under investigation to ensure that electric power needs will be met at the present and in the future.

## Electronic Design Automation Facility

Industrial-grade electronic design automation software suite and intergrated design environment for digital, analog and mixed-signal systems development. Field Programmable Gate Array (FPGA) development hardware. Most up-to-date FPGA/embedded system development hardware kits. Printed circuit board production facility. Also see Drexel VLSI Laboratory.

## Microwave-Photonics Device Laboratories

The laboratory is equipped with test and measurement equipment for high-speed analog and digital electronics and fiber optic systems. The test equipment includes network analyzers from Agilent (100kHz- 1.3 GHz and 45 Mhz-40 GHz), and Anritsu (45 MHz-6 GHz); spectrum analyzers from Tektronix, HP, and Agilent with measurement capability of DC to 40 GHz and up to 90 GHz using external mixers; signal generators and communication channel modulators from HP, Rhode-Schwartz, Systron Donner, and Agilent; microwave power meter and sensor heads, assortment of passive and active microwave components up to 40 GHz ; data pattern generator and BER tester up to 3Gb/s; optical spectrum analyzer from Anritsu and power meters from HP; single and multimode fiber optic based optical transmitter and receiver boards covering ITU channels at data rates up to 10Gb/s; passive optical components such as isolator, filter, couplers, optical connectors and fusion splicer; LPKF milling machine for fabrication of printed circuit boards; wire-bonding and Cascade probe stations; Intercontinental test fixtures for testing of MMIC circuits and solid-state transistors; state-of-the-art microwave and electromagnetic CAD packages such as Agilent ADS, ANSYS HFSS, and COMSOL multi-physics module.

## Music and Entertainment Technology Laboratory

The Music and Entertainment Technology Laboratory (MET-lab) is devoted to research in digital media technologies that will shape the future of entertainment, especially in the areas of sound and music. We employ digital signal processing and machine learning to pursue novel applications in music information retrieval, music production and processing technology, and new music interfaces. The MET-lab is also heavily involved in outreach programs for K-12 students and hosts the Summer Music Technology program, a one-week learning experience for high school students. Lab facilities include a sound isolation booth for audio and music recording, a digital audio workstation running ProTools, two large multi-touch display interfaces of our own design, and a small computing cluster for distributed processing.

## NanoPhotonics+ Lab (http://drexelnanophotonics.com)

Our research is primarily in the area of nanophotonics with a focus on the nanoscale interaction of light with matter. Interests include: liquid crystal/polymer composites for gratings, lenses and HOEs; liquid crystal interactions with surfaces and in confined nanospaces; alternative energy generation through novel photon interactions; ink-jet printed conducting materials for RF and photonic applications; and the creation and development of smart textiles technologies including soft interconnects, sensors, and wireless implementations.

## Opto-Electro-Mechanical Laboratory

This lab concentrates on the system integration on optics, electronics, and mechanical components and systems, for applications in imaging, communication, and biomedical research. Research areas include: Programmable Imaging with Optical Micro-electrical-mechanical systems (MEMS), in which microscopic mirrors are used to image light into a single photodetector; Pre-Cancerous Detection using White Light Spectroscopy, which performs a cellular size analysis of nuclei in tissue; Free-space Optical Communication using Space Time Coding, which consists of diffused light for computer-to-computer communications, and also tiny lasers and detectors for chip-to-chip communication; Magnetic Particle Locomotion, which showed that particles could swim in a uniform field;

and Transparent Antennas using Polymer, which enables antennas to be printed through an ink-jet printer.

## Plasma and Magnetics Laboratory

Research is focused on applications of electrical and magnetic technologies to biology and medicine. This includes the subjects of non-thermal atmospheric pressure plasma for medicine, magnetic manipulation of particles for drug delivery and bio-separation, development of miniature NMR sensors for cellular imaging and carbon nanotube cellular probes.

## Power Electronics Research Laboratory

The Power Electronics Research Laboratory (PERL) is involved in circuit and design simulation, device modeling and simulation, and experimental testing and fabrication of power electronic circuits. The research and development activities include electrical terminations, power quality, solar photovoltaic systems, GTO modeling, protection and relay coordination, and solid-state circuit breakers. The analysis tools include EMPT, SPICE, and others, which have been modified to incorporate models of such controllable solid-state switches as SCRs, GTOs, and MOSFETs. These programs have a wide variety and range of modeling capabilities used to model electromagnetics and electromechanical transients ranging from microseconds to seconds in duration. The PERL is a fully equipped laboratory with 42 kVA AC and 70 kVA DC power sources and data acquisition systems, which have the ability to display and store data for detailed analysis. Some of the equipment available is a distribution and HV transformer and three phase rectifiers for power sources and digital oscilloscopes for data measuring and experimental analysis. Some of the recent studies performed by the PERL include static VAR compensators, power quality of motor controllers, solid-state circuit breakers, and power device modeling which have been supported by PECO, GE, Gould, and EPRI.

## RE Touch Lab

The RE Touch Lab is investigating the perceptual and mechanical basis of active touch perception, or haptics, and the development of new technologies for stimulating the sense of touch, allowing people to touch, feel, and interact with digital content as seamlessly as we do with objects in the real world. We study the scientific foundations of haptic perception and action, and the neuroscientific and biomechanical basis of touch, with a long-term goal of uncovering the fundamental perceptual and mechanical computations that enable haptic interaction. We also create new technologies for rendering artificial touch sensations that simulate those that are experienced when interacting with real objects, inspired by new findings on haptic perception.

## Testbed for Power-Performance Management of Enterprise Computing Systems

This computing testbed is used to validate techniques and algorithms aimed at managing the performance and power consumption of enterprise computing systems. The testbed comprises a rack of Dell 2950 and Dell 1950 PowerEdge servers, as well as assorted desktop machines, networked via a gigabit switch. Virtualization of this cluster is enabled by VMWare's ESX Server running the Linux RedHat kernel. It also comprises of a rack of ten Apple Xserve machines networked via a gigabit switch. These servers run the OS X Leopard operating systems and have access to a RAID with TBs of total disk capacity.

# Electrical and Computer Engineering Faculty

Suryadevara Basavaiah, PhD *(University of Pennsylvania).* Teaching Professor. Computer engineering; computer engineering education; custom circuit design; VLSI technology; process and silicon fabrication.

Tom Chmielewski, PhD *(Drexel University).* Assistant Teaching Professor. Modeling and simulation of electro-mechanical systems; Optimal, Adaptive and Non-Linear Control; DC Motor Control; System Identification; Kalman Filters (Smoothing Algorithms, tracking); image processing, Robot design; Biometric technology and design of embedded systems for control applications utilizing MATLAB and SIMULINK

Fernand Cohen, PhD *(Brown University).* Professor. Surface modeling; tissue characterization and modeling; face modeling; recognition and tracking.

Andrew Cohen, PhD *(Rensselaer Polytechnic Institute).* Associate Professor. Image processing; multi-target tracking; statistical pattern recognition and machine learning; algorithmic information theory; 5-D visualization.

Kapil Dandekar, PhD *(University of Texas-Austin) Director of the Drexel Wireless Systems Laboratory (DWSL); Associate Dean of Research, College of Engineering.* Professor. Cellular/mobile communications and wireless LAN; smart antenna/MIMO for wireless communications; applied computational electromagnetics; microwave antenna and receiver development; free space optical communication; ultrasonic communication; sensor networks for homeland security; ultrawideband communication.

Afshin Daryoush, PhD *(Drexel University).* Professor. Microwave photonics systems; nonlinear microwave circuits; RFIC and wireless communications; antennas and radiating systems; electromagnetic interaction with biological systems.

Bruce A. Eisenstein, PhD *(University of Pennsylvania) Arthur J. Rowland Professor of Electrical and Computer Engineering; Vice Dean, College of Engineering.* Professor. Pattern recognition; estimation; decision theory; digital signal processing.

Adam K. Fontecchio, PhD *(Brown University) Associate Dean for Undergraduate Affairs; Associate Director, Expressive and Creative Interactive Technologies (EXCITE) Center.* Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park).* Professor. Biological and biomedical applications of nanoscale magnetic systems.

Eli Fromm, PhD *(Jefferson Medical College) Roy A. Brothers University Professor / Director for Center of Educational Research.* Professor. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania) Assistant EDE Department Head; Liason for Evening Programs.* Professor. Computerized instruments and measurements; undergraduate engineering education.

Allon Guez, PhD *(University of Florida).* Professor. Intelligent control systems; robotics, biomedical, automation and manufacturing; business systems engineering.

Mark Hempstead, PhD *(Harvard University) Junior Colehower Chair.* Assistant Professor. Computer engineering; power-aware computing; computer architecture; low power VLSI Design; wireless sensor networks.

Peter R. Herczfeld, PhD *(University of Minnesota) Lester A. Kraus Professor/Director, Center for Microwave/Lightwave Engineering.* Professor. Lightwave technology; microwaves; millimeter waves; fiberoptic and integrated optic devices.

Leonid Hrebien, PhD *(Drexel University).* Professor. Tissue excitability; acceleration effects on physiology; bioinformatics.

Paul R. Kalata, PhD *(Illinois Institute of Technology).* Associate Professor. Stochastic and adaptive control theory; identification and decision theory; Kalman filters.

Nagarajan Kandasamy, PhD *(University of Michigan).* Associate Professor. Embedded systems, self-managing systems, reliable and fault-tolerant computing, distributed systems, computer architecture, and testing and verification of digital systems.

Bruce Katz, PhD *(University of Illinois).* Adjunct Professor. Neural networks; the study of aesthetics; artificial intelligence; music perception.

Youngmoo Kim, PhD *(Massachusetts Institutie of Technology) Director, Expressive and Creative Interaction Technologies (EXCITE) Center.* Associate Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Timothy P. Kurzweg, PhD *(University of Pittsburgh) Associate Department Head for Undergraduate Studies and Director of the BSE Program.* Associate Professor. Optical MEM modeling and simulation; system-level simulation; computer architecture.

Mohammad Madihian, PhD *(Shizuoka University).* Adjunct Professor. Solid-state device-circuit interaction; microwave and millimeter-wave monolithic circuit design and evaluation technology; solid-state power generation/amplification/mixing technology; single/multi-mode wireless RF/IF transceiver technology

Karen Miu, PhD *(Cornell University).* Professor. Power systems; distribution networks; distribution automation; optimization; system analysis.

Bahram Nabet, PhD *(University of Washington).* Professor. Optoelectronics; fabrication and modeling; fiber optic devices; nanoelectronics; nanowires.

Prawat Nagvajara, Ph.D. *(Boston University).* Associate Professor. System on a chip; embedded systems; power grid computation; testing of computer hardware; fault-tolerant computing; VLSI systems; error control coding.

Vasileios Nasis, PhD *(Drexel University).* Associate Teaching Professor. Imaging with MOEMS, Projection systems using MEMS/MOEMS, Wireless communications, Remote monitoring, sensor networks.

Dagmar Niebur, PhD *(Swiss Federal Institute of Technology).* Associate Professor. Intelligent systems; dynamical systems; power system monitoring and control.

Chika Nwankpa, PhD *(Illinois Institute of Technology) Interum Department Head.* Professor. Power system dynamics; power electronic switching systems; optically controlled high power switches.

Christopher Peters, PhD *(University of Michigan, Ann Arbor).* Teaching Professor. Nuclear reactor design; ionizing radiation detection; nuclear forensics; power plant reliability and risk analysis; naval/marine power and propulsion; directed energy/high power microwaves; nonstationary signal processing; radar; electronic survivability/susceptibility to harsh environments; electronic warfare.

Karkal S. Prahbu, PhD *(Harvard University).* Teaching Professor. Computer and software engineering; advanced microprocessors and distributed operating systems.

Gail L. Rosen, PhD *(Georgia Institute of Technology).* Associate Professor. Signal processing, signal processing for biological analysis and modeling, bio-inspired designs, source localization and tracking.

Ioannis Savidis, PhD *(University of Rochester) Director of the Integrated Circuits and Electronics (ICE) Design and Analysis Laboratory.* Assistant Professor. Analysis, modeling, and design methodologies for high performance digital and mixed-signal integrated circuits; Emerging integrated circuit technologies; Electrical and thermal modeling and characterization, signal and power integrity, and power and clock delivery for 3-D IC technologies.

Kevin J. Scoles, PhD *(Dartmouth College).* Associate Professor. Microelectronics; electric vehicles; solar energy; biomedical electronics.

Harish Sethu, PhD *(Lehigh University).* Associate Professor. Protocols, architectures and algorithms in computer networks; computer security; mobile ad hoc networks; large-scale complex adaptive networks and systems.

James Shackleford, PhD *(Drexel University).* Assistant Professor. Medical image processing, high performance computing, embedded systems, computer vision, machine learning.

P. Mohana Shankar, PhD *(Indian Institute of Technology) Allen Rothwarf Professor of Electrical and Computer Engineering.* Professor. Wireless communications; biomedical ultrasonics; fiberoptic bio-sensors.

Matthew Stamm, PhD *(University of Maryland, College Park) Head, Multimedia and Information Security Laboratory (MSL).* Assistant Professor. Information Security; Multimedia Forensics and Anti-Forensics; Information Verification; Adversarial Dynamics; Signal Processing.

Baris Taskin, PhD *(University of Pittsburgh).* Associate Professor. Electronic design automation (EDA) of integrated circuits, high-performance VLSI circuits and systems, sequential circuit timing and synchronization, system-on-chip (SOC) design, operational research, VLSI computer-aided design.

Lazar Trachtenberg, DSc *(Israel Institute of Technology).* Professor. Fault tolerance; multi-level logic synthesis; signal processing; suboptimal filtering.

Yon Visell, PhD *(McGill University).* Assistant Professor. Haptic display engineering, material and biomechanical contact physics, neuroscientific and physical basis of human tactile sensation/perception, haptic human-machine interaction, sensorimotor learning, interaction in virtual reality

John Walsh, PhD *(Cornell University).* Associate Professor. Performance and convergence of belief/expectation propagation and turbo decoding/equalization/synchronization, permeation models for ion channels, composite adaptive systems theory.

Steven Weber, PhD *(University of Texas-Austin) Assistant Department Head for Graduate Affairs, Electrical and Computer Engineering.* Associate Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice Cavalcante de Oliveira, PhD *(Georgia Institute of Technology).* Associate Professor. Next generation Internet; quality of service in computer communication networks; wireless networks.

## Interdepartmental Faculty

Dov Jaron, PhD *(University of Pennsylvania) Calhoun Distinguished Professor of Engineering in Medicine.* Professor. Mathematical, computer and electromechanical simulations of the cardiovascular system.

Jeremy R. Johnson, PhD *(Ohio State University).* Professor. Computer algebra; parallel computations; algebraic algorithms; scientific computing.

John Lacontora, PhD *(New Jersey Institute of Technology).* Associate Research Professor. Service engineering; industrial engineering.

Ryszard Lec, PhD *(University of Warsaw Engineering College).* Professor. Biomedical applications of visoelastic, acoustoptic and ultrasonic properties of liquid and solid media.

Spiros Mancoridis, PhD *(University of Toronto) Sr. Associate Dean for Computing and CCI Academic Affairs.* Professor. Software engineering; software security; code analysis; evolutionary computation.

Karen Moxon, PhD *(University of Colorado).* Associate Professor. Cortico-thalamic interactions; neurobiological perspectives on design of humanoid robots.

Paul Y. Oh, PhD *(Columbia University).* Adjunct Professor. Smart sensors servomechanisms; machine vision and embedded microcomputers for robotics and mechatronics.

Banu Onaral, Ph.D. *(University of Pennsylvania) H.H. Sun Professor / Director, School of Biomedical Engineering Science and Health Systems.* Professor. Biomedical signal processing; complexity and scaling in biomedical signals and systems.

Kambiz Pourrezaei, PhD *(Rensselaer Polytechnic University).* Professor. Thin film technology; nanotechnology; near infrared imaging; power electronics.

William C. Regli, PhD *(University of Maryland-College Park).* Professor. Artificial intelligence; computer graphics; engineering design and Internet computing.

Arye Rosen, PhD *(Drexel University) Biomedical Engineering and Electrical Engineering.* Microwave components and subsystems; utilization of RF/microwaves and lasers in therapeutic medicine.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering.* Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces; scanning probe microscopy; laser spectroscopy, including Raman scattering.

Aydin Tozeren, PhD *(Columbia University) Distinguished Professor and Director, Center for Integrated Bioinformatics, School of Biomedical Engineering, Science & Health Systems.* Professor Emeritus. Breast cell adhesion and communication, signal transduction networks in cancer and epithelial cells; integrated bioinformatics, molecular profiling, 3D-tumors, bioimaging.

Aspasia Zerva, PhD *(University of Illinois).* Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

## Emeritus Faculty

Robert Fischl, PhD *(University of Michigan) John Jarem Professor Emeritus / Founder of the Center for Electric Power Engineering.* Professor Emeritus. Power: systems, networks, controls, computer-aided design, power systems, solar energy.

Vernon L. Newhouse, PhD *(University of Leeds) Disque Professor Emeritus.* Professor Emeritus. Biomedical and electrophysics: ultrasonic flow measurement, imaging and texture analysis in medicine, ultrasonic nondestructive testing and robot sensing, clinical engineering.

Hun H. Sun, PhD *(Cornell University) Ernest O. Lange Professor Emeritus.* Professor Emeritus. Systems and signals in biomedical control systems.

Oleh Tretiak, ScD *(MIT).* Professor Emeritus. Image processing; tomography; image registration; pattern recognition.

## Elec Comp Engr-Computers Courses

**ECEC 500 Fundamentals Of Computer Hardware 3.0 Credits**
Covers computer organization and architecture; elements of computer hardware, processors, control units, and memories; hardware for basic mathematical operations; tradeoffs between speed and complexity; examples of embedded systems; microcontrollers; systems modeling.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 501 Computational Principles of Representation and Reasoning 3.0 Credits**
This course presents fundamentals of discrete mathematics as applied within the computer engineering and manufacturing environment. Students are given the theoretical background in representation and reasoning for a broad variety of engineering problems solving situations. Entity-relational techniques of representation are demonstrated to evolve into the object-oriented approach. Various search techniques are applied in the cases of representing engineering systems by using theory of automata techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 502 Principles of Data Analysis 3.0 Credits**
This course presents theoretical methods and techniques of model development applicable within the computer engineering design and manufacturing environment. Students are given the theoretical background in data analysis (including "data mining"). Emphasis is on hybrid systems and discrete events systems. Various methods of recognizing regularities in data will be presented. Elements of the theory of clustering and classification will be dealt with for the paradigm of software and hardware problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 503 Principles of Decision Making 3.0 Credits**
This course presents theoretical fundamentals and engineering techniques of decision making and problem solving applicable within the computer engineering design and manufacturing environment. Students are given the theoretical background in optimization methods for a broad variety of situation. Elements of the theory of planning and on-line control of systems are presented within the scope of software and hardware computer design and control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 511 Combinational Circuit Design 3.0 Credits**
Representing arithmetic. Logic and syntax data for machine processing. Switching algebra: Boolean and multiple values. Identification and classification of functions. Realizing completely specified and incompletely specified Boolean functions. Issues in designing large communication/control Boolean functions. Fault and testing of Boolean function.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 512 Sequential Circuit Design 3.0 Credits**
Finite automata and their realization by sequential machines, capabilities, transformation, and minimization of finite automata, linear finite automata. Clocked pulsed and level mode sequential circuits. Malfunctions in sequential circuits: hazards, races, lockouts, metastability. Issues of state assignment. Evolution of memory elements design: ROM vs. RAM vs. associative memory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 511 [Min Grade: C]

**ECEC 513 Design for Testability 3.0 Credits**
Economics vs. Complexity vs. Strategy of Testing; Fault Models; Test Generation; Testability Analysis & Designing Testable Circuits; Testing Microprocessors, Memories and Computer Components; Test Data Compression; Fault Tolerant Hardware; Reliably vs. Availability; Redundancy and Error Correcting Codes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 511 [Min Grade: C] and ECEC 512 [Min Grade: C]

**ECEC 520 Dependable Computing 3.0 Credits**
Fundamental design issues involved in building reliable, safety-critical, and highly available systems. Topics include testing and fault-tolerant design of VLSI circuits, hardware and software fault tolerance, information redundancy, and fault-tolerant distributed systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 541 Robotic Computer Interface Controls I 3.0 Credits**
Covers sensors, actuators, mechanical components of robots, kinematics, inverse kinematics, dynamics, and equations of motion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 542 Robotic Computer Interface Controls II 3.0 Credits**
Covers the robot control problem, including PD, PID, position, force and hybrid controllers, resolved rate and acceleration control, and multiprocessor architecture.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 641 [Min Grade: C] and ECES 643 [Min Grade: C] and ECEC 541 [Min Grade: C]

**ECEC 543 Robotic Computer Interface Controls III 3.0 Credits**
Covers non-linear control techniques, FLDT, and advanced topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 542 [Min Grade: C]

**ECEC 571 Introduction to VLSI Design 3.0 Credits**
This is an introductory course where systematic understanding, design and analysis of digital VLSI integrated circuits will be covered. The course will begin with a review of CMOS transistor operation and semiconductor processes. Logic design with CMOS transistor and circuit families will be described. Specifically, layout, design rules, and circuit simulation will be addressed. Performance metrics will be analyzed in design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 572 Custom VLSI Design & Analysis I 3.0 Credits**
This is the first of two courses offered on Custom VLSI circuit and systems design and analysis. An understanding of VLSI integrated circuits is achieved through circuit design and analysis. This course focuses exclusively on high performance digital CMOS VLSI circuit and systems design, although some topics on mixed-signal circuits are also addressed. Design and analysis of VLSI integrated circuits will be covered from the circuits and systems design perspectives. First, a thorough analysis of interconnect networks is presented. The second part of the class focuses on synchronization of high performance ICs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 571 [Min Grade: C]

**ECEC 573 Custom VLSI Design & Analysis II 3.0 Credits**
This is the second of two courses offered on Custom VLSI circuit and systems design and analysis. An understanding of VLSI integrated circuits is achieved through circuit design and analysis. This course focuses exclusively on high performance digital CMOS VLSI circuit and systems design, although some topics on mixed-signal circuits are also addressed. The primary focus is on-chip power management. Power generation techniques are discussed and different power converters are analyzed. Power distribution networks are presented with a focus on the different distribution architectures and output impedance characteristics. Techniques to reduce power supply noise are also provided. A secondary focus examines substrate noise in mixed-signal systems and techniques to reduce substrate noise.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 571 [Min Grade: C]

**ECEC 574 ASIC Design I 3.0 Credits**
This course will focus exclusively on digital CMOS Application Specific Integrated Circuit (ASIC) systems design and automation. The ASIC physical design flow, including logic synthesis, floorplanning, placement, clock tree synthesis, routing and verification will be presented. These back-end physical design flow steps will also be covered through hands-on practice using industrial VLSI CAD tools. Contemporary design practices will be reviewed and presented in experiments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 575 ASIC Design II 3.0 Credits**
Design and analysis of VLSI integrated circuits will be covered from a systems design perspective. System timing, arithmetic building block and memory block design processes will be presented. Design tasks in a quarter-long, small-complexity processor design project will cover the back-end of the IC design flow range, from RTL synthesis to timing and power analysis. Projects will be performed in a hierarchical group, similar to an industrial setting, with other graduate and undergraduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 572 [Min Grade: C]

**ECEC 600 Fundamentals of Computer Networks 3.0 Credits**
Fundamentals design principles of ATM, Internet and local area networks; protocol layers and the Internet Architecture; medium access protocols; application protocols and TCP/IP utilities; basic principles and virtual circuit switching; naming and addressing; flow and congestion control protocols; routing algorithms; Quality-of-Service in computer networks; security issues in networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 621 High Performance Computer Architecture 3.0 Credits**
Maximizing single processor performance. Concepts and techniques for design of computer systems. Processor design, instruction set architecture design and implementation, memory hierarchy, pipelines processors, bus bandwidth, processor/memory interconnections, cache memory, virtual memory, advanced I/O systems, performance evaluation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 622 Parallel Computer Architecture 3.0 Credits**
Advanced techniques of computer design. Use of parallel processing to achieve high performance levels. Fine and coarse grained parallelism. Multiple CPU parallelism, through multiprocessors, array and vector processors. Dataflow architectures and special purpose processors. Design implications of memory latency and bandwidth limitations. Speedup problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 621 [Min Grade: C]

**ECEC 623 Advanced Topics in Computer Architecture 3.0 Credits**
This course teaches advanced concepts of modern computer architecture and introduces the current challenges faced by computer architects. These challenges include power consumption, transistor variability, and processor heterogeneity. Students develop their research skills through a self directed research project with a final presentation and conference style writeup.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 621 [Min Grade: C]

**ECEC 631 Principles of Computer Networking 3.0 Credits**
Principles of circuit switching, packet switching and virtual circuits; protocol layering; application layer protocols for e-mail and web applications; naming and addressing; flow control and congestion avoidance with TCP; Internet Protocol (IP); routing algorithms; router architectures; multicast protocols; local area network technologies and protocols; issues in multimedia transmissions; scheduling and policing; Quality-of-Service and emerging Internet service architectures; principles of cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 632 Performance Analysis of Computer Networks 3.0 Credits**
Covers probability theory and its applications to networks, random variable and random processes; Markov chains, multi-dimensional Markov chains; M/M/1, M/M/m, M/M/m/m, M/G/1 and G/G/1 queueing systems and their applications in computer networks; analysis of networks of queues: Kleinrock Independence Approximation; Time-reversibility and Burke's theorem; Jackson's theorem; the phenomenon of long-range dependence and its implications in network design and traffic engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 631 [Min Grade: C]

**ECEC 633 Advanced Topics in Computer Networking 3.0 Credits**
perspectives in the areas of switch/router architectures, scheduling for best-effort and guaranteed services, QoS mechanisms and architectures, web protocols and applications, network interface design, optical networking, and network economics. The course also includes a research project in computer networking involving literature survey, critical analysis, and finally, an original and novel research contribution.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 631 [Min Grade: C] and ECEC 632 [Min Grade: C]

**ECEC 654 Knowledge Engineering I 3.0 Credits**
Covers conceptual modeling, including an overview of knowledge representation. Includes semantic networks, reduced semantic networks, logic of incomplete knowledge bases, extensional semantic networks, and applications of conceptual models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 655 Knowledge Engineering II 3.0 Credits**
Covers expert systems, including language and tools of knowledge engineering. Includes reasoning about reasoning, design and evaluation, heuristics in expert systems, expert systems for decision support, and expert systems in conceptual design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 654 [Min Grade: C]

**ECEC 656 Knowledge Engineering III 3.0 Credits**
Covers information-intensive systems, including information representation in autonomous systems. Includes clauses and their validation; clustering in linguistic structures; linguistic and pictorial knowledge bases; discovery in mathematics, including am; and methods of new knowledge generation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 655 [Min Grade: C]

**ECEC 661 VLSI Design 3.0 Credits**
Covers CMOS design styles, techniques, and performance; VLSI computer hardware, arithmetic units, and signal processing systems; and cat tools for layout design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 662 VLSI Array Processors I 3.0 Credits**
Covers VLSI testing, including design for testability and parallel computer architectures; signal and image processing algorithms and mapping algorithms onto array structures; and systolic array processors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 661 [Min Grade: C]

**ECEC 663 VLSI Array Processors II 3.0 Credits**
Covers wavefront array processors; matching hardware to arrays; hardware design, systems design, and fault-tolerant design; and implementations and VLSI design projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 662 [Min Grade: C]

**ECEC 671 Electronic Design Automation for VLSI Circuits I 3.0 Credits**
This course focuses on the electronic design automation problems in the design process of VLSI integrated circuits. In this first quarter of the course, algorithms, techniques and heuristics structuring the foundations of contemporary VLSI CAD tools are presented. Boolean algebra, graph theory, logic minimization and satisfiability topics are presented.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 672 Electronic Design Automation for VLSI Circuits II 3.0 Credits**
This course focuses on the electronic design automation problems in the design process of VLSI integrated circuits. In this second quarter of the course, physical VLSI design steps of technology mapping, floor planning, placement, routing and timing and presented individual and team-based small-to-medium scale programming projects are assigned.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 671 [Min Grade: C]

**ECEC 673 Deep Sub-Micron Integrated Circuit Design 3.0 Credits**
This course focuses on the design challenges of digital VLSI integrated circuits in deep sub-micron manufacturing technologies. Automation challenges and high-performance circuit design techniques such as low-power and variation-aware design are presented. The course material is delivered in a lecture format structured on recent presentations, articles, and tutorials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 671 [Min Grade: C]

**ECEC 690 Special Topics Computer Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 697 Research in Computer Engineering 1.0-12.0 Credit**
Research in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 699 Supervised Study in Computer Engineering 9.0 Credits**
Supervised study in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 890 Advanced Special Topics in Computer Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 891 Advanced Topics in Computer Engineering 0.5-9.0 Credits**
Advanced topics in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 898 Master's Thesis in Computer Engineering 1.0-12.0 Credit**
Master's thesis in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 997 Dissertation Research in Computer Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 998 Ph.D. Dissertation in Computer Engineering 1.0-12.0 Credit**
Ph.D. dissertation in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Elec Computer Engr-Systems Courses

**ECES 510 Analytical Methods in Systems 3.0 Credits**
This course is intended to provide graduate student in the field of signal and image processing with the necessary mathematical foundation, which is prevalent in contemporary signal and image processing research and practice.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 511 Fundamentals of Systems I 3.0 Credits**
Core course. Covers linear operators, including forms and properties (differential equations, transfer function, state space, causality, linearity, and time invariance); impulse response, including convolution, transition matrices, fundamental matrix, and linear dynamical system; definition, including properties and classification; representation, including block diagrams, signal flow, and analog and digital; properties, including controllability and observability; and eigenstructure, including eigenvalues and eigenvector and similarity transformations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 512 Fundamentals of Systems II 3.0 Credits**
Core course. Covers realization and identification, including minimal realization, reducibility and equivalence of models, and identification of systems; stability, including bounded input-bounded output, polynomial roots, and Lyapunov; and feedback compensation and design, including observers and controllers and multi-input/multi-output systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 511 [Min Grade: C]

**ECES 513 Fundamentals of Systems III 3.0 Credits**
Core course. Covers multivariable systems, numerical aspects of system analysis and design, design of compensators, elements of robustness, and robust stabilization.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 521 Probability & Random Variables 3.0 Credits**
Probability concepts. Single and multiple random variables. Functions of random variables. Moments and characteristic functions. Random number and hypothesis testing. Maximum likelihood estimation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 522 Random Process & Spectral Analysis 3.0 Credits**
Random Process. Poisson Process, Shot Noise. Gaussian Process. Matched Filters. Kalman Filters. Power Spectral Density. Autocorrelation and cross correlation. PSD estimation. Entropy. Markov Processes. Queuing Theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C]

**ECES 523 Detection & Estimation Theory 3.0 Credits**
Detection of signals in noise. Bayes criterion. NP criterion. Binary and M_ary hypotheses. Estimation of signal parameters. MLE and MAP estimation. 1D and 2D signals. ROC Analyses. Decision fusion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C] and ECES 522 [Min Grade: C]

**ECES 558 Digital Signal Processing for Sound & Hearing 3.0 Credits**
Introduction to the computational modeling of sound and the human auditory system. Signal processing issues, such as sampling, aliasing, and quantization, are examined from an audio perspective. Covers applications including audio data compression (mp3), sound synthesis, and audio watermarking.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 559 Processing of the Human Voice 3.0 Credits**
Introduction to the computational modeling of the human voice for analysis, synthesis, and recognition. Topics covered include vocal physiology, voice analysis-synthesis, voice data coding (for digital communications, VoIP), speaker identification, speech synthesis, and automatic speech recognition.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C] and ECES 558 [Min Grade: C]

**ECES 561 Medical Robotics I 3.0 Credits**
This course will introduce the emerging, multidisciplinary field of medical robotics. Topics include: introduction to robot architecture, kinematics, dynamics and control; automation aspects of medical procedures; safety, performance limitations; regulatory and economics and future developments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 562 Medical Robotics II 3.0 Credits**
This course will continue the introduction to the emerging, multidisciplinary field of medical robotics. Topics include: medical procedure automation; robot testing and simulation techniques; This is a project based course that will afford students the opportunity to work with existing medical robotic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 561 [Min Grade: C]

**ECES 604 Optimal Estimation & Stochastic Control 3.0 Credits**
Introduction to control system problems with stochastic disturbances; linear state space filtering, Kalman Filtering, Non-linear systems; extended Kalman Filtering. Robust and H-infinity methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C] and ECES 521 [Min Grade: C]

**ECES 607 Estimation Theory 3.0 Credits**
General characteristics of estimators. Estimators: least squares, mean square, minimum variance, maximum a posteriori, maximum likelihood. Numerical solution. Sequential estimators.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 614 Passive Network Synthesis 3.0 Credits**
An introduction to approximation theory; driving point functions; realizability by lumped-parameter circuits; positive real functions; properties of two and three element driving point functions and their synthesis; transfer function synthesis; all-pass networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 615 Analysis & Design of Linear Active Networks 3.0 Credits**
DC and AC models of bipolar transistors and FETs; design of differential operational amplifiers; optimal design of broad-band IC amplifiers; design of tuned amplifiers; design for optimal power gain, distortion, and efficiency; noise in transistor circuits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 621 Communications I 3.0 Credits**
Covers modulation techniques: baseband PAM, passband PAM, QAM, and PSK; orthogonal signaling: FSK; symbol/vector detection: matched filter and correlation detector; sequence detection: ISI; equalization: adaptive and blind; carrier synchronization; and timing recovery.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 622 Communications II 3.0 Credits**
Covers shot noise, noise in detectors, analog fiberoptic systems, carrier and subcarrier modulation, digital systems bit error rates for NRZ and RZ formats, coherent optical communication systems-heterodyne and homodyne systems, wavelength division multiplexing, system design concepts, power budgets, rise time budgets, and optical switching networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 623 Communications III 3.0 Credits**
Covers fundamentals of information theory: information measure, entropy, and channel capacity; source encoding and decoding; rate distortion theory; linear codes; block codes; convolutional codes, Viterbi algorithm; encryption and decryption; and spread spectrum communications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 631 Fundamentals of Deterministic Digital Signal Processing 3.0 Credits**
Fundamentals of Deterministic Digital Signal Processing. This course introduces the fundamentals of deterministic signal processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 632 Fundamentals of Statistical Digital Signal Processing 3.0 Credits**
Fundamentals of Statistical Deterministic Digital Signal Processing. The course covers topics on statistical signal processing related to data modeling, forecasting and system identification.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 640 Genomic Signal Processing 3.0 Credits**
This course focuses on signal processing applied to analysis and design of biological systems. This is a growing area of interest with many topics ranging from DNA sequence analysis, to gene prediction, sequence alignment, and bio-inspired signal processing for robust system design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 642 Optimal Control 3.0 Credits**
Introduces the concept of optimal control first by static optimization for state space formulated systems. The concept is expanded as the linear quadratic regulator problem for dynamic systems allowing solution of the optimal control and suboptimal control problems for both discrete and continuous time. Additional topics include the Riccati equation, the tracking problem, the minimum time problem, dynamic programming, differential games and reinforcement learning. The course focuses on deriving, understanding, and implementation of the algorithms.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 643 Digital Control Systems Analysis & Design 3.0 Credits**
Covers analysis and design of sampled-data control system using Z-transform and state-variable formulation, sampling, data reconstruction and error analysis, stability of linear and non-linear discrete time systems by classical and Lyapunov's second method, compensator design using classical methods (e.g., rootlocus) and computer-aided techniques for online digital controls, optimal control, discrete-time maximum principle, sensitivity analysis, and multirate sampled-data systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 513 [Min Grade: C]

**ECES 644 Computer Control Systems 3.0 Credits**
Introduction to the fundamentals of real-time controlling electromechanical dynamic systems, including modeling, analysis, simulation, stabilization and controller design. Control design approaches include: pole placement, quadratic and robust control performances.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 651 Intelligent Control 3.0 Credits**
Concepts of Intelligence in Engineering Systems, Learning Automation, Principles of Knowledge Representation. Levels of Resolution and Nestedness. Organization of Planning: Axioms and Self-Evident Principles.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 660 Machine Listening and Music IR 3.0 Credits**
This course introduces methods for the computational analysis, recognition, and understanding of sound and music from the acoustic signal. Covered applications include sound detection and recognition, sound source separation, artist and song identification, music similarity determination, and automatic transcription.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 670 Seminar in Systems I 2.0 Credits**
Involves presentations focused on recent publications and research in systems, including communications, controls, signal processing, robotics, and networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 671 Seminar in Systems II 2.0 Credits**
Continues ECES 670.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 672 Seminar in Systems III 2.0 Credits**
Continues ECES 671.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 681 Fundamentals of Computer Vision 3.0 Credits**
Develops the theoretical and algorithmic tool that enables a machine (computer) to analyze, to make inferences about a "scene" from a scene's "manifestations", which are acquired through sensory data (image, or image sequence), and to perform tasks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 682 Fundamentals of Image Processing 3.0 Credits**
The course introduces the foundation of image processing with hands-on settings. Taught in conjunction with an imaging laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 631 [Min Grade: C]

**ECES 684 Imaging Modalities 3.0 Credits**
This course is intended to produce students and image processing with a background on image formation in modalities for non-invasive 3D imaging. The goal is to develop models that lead to qualitative measures of image quality and the dependence of quality imaging system parameters.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 685 Image Reconstruction Algorithms 3.0 Credits**
This course is intended to provide graduate students in signal and image processing with an exposure to the design and evaluation of algorithms for tomographic imaging.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 684 [Min Grade: C] and BMES 621 [Min Grade: C]

**ECES 690 Special Topics in Systems Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 697 Research In Systems Engineering 1.0-12.0 Credit**
Research in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 699 Supervised Study in Systems Engineering 9.0 Credits**
Supervised study in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 801 Advanced Topics in Systems I 3.0 Credits**
Familiarizes students with current research results in their field of interest, specifically in works reported in such journals as The IEEE Transactions.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 802 Advanced Topics in Systems II 3.0 Credits**
Continues ECES 801.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 803 Advanced Topics in Systems III 3.0 Credits**
Continues ECES 802.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 811 Optimization Methods for Engineering Design 3.0 Credits**
Applications of mathematical programming and optimization methods in engineering design problems such as networks, control, communication, and power systems optimization. Optimization problem definition in terms of objective function, design variables, and design constraints. Single variable and multivariable search methods for unconstrained and constrained minimization using Fibonacci, gradient, conjugate gradient, Fletcher-Powell methods and penalty function approach. Classical optimization--Lagrange multiplier, Kuhn-Tucker conditions. Emphasis is on developing efficient digital computer algorithms for design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 812 Mathematical Program Engineering Design 3.0 Credits**
Approximation theory projection theorem. Solution of nonlinear equations by Newton-Raphson method. Resource allocation, linear programming, and network flow problems. Integer programming for digital filter design and power system expansion problems. Gamory's algorithm.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 813 Computer-Aided Network Design 3.0 Credits**
Simulation and circuit analysis programs: PCAP, MIMIC, GASP. Data structures. Algorithms. Languages. Interactive I/O. Integration of subroutines for simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 817 Non-Linear Control Systems 3.0 Credits**
Covers key topics of feedback linearization, sliding mode control, model reference adaptive control, self-tuning controllers and on-line parameter estimation. In addition additional no n-linear topics such as Barbalat's Lemma, Kalman-Yakubovich Lemma, passivity, absolute stability, and establishing boundedness of signals are presented. The focus of the course is the understanding each of these algorithms in detail through derivation and their implementation through coding in Matlab and Simulink.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 513 [Min Grade: C]

**ECES 818 Machine Learning & Adaptive Control 3.0 Credits**
System identification and parameter estimation, gradient search, least squares and Neural Networks methods. Closed loop implementation of system learning and self-organizing controllers. Random searching learning systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 512 [Min Grade: C]

**ECES 821 Reliable Communications & Coding I 3.0 Credits**
Covers fundamentals of information theory, including measures of communication, channel capacity, coding for discrete sources, converse of coding system, noisy-channel coding, rate distortion theory for memoryless sources and for sources with memory, and universal coding.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 521 [Min Grade: C] and ECES 522 [Min Grade: C]

**ECES 822 Reliable Communications & Coding II 3.0 Credits**
Introduces algebra of coding, including groups, rings, fields, and vector fields. Covers finite fields, decoding circuitry, techniques for coding and decoding, linear codes, error-correction capabilities of linear codes, dual codes and weight distribution, important linear block codes, perfect codes, and Plotkin's and Varshamov's bounds.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 821 [Min Grade: C]

**ECES 823 Reliable Communications & Coding III 3.0 Credits**
Continues techniques for coding and decoding. Covers convolutional codes; Viterbi algorithm; BCH, cyclic, burst-error-correcting, Reed-Solomon, and Reed-Muller codes; and elements of cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 822 [Min Grade: C]

**ECES 890 Advanced Special Topics in Systems Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 898 Master's Thesis in Systems Engineering 1.0-12.0 Credit**
Master's thesis in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 921 Reliable Communications & Coding I 3.0 Credits**
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECES 997 Dissertation Research in Systems Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECES 998 Ph.D. Dissertation in Systems Engineering 1.0-12.0 Credit**
Ph.D. dissertation in systems engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Engineering Management

*Master of Science in Engineering Management (MSEM): 45.0 quarter credits*

## About the Program

The engineering management program (http://www.drexel.edu/egmt) is designed to provide the background in management science necessary to advance from purely technical positions to supervisory responsibilities in such areas as research and development, production, engineering, design, and technical marketing. Study can be on a part-time or full-time basis, and all courses are offered online.

In our increasingly complex, technologically-oriented economy, demand has risen for professionals with the expertise to manage both human and technological resources — a combination of talents crucial to organizations competing in the global marketplace. Students graduating with the master's in engineering management are significantly better positioned to meet the challenge.

Engineering management is a multidisciplinary program offering a core curriculum and specialization in a selected area of technology or management. Majors in engineering management must hold a bachelor's degree in engineering, basic science, or a related field. The program is open to those professionals who aspire to be engineering or technically based managers.

## Dual-Degree Requirements

Students may simultaneously pursue the master's in engineering management and another master's degree. Students must satisfy program requirements for each degree, with a maximum of 15.0 credits transferred from one program to the other. (The master's in engineering management requires 45.0 credits; if the other degree requires 45.0 credits, then 60.0 credits are required under the dual degree program.)

Approval for the dual degree program must be obtained from the program advisor in each department or program.

## Graduate Co-op Program (GCP)

The Graduate Co-op Program (graduate intern or co-op program) is available to master's-level engineering management students. The opportunity to spend six months in industry provides a significant opportunity for the engineer in transition to management. Through Drexel's Steinbright Career Development Center (http://www.drexel.edu/scdc/coop/graduate) , students can explore new career directions. This program requires 6.0 additional credits, 3.0 for each term in industry.

## Certificate Opportunity

The engineering management program also offers a four-course graduate certificate in engineering management.

Students can apply to pursue the graduate certificate in engineering management, earn the credential, and subsequently apply those credits toward completion of a master's in engineering management. However, current students in pursuit of the master's in engineering management may not simultaneously pursue the graduate certificate.

Non-engineering management graduate students in the college of engineering (including those in the accelerated bachelor's/master's program) are welcome to apply for the certificate in engineering management, with advisor approval, and they can do so while simultaneously pursuing their primary degree.

## Additional Information

For more information about the program, visit the Drexel Online Engineering Management (http://www.drexel.com/online-degrees/engineering-degrees/ms-egmt) program page.

## Admission Requirements

Admission to this program requires:

- A four-year bachelor of science degree in engineering from an ABET-accredited institution in the United States or an equivalent international institution. Bachelor's degrees in math or the physical sciences may also be considered for provisional admission.
- Minimum cumulative undergraduate GPA of 3.0. If any other graduate work has been completed, the average GPA must be at least 3.0.
- Complete graduate school application.
- Official transcripts from all universities or colleges and other post-secondary educational institutions (including trade schools) attended.
- Two letters of recommendation, professional or academic (professional preferred).
- Resume
- A 750-word essay on one of two prompts: technical analysis problem or human resource problem (details of each problem are included in the essay tab of the online application).
- International students must submit an Internet-based TOEFL (IBT = score of 100 or higher).

At least five years of relevant professional work experience are recommended, but not required.

Interested students should complete the Drexel University Online admission application (http://www.drexel.com/online-degrees/engineering-degrees/ms-egmt/admissions.aspx) for admission into this online program.

## Degree Requirements

The master's in engineering management degree requires 45.0 credits, including 30.0 credits in required core courses and 15.0 graduate elective credits. These electives may be taken in other colleges at Drexel consistent with the plan of study and any required prerequisites.

Students may take their required elective credits from any graduate-level course(s) in engineering, business, or another college for which they have adequate preparation and can obtain approvals from the college and the engineering management program.

All candidates are encouraged to discuss areas of interest with the program advisor and to develop a proposed plan of study during the early stages of the program.

Note: Specific course requirements will be waived for students who have taken equivalent courses elsewhere.

| **Engineering Management** | | |
|---|---|---|
| EGMT 501 | Engineering Management | 3.0 |
| EGMT 502 | Advanced Engineering Management | 3.0 |
| EGMT 504 | Engineering Management Communications | 3.0 |
| EGMT 581 | Human Relations and Organizational Behavior | 3.0 |
| **Quantitative Analysis** | | |
| EGMT 571 | Managerial Statistics | 3.0 |
| EGMT 572 | Statistical Data Analysis [*] | 3.0 |
| EGMT 573 | Operations Research | 3.0 |
| **Economics and Financial Management** | | |
| EGMT 531 | Engineering Economic Evaluation & Analysis | 3.0 |
| EGMT 535 | Financial Management | 3.0 |
| **Engineering Management Capstone** | | |
| EGMT 692 | Engineering Management Capstone | 3.0 |
| **Electives** | | |
| Select five of the following electives: [**] | | 15.0 |
| EGMT 536 | Advanced Financial Management for Engineers | |
| EGMT 650 | Engineering Leadership | |
| **Marketing & Business Development** | | |
| EGMT 614 | Marketing: Identifying Customer Needs | |
| EGMT 615 | Product Conceptualization and Development | |
| EGMT 616 | Technology Conceptualization and Development | |
| EGMT 660 | Sustainable Business Practices for Engineers | |
| **Project Management** | | |
| EGMT 620 | Engineering Project Management | |
| EGMT 625 | Project Planning, Scheduling and Control | |
| EGMT 630 | Global Engineering Project Management | |
| **Systems Engineering & Systems Thinking** | | |
| EGMT 635 | Visual System Mapping | |
| EGMT 685 | Systems Engineering Management | |
| EGMT 688 | Systems Engineering Analysis I | |
| EGMT 690 | Systems Engineering Analysis II | |
| **Engineering Law & Ethics** | | |
| EGMT 610 | Ethics & Business Practices for Engineers | |

| EGMT 652 | Engineering Law |
|---|---|
| **Other Approved Electives** | |
| EGMT 680 | Special Topics in Engineering Management |
| SYSE 510 | Systems Engineering Process |
| SYSE 511 | Systems Engineering Tools |
| SYSE 520 | Sustainment and Integrated Logistics |
| SYSE 521 | Integrated Risk Management |
| SYSE 522 | Supply Chain Systems Engineering |
| SYSE 523 | Systems Reliability Engineering |
| SYSE 524 | Systems Reliability, Availability & Maintainability Analysis |
| SYSE 525 | Statistical Modeling & Experimental Design |
| SYSE 530 | Systems Engineering Design |
| SYSE 531 | Systems Architecture Development |
| SYSE 532 | Software Systems Engineering |
| SYSE 533 | Systems Integration and Test |
| **Total Credits** | **45.0** |

\*    EGMT 572 Statistical Data Analysis requires as a prerequisite EGMT 571 Managerial Statistics or approval from the program administration to complete a waiver and request to take then pass the STAT Placement Exam in place of EGMT 571. If approved for the waiver of EGMT 571, students will be eligible to complete an upper level course substitution to satisfy the degree requirements. More information on this option is available on the Engineering Management website (http://www.drexel.edu/egmt/programs/onlinemasters/EGMT%20571).

\*\*   Students may select electives from other disciplines outside of Engineering Management with prior approval from their advisor.

# Certificate in Engineering Management

*Certificate Level: Graduate*
*Admissions Requirements: Undergraduate degree in engineering*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 12.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Expected Time to Completion: 1 years*
*Financial Aid Eligibility: Not aid eligible*

This program is a superb training ground for engineers and scientists who want to obtain a solid foundation in critical areas in management, communications, economics and finance without having to commit to the entire graduate program. After completing the program, students have the option of applying the earned credits toward a master's degree in engineering management.

Admission to this program requires:

- A four-year bachelor of science degree in engineering from an ABET-accredited institution in the United States or an equivalent international institution. Bachelor's degrees in math or the physical sciences may also be considered for provisional admission.
- Minimum cumulative undergraduate GPA of 3.0. If any other graduate work has been completed, the average GPA must be at least 3.0.
- Complete graduate school application.
- Official transcripts from all universities or colleges and other post-secondary educational institutions (including trade schools) attended.

- Two letters of recommendation, professional or academic (professional preferred).
- Resume
- A 750-word essay on one of two prompts: technical analysis problem or human resource problem (details of each problem are included in the essay tab of the online application).
- International students must submit an Internet-based TOEFL (IBT = score of 100 or higher).

At least five years of relevant professional work experience are recommended, but not required.

Continuing master's students pursuing other technical disciplines may also complete the certificate courses as electives with approval from their advisor (e.g., electrical engineering master's students may complete these four courses to satisfy four of their five elective requirements).

This certificate is awarded to students who successfully complete the following four graduate-level courses from the master's in engineering management (http://www.drexel.edu/egmt/resources/current/catalog) curriculum:

| **Requirements** | | |
|---|---|---|
| EGMT 501 | Engineering Management | 3.0 |
| EGMT 504 | Engineering Management Communications | 3.0 |
| EGMT 531 | Engineering Economic Evaluation & Analysis | 3.0 |
| EGMT 535 | Financial Management | 3.0 |
| **Total Credits** | | **12.0** |

The program is administered through Drexel Online. Applications to the certificate program are managed by Drexel Online. For the most current admission information, please visit www.drexel.com (http://www.drexel.com/online-degrees/engineering-degrees/cert-egmt).

# Engineering Management Faculty

James Breen, MBA, PE *(Drexel University)*. Adjunct Instructor. Vice President of Manufacturing Network Strategy at Johnson & Johnson.

James C. Deiner, MBA *(Cornell University)*. Adjunct Professor. Expert in IT projects in the pharmaceutical, logistics and financial services industries.

James Lill, MS, PE *(Drexel University)*. Adjunct Instructor. Director of Facilities, Planning and Management for the Downingtown Area School District.

Carole Mablekos, PhD *(Purdue University)*. Assistant Professor. Public speaking, technical writing, organizational behavior, and business writing courses.

Milena McCall, PhD *(New York University)*. Adjunct Instructor. Managerial communications.

Don Pippins, BS *(Georgia Institute of Technology)*. Adjunct Instructor.

Fredric Plotnick, PhD, JD, PE *(Drexel University; Widener University)*. Adjunct Professor. CEO and principal consultant of Engineering & Property Management Consultants, Inc.

Curtis Pontz, LLB *(Temple University)*. Adjunct Professor. Expertise in corporate compliance and business ethics.

Michael Scheuermann, PhD *(Drexel University)*. Adjunct Professor. Executive Director of the Online Learning Council, focused on quality, accessibility, retention, scalability, student support and engagement, as well as communication.

Stephen Smith, PhD *(Drexel University)*. Adjunct Professor. Development of online learning and distance teaching/learning techniques for engineering.

Ernest Weiler, PhD *(University of Nebraska)*. Adjunct Professor. Past Director of Corporate EHS Shared Services at Rohm & Haas.

John Zolan, MS *(Illinois Institute of Technology)*. Adjunct Professor. Power generation and alternative energy; Conversion of waste products to ethanol or electricity.

## Interdepartmental Faculty

Robert Brehm, PhD, PE, FASCE *(Drexel University)*. Associate Teaching Professor. International infrastructure delivery; response to natural catastrophes; risk assessment and mitigation strategies; project management techniques.

## Courses

### EGMT 501 Engineering Management 3.0 Credits
The course will cover the history and evolution of management theory as well as planning, organizational design, management styles, motivation/rewards/punishments and problem solving. Emphasis will be on developing a systemic, holistic approach. This course is designed to provide the necessary business knowledge for further study in the Engineering Management advanced courses. Students will have the opportunity to analyze issues dealing with various aspects of management. In addition, the required writing assignments should aid in developing critical thinking and written communication skills.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### EGMT 502 Advanced Engineering Management 3.0 Credits
The course will develop a framework that can be used to effectively manage organizations for sustainable high performance. It will build on the fundamentals that were learned in Engineering Management I and explore concepts related to change, strategy, culture, complexity, systems thinking, learning, creativity, problem solving, and innovation. Upon completing the course the student will have an enhanced ability to bring creativity to management and leadership challenges as well as an appreciation of the processes, skills, and attitude needed for success.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 501 [Min Grade: C]

### EGMT 504 Engineering Management Communications 3.0 Credits
Teaches effective communication skills, both written and spoken, and strategies essential for success in the workplace. Addresses interpersonal issues, communicating across functional disciplines. Uses the Design Approach. Addresses the communication demands of engineers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### EGMT 515 Infrastructure Systems & Performance Evaluation 3.0 Credits
Characterization of transportation, building, urban water resources and power distribution infrastructure. Capacity, functional performance and serviceability metrics. Risk and vulnerability concepts. Physical deterioration mechanisms. Asset management principles. Data management supporting scoping and sequencing of facility maintenance,repair, upgrading, interconnection, expansion or replacement.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### EGMT 516 Infrastructure Project & Program Planning 3.0 Credits
Coordination of infrastructure systems with multiple integrated projects through concept development, regulatory, environmental and economic screening, and then through design, construction, commissioning, operation and maintenance. Includes definition of program objectives and geographic limits; assessing asset conditions; sustainability and stakeholder analysis, team assembly and governance; defining performance and status reporting metrics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 501 [Min Grade: C]

### EGMT 517 Public Value & Participation in Infrastructure Decision 3.0 Credits
Adjusting sponsoring agency plans and program for external statutory and informal inputs, including regulatory approvals, environmental assessment, interested and affected party stakeholder concerns, life cycle sustain ability, and resource allocation. Includes communication of and transparent ratification of tradeoffs in expectations of project performance and reliability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 516 [Min Grade: C]

### EGMT 520 Infrastructure Capstone Project 3.0 Credits
Group project to produce an engineering- intensive submission for approval by a regulatory agency, addressing compliance with regulatory, codes and professional standards and resource requirements. The student team, with diverse backgrounds, will prepare and present the report to the designated entity, following the procedures and protocols that it has published.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 501 [Min Grade: C] and EGMT 515 [Min Grade: C] and EGMT 516 [Min Grade: C]

### EGMT 531 Engineering Economic Evaluation & Analysis 3.0 Credits
Provides a review of economic analysis, with emphasis on those phases of major interest to engineering administration. Covers the calculation of economic equivalence, inflation and the purchasing power of money, decision-making among alternatives, evaluation of public activities, and estimation of costs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 535 Financial Management 3.0 Credits**
Studies the features of accounting data essential to the interpretation and evaluation of engineering operations and financial position of the engineering enterprise. Analyzes financial statements and reports from the point of view of management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 531 [Min Grade: C]

**EGMT 536 Advanced Financial Management for Engineers 3.0 Credits**
Covers advanced problems in planning, controlling, and directing engineering and other operating costs through budgeting and analysis of cost data. Studies judging of profitability, liquidity, and the organizational structure of the engineering functions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 535 [Min Grade: C] and EGMT 531 [Min Grade: C]

**EGMT 571 Managerial Statistics 3.0 Credits**
Covers probability, including random variables and probability distributions, mathematical expectation, discrete probability distributions, continuous probability distributions, sampling and sampling distribution, and estimators and confidence intervals. Includes applications to engineering and industrial problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 572 Statistical Data Analysis 3.0 Credits**
Continues EGMT 571. Covers hypothesis testing, linear regression and correlation, multiple regression, and some topics from analysis of variance and non-parametric statistics. Introduces quality control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 571 [Min Grade: C]

**EGMT 573 Operations Research 3.0 Credits**
Covers deterministic modeling, including linear programming; the Simplex Method; theory of the Simplex Method; duality and sensitivity analysis; transportation, transshipment, and assignment problems; problem formulation; goal programming; network analysis; dynamic programming; and integer and non-linear programming. Discusses case study applications of engineering and management problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 571 [Min Grade: C] and EGMT 572 [Min Grade: C]

**EGMT 581 Human Relations and Organizational Behavior 3.0 Credits**
Covers morale and discipline in management situations. Includes case studies stressing the prevention of and solution to employee problems by means of appropriate policies, techniques, practices, and procedures. Examines group dynamics from the point of view of both psychological and sociological factors under varying situations, especially industrial.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 504 [Min Grade: C] and EGMT 501 [Min Grade: C]

**EGMT 605 Research & Development Management I 3.0 Credits**
Analyzes the issues and concepts involved in strategic and corporate development planning in the modern technologically oriented company. Pays particular attention to the fundamentals of corporate planning as they relate to the research and development product planning of the corporation. Includes some case studies. May be taken independently of EGMT 606.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 606 Research & Development Management II 3.0 Credits**
Analyzes the issues and concepts involved in the management of research and development and its functional relationship to other elements of the corporate structure. Pays particular attention to the functional characteristics of the product line, company growth by technological innovation, application of systems engineering concepts to the corporate organization, and changing concepts in management structures to accommodate advances in science and technology. May be taken independently of EGMT 605.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 610 Ethics & Business Practices for Engineers 3.0 Credits**
Course will raise level of awareness and sensitivity of and teach how to create a workplace valuing ethical behavior and business conduct. Discusses engineering ethics, how to establish and administer an effective corporate compliance program, case studies and application of the case method, ethical implications of business practice issues in the workplace.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 614 Marketing: Identifying Customer Needs 3.0 Credits**
Prepares students for management of research and development by exposing them to the needs of the environment and industries outside of their employers. Teaches students how to find business opportunities based on the wants and needs of customers. Focuses on the marketing of engineering services and engineered products to industrial and governmental customers. Explores the interdependence of engineering marketing, manufacturing, and finance through strategic business planning. Covers industrial and government procurement, sales techniques, costs, pricing, marketing research, proposal preparation, and client relationships.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 501 [Min Grade: C]

**EGMT 615 Product Conceptualization and Development 3.0 Credits**
Covers two broad themes: (1) innovation processes and (2) specific tools to use in the process. The course will acquaint students with the nature and the fundamental concepts of innovation processes, develop an understanding of which innovation processes are best applied to specific competitive environments and basic skill in the use of specific engineering and management tools useful in the development of innovative products, services and business models and the integration of the engineering/management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 616 Technology Conceptualization and Development 3.0 Credits**
Analyzes the issues and concepts involved in the management of research and development and its functional relationship to other elements of the corporate structure. Pays particular attention to the functional characteristics of the product line, company growth by technological innovation, application of systems engineering concepts to the corporate organization, and changing concepts in management structures to accommodate advances in science and technology.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 620 Engineering Project Management 3.0 Credits**
This course addresses the fundamentals of project management, and the techniques to ensure successful project execution. The course will look at qualitative and quantitative project management techniques, the impact of technology on PM, cost and schedule controls, financial considerations, leadership, team development, how other industries approach project management, and planning. We will also examine case studies of project management for international projects, different industries, and outsourcing situations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 625 Project Planning, Scheduling and Control 3.0 Credits**
This course provides a basic understanding of project planning and control by examining concepts and theories. Emphasis is placed on planning and control of technology based organizations. Upon successful completion of this course, students should be able to use the tools and concepts of project control and apply them.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 571 [Min Grade: C]

**EGMT 630 Global Engineering Project Management 3.0 Credits**
This course will focus on strategies and techniques needed for managing a global project in an engineering environment. Develop concepts of leadership for diverse global teams comm. strategies, cultural considerations, organizational structure, collaborative tools & techniques, risk mitigation and contracting strategies, legal and financial issues when executing a global engineering project. Highlight techniques used in design/construction, prod, devpt and technology transfer projects. Essential in today's environment of global competition.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 635 Visual System Mapping 3.0 Credits**
Visual System Mapping is an elective course designed to unlock creativity used to solve problems, accelerate learning and improve communications. Application of VSM techniques provides an advantage to solution development, collaboration and consensus in business problems for success in today's highly complex and competitive environment. VSM was inspired by a technique known as "Mind Mapping, and was designed to improve the use of the brain in learning and mastery and has been demonstrated to lead to enhanced creativity and better results. Practitioners can expect to have fun while virtually guaranteeing breakthrough outcomes. This course allows students to learn techniques and methods and apply them to personal, professional and organizational issues on individual and team projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 501 [Min Grade: C]

**EGMT 650 Engineering Leadership 3.0 Credits**
Course will explore concepts related to effective leadership within practice of engineering. Equips practicing engineers to move beyond engineering training to focus on algorithms and analysis and develop a broad understanding of leadership effectiveness in a technically oriented work place. Course will include models related to sustainable, high performance and topics related to living, learning, effectiveness, power, influence, networking, and systems thinking. Emphasis on developing systems thinking.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 501 [Min Grade: C] and EGMT 502 [Min Grade: C]

**EGMT 652 Engineering Law 3.0 Credits**
Examines the influence of contract, tort, and property law on engineering and construction activities. Includes legal principles relating to management of engineering organizations and governmental departments, and legal procedures of interest to engineers. Covers contracts, professional malpractice, expert testimony, intellectual property law, and business organizations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 660 Sustainable Business Practices for Engineers 3.0 Credits**
The course will give students a broad and practical understanding of various environmental issues as well as sustainability concepts. The challenges associated with sustainable development are multifaceted involving economic, social and environmental concerns. These concerns are altering business strategies and practices and are leading to new opportunities.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 501 [Min Grade: C]

**EGMT 680 Special Topics in Engineering Management 3.0 Credits**
Covers selected advanced-level topics in the field of engineering management. Specific topics for each term will be announced prior to registration.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**EGMT 685 Systems Engineering Management 3.0 Credits**
Course teaches the art of systems engineering. Students will learn SE processes and skills to integrate user needs, manage requirements, conduct technological evaluation and build elaborate system architecture, to assess risk, establish financial and schedule constraints. Course provides pedagogically sound approach to the subject matter. Any graduate students involved with new product development, technology development and/or integration will find this course useful.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 688 Systems Engineering Analysis I 3.0 Credits**
Introduces multiple System Engineering Analysis practices used to execute systems engrineering processes. Provides foundation to execute, monitor, and manage the traditional practices and also develops ability to modify and establish new practices based on this massive foundation. Instills confidence so student can contribute, lead, monitor or manage any systems effort.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 690 Systems Engineering Analysis II 3.0 Credits**
This course is a crossover course for Engineering Management majors and Systems Engineering majors. The course focuses on a combination of deterministic and stochastic quantitative techniques and tools used for systems analysis, engineering analysis, and managerial analysis. Associated topics will be Probability Theory to support Decision Analysis, Pareto Trade Off Models, Analytical Hierarchy Process, Inventory Management & Control Operations, Waiting Line Models and Simulation & Modeling techniques. Emphasis will be placed on spreadsheet modeling and Monte Carlo simulation. The primary focus will be on utilizing excel based models and tools to support quantitative systems analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 572 [Min Grade: C] and EGMT 573 [Min Grade: C]

**EGMT 692 Engineering Management Capstone 3.0 Credits**
Uses the case method to provide a thorough study of engineering management and administrative procedures in recognizing and solving engineering problems. Emphasizes strategic planning and policy decisions that affect the image and success of the whole organization in its domestic and global environments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 501 [Min Grade: C] and EGMT 502 [Min Grade: C] and EGMT 531 [Min Grade: C] and EGMT 535 [Min Grade: C]

**EGMT 699 Independent Study 0.5-9.0 Credits**
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**EGMT 799 Research 0.5-20.0 Credits**
Involves the selection and solution of a problem in the field of engineering management. Expects students to conduct independent research and demonstrate the ability to employ one or more of the managerial tools to which they were exposed. Emphasizes the composition and organization of the paper, the logical development of a solution to the problem, and the contribution of the solution to knowledge.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**EGMT 898 Master's Thesis 0.5-20.0 Credits**
Involves the study and investigation of a research or development problem in the area of the student's major elective. Requires the problem to be reported in a dissertation under the direction of a faculty adviser. No credit will be granted until thesis is completed and approved.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

# Environmental Engineering

*Master of Science in Environmental Engineering (MSENE): 45.0 quarter credits*
*Doctor of Philosophy: 90.0 quarter credits*

## About the Program

Programs in environmental engineering are available with specializations in air pollution, hazardous and solid waste, subsurface contaminant hydrology, water resources, water and wastewater, and sustainability treatment.

Environmental engineering is concerned with protecting human, animal, and plant populations from the effects of adverse environmental factors, including toxic chemicals and wastes, pathogenic bacteria, and global warming.

Environmental engineers also try to minimize the effect of human activities on the physical and living environment so that we can all live more healthy and sustainable lives. This field builds on other branches of engineering, especially civil, chemical, and mechanical engineering. It also builds on information from many of the sciences, such as chemistry, physics, hydrology, geology, atmospheric science, and several specializations of biology (ecology, microbiology) and public health. Students who elect to study environmental engineering will become familiar with many of these areas because maintaining and improving the environment requires that problems be evaluated and solutions found using a multidisciplinary approach.

For more information about this program, visit the MS in Environmental Engineering (http://www.drexel.edu/cae/academics/grad-doctoral-programs) web page.

## Admission Requirements

In addition to the general entrance requirements for all environmental engineering applicants, entrance to the MS in Environmental Engineering program requires an undergraduate engineering degree from an ABET-approved institution. Students lacking this credential will be required to complete additional undergraduate courses to incorporate related elements of the functional equivalent of the ABET engineering BS degree. Typically, courses must be taken in computer programming, differential equations, linear algebra and fluid mechanics.

For additional information on how to apply, visit Drexel's Admissions page for Environmental Engineering (http://www.drexel.edu/grad/programs/coe/environmental-engineering) .

## Degree Requirements: MS in Environmental Engineering

The MS in Environmental Engineering program requires 45.0 credits of coursework. Both a theses and a non-thesis option are available. It is possible to finish the MS degree on either a part-time or full-basis. The

degree consists of a set of core courses, a sequence in one of several areas of emphasis (treatment process, human risks, water resources, environmental modeling, and air quality) and completion of cognate and elective sequences. After the first term of study, a detailed plan of study is developed with the student's graduate advisor.

**Core Courses**

| | | |
|---|---|---|
| ENVE 660 | Chemical Kinetics in Environmental Engineering | 3.0 |
| ENVS 501 | Chemistry of the Environment | 3.0 |
| ENVS 516 | Sanitary Microbiology | 3.0 |
| Statistics Course (for example, ENVS 506 Biostatistics) | | 3.0 |
| Environmental Policy Course | | 3.0 |
| Additional Sequence Courses, Electives, and/or Thesis course | | 30.0 |
| **Total Credits** | | **45.0** |

# Degree Requirements: PhD in Environmental Engineering

Applicants to the doctoral program are judged on the basis of academic excellence and the alignment of their research interests with those of the faculty in the School. To be awarded the PhD, students must complete a major research project publishable in peer-reviewed journals. The degree requires a total of 90 credits; credits earned toward a master's degree may apply toward the 90. There is no prescribed coursework—students must take courses needed to complete their research under guidance of an academic advisor. There is a one-year residency requirement. Students must successfully pass the candidacy examination, the proposal defense, and a PhD dissertation and oral defense.

Prospective PhD student are welcome to contact the Department (http://www.drexel.edu/cae) to discuss their research interests.

# Dual Degree

## Dual MS Degree

The university encourages students with broad interest to consider a dual-master's option. Students can simultaneously work on two master's degree, applying to both programs a limited number of credits (a maximum of 15 to each). Applicants interested in a dual degree should apply for just one program; once enrolled at Drexel, the student may then request admission to the second program. The graduate advisors from both degree programs must approve the student's enrollment, and they must approve the transfer of credits from one program to another. Applicants considering two degrees are encouraged to contact the appropriate academic departments.

## Bachelor's/Master's Dual Degree Program

The BS/MS dual degree is an accelerated program providing the academically qualified student an opportunity to simultaneously earn both BS and MS degrees (two diplomas are awarded) in program areas of his/her choice in five years, the time normally required to finish a bachelor's degree alone. Because both degrees are completed in the time usually required for the bachelor's degree, both degrees may be completed at the undergraduate tuition rate.

The five-year completion period is possible because fewer undergraduate credits are required for the combined degrees (180 instead of 192). Also, co-op experience may be adjusted (two co-op periods instead of three) giving the BS/MS student two additional quarters to take courses. If needed, students may also take evening courses while on co-op.

The program combines the practical work experience of Drexel undergraduate cooperative education with the graduate credentials of an advanced degree. Students may earn both degrees in the same major, or may complete their master's degree in a different field. With both an undergraduate and graduate degree and practical work experience, BS/MS graduates enter the work force with specialized knowledge and training.

Students interested in the Environmental Engineering BS/MS program, may contact Dr. Charles N. Haas at haas@drexel.edu for more information.

# Facilities

The Department of Civil, Architectural, and Environmental Engineering is well equipped with state-of-the-art facilities:

- Analytical instrumentation for measuring biological and chemical contaminants in air, water and land
- Field sampling equipment for water and air measurements
- Molecular biology capability
- Computational facilities including access to multi-processor clusters, and advanced simulation and data analysis software

# Civil, Architectural and Environmental Engineering Faculty

Abieyuwa Aghayere, PhD, P.Eng *(University of Alberta)*. Professor. Structural design - concrete, steel and wood; Structural failure analysis and retrofitting of existing structures; New structural systems and materials.

Emin A. Aktan, PhD *(University of Illinois at Urbana-Champaign) John Roebling Professor of Infrastructure Studies*. Professor. Structural engineering; infrastructure; evaluation; intelligent systems.

Ivan Bartoli, PhD *(University of California, San Diego)*. Assistant Professor. Non-destructive evaluation and structural health monitoring; dynamic identification, stress wave propagation modeling.

Robert Brehm, PhD, PE, FASCE *(Drexel University)*. Associate Teaching Professor. International infrastructure delivery; response to natural catastrophes; risk assessment and mitigation strategies; project management techniques.

S.C. Jonathan Cheng, PhD *(West Virginia University)*. Associate Professor. Soil mechanics; geosynthetics; probabilistic design; landfill containments.

Peter DeCarlo, PhD *(University of Colorado)*. Assistant Professor. Outdoor air quality, particulate matter size and composition instrumentation and measurements, source apportionment of ambient particulate matter, climate impacts of particulate matter.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute)*. Associate Professor. Soil mechanics; geoenvironmental; ground improvement; sustainability.

Patrick Gurian, PhD *(Carnegie-Mellon University)*. Associate Professor. Risk analysis of environmental and infrastructure systems, novel adsorbent materials, environmental standard setting, Bayesian statistical modeling, community outreach and environmental health.

Charles N. Haas, PhD *(University of Illinois-Urbana) L. D. Betz Professor and Department Head, Civil, Architectural and Environmental Engineering.* Professor. Control of human exposures to and risk assessment of pathogenic organisms; water and waste treatment; homeland security.

Ahmad Hamid, PhD *(McMaster University).* Professor. Engineered masonry; building; cladding; prestressed concrete.

Y. Grace Hsuan, PhD *(Imperial College).* Professor. Polymeric and cementitioius materials; geosynthetic reliability and durability.

Joseph B. Hughes, PhD *(University of Iowa) Dean of the College of Engineering.* Distinguished Professor. Biological processes and applications of nanotechnology in environmental systems.

Roger Marino, PhD *(Drexel University).* Associate Teaching Professor. Fluid Mechanics, Water Resources, Engineering Education, Land Development

Joseph P. Martin, PhD *(Colorado State University).* Professor. Geoenvironmental engineering; urban environmental hydrology; transportation.

James E. Mitchell, MArch *(University of Pennsylvania).* Associate Professor. Architectural engineering design; building systems.

Franco Montalto, PhD *(Cornell University).* Associate Professor. Effects of built infrastructure on societal water needs, ecohydrologic patterns and processes, ecological restoration, green design, water interventions.

Franklin Moon, PhD *(Georgia Institute of Technology).* Associate Professor. Full-scale structural testing, structural dynamics, evaluation and rehabilitation of existing structures.

Joseph V. Mullin, PhD *(Pennsylvania State University).* Senior Lecturer. Structural material behavior, engineering economy and design.

Mira S. Olson, PhD *(University of Virginia).* Associate Professor. Groundwater; environmental fluid mechanics; hydrology.

Anu Pradhan, PhD *(Carnegie Mellon University).* Assistant Professor. Infrastructure management, construction engineering, transportation engineering, sensing system, geographic information system, statistical machine learning.

Yared Shifferaw, PhD *(Johns Hopkins University).* Assistant Professor. Computational and experimental mechanics, structural stability, optimization, health monitoring and hazard mitigation, sustainable structures, emerging materials, thin-walled structures and metallic structures.

Kurt Sjoblom, PhD *(Massachusetts Institute of Technology).* Assistant Professor. Laboratory testing of geomaterials, geotechnical engineering, foundation engineering.

Sabrina Spatari, PhD *(University of Toronto).* Assistant Professor. Research in industrial ecology; development and application of life cycle assessment (LCA) and material flow analysis (MFA) methods for guiding engineering and policy decisions; specific interest in biomass and bioenergy, biofuels, and urban infrastructure.

Michael Waring, PhD *(University of Texas-Austin).* Assistant Professor. Indoor air quality and building sustainability; indoor particulate matter fate and transport; indoor chemistry and particle formation; secondary impacts of control technologies and strategies.

Jin Wen, PhD *(University of Iowa).* Associate Professor. Architectural engineering, building control systems, indoor air quality.

Aspasia Zerva, PhD *(University of Illinois).* Professor. Earthquake engineering; mechanics; seismicity; probabilistic analysis.

## Interdepartmental Faculty

Eugenia Ellis, PhD *(Virginia Polytechnic State University).* Associate Professor. Registered architect; interior design, extended-care facilities design, research on spatial visualization, perception and imagination.

Bakhtier Farouk, PhD *(University of Delaware) Billings Professor of Mechanical Engineering.* Professor. Heat transfer; combustion; numerical methods; turbulence modeling; materials processing.

Tony H. Grubesic, PhD *(The Ohio State University) Director of the Center for Spatial Analytics and Geocomputation (CSAG).* Professor. Geographic information science, spatial analysis, development, telecommunication policy, location modeling.

## Emeritus Faculty

Harry G. Harris, PhD *(Cornell University).* Professor Emeritus. Structural models, dynamics of structures, plates and shells, industrialized building construction.

Robert M. Koerner, PhD *(Duke University).* Harry Bownam Professor Emeritus. Geosynthetic engineering; soil mechanics; water resources.

Richard Weggel, PhD *(University of Illinois) Samuel S. Baxter Professor Emeritus; Civil and Environmental Engineering.* Professor Emeritus. Coastal engineering; hydraulics engineering; hydrology.

Richard Woodring, PhD *(University of Illinois) Dean of Engineering Emeritus.* Professor Emeritus. Structural engineering, reinforced concrete.

## Courses

**ENVE 516 Fundamentals of Environmental Biotechnology 3.0 Credits**
This is an introductory course in environmental biotechnology for upper-level undergraduates and graduate students in engineering. The fundamentals of microbiology and molecular biology important to environmental engineering applications will be emphasized.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 529 Environmental Noise 3.0 Credits**
Covers the fundamentals of acoustic propagation, instrumentation, noise descriptors, hearing damage and other health effects, occupational noise, noise abatement techniques, modeling the noise near highways and airports, and EPA strategy for reducing environmental noise exposure.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 534 Industrial Ventilation 3.0 Credits**
Covers principles of air movement related to ventilation and air-conditioning facilities for the maintenance of suitable environmental conditions in work areas. Includes principles of industrial processes and air pollution abatement equipment, including air flow, ducts, fans, motors, and hoods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 535 Industrial Safety 3.0 Credits**
Examines the impact of accidents, liability considerations, legislation and regulation of safety, osha codes and standards, hazards and their analysis and control, risk assessment, major types of accidents and their impacts, and accident investigation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 546 Solid Waste Systems 3.0 Credits**
Analyzes the public health, economic, and political aspects in the operation and design of storage, collection, and disposal of solid waste materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 550 Recycling of Materials 3.0 Credits**
This course will examine the selection criteria for recycling component materials. Recycling involves both reusing materials for energy applications and reprocessing materials into new products.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 555 Geographic Information Systems 3.0 Credits**
The course provides grounding in fundamental principles of GIS, and achieves understanding through hands on practical laboratories. Course topics include: spatial reference systems, geographic data theory and structures, structures, spatial analysis tools, functions and algorithms, GIS data sources, compilation and quality, and GIS project design and planning.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 560 Fundamentals of Air Pollution Control 3.0 Credits**
Fundamental topics with regard to the formation and control of air pollutants are studied. This course provides strong foundation for engineers who will be involved in the development of engineering solutions for industrial air pollution prevention and design, development or selection of air pollution control devices and systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 570 Industrial Ecology 3.0 Credits**
Industrial Ecology (IE) is an evolving view of industrial operations which seeks to design processes and manufacture products in such a way to minimize and optimize their environmental interactions. IE borrows the analogy from nature that "waste" from one organism is "food" for another. Within the "technosphere", the organization in which economic processes and activities are conducted by humans, IE uses the evolving tools life cycle assessment (LCA), material flow analysis (MFA), and economic valuation, to explore novel approaches to minimizing waste stocks and flows at both micro and macro levels.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 240 [Min Grade: B-] and ENVE 300 [Min Grade: B-]

**ENVE 571 Environmental Life Cycle Assessment 3.0 Credits**
This course provides graduate engineering students with an enhanced skill set to permit them to cooperate more fully in the sustainable design and planning of engineering systems. Students will be introduced to the systems analysis modeling approaches life cycle assessment (LCA) and material flow analysis (MFA), and will explore research-oriented aspects of the methods and their application in engineering design, decisions, and public policy.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVE 300 [Min Grade: B-] and CIVE 240 [Min Grade: B-]

**ENVE 602 Water Quality Control Lab 3.0 Credits**
Introduces analytical procedures in the assessment of water quality as applied to the analysis of natural waters and wastewaters, and to the control of water and waste treatment processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 501 [Min Grade: C]

**ENVE 603 Hazardous Waste Analysis Lab 3.0 Credits**
Introduces methods of sampling and analysis of hazardous environmental pollutants. Emphasizes inorganic and organic pollutants found at hazardous waste disposal sites. Includes application of leachability and extraction tests.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 501 [Min Grade: C]

**ENVE 604 Solid Waste Analysis 3.0 Credits**
Uses chemical and physical techniques to analyze the composition of solid waste material. Emphasizes combustible, organic, and toxic fractions of solid wastes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 501 [Min Grade: C]

**ENVE 607 Environmental Systems Analysis 3.0 Credits**
Surveys system concepts, theories, and analytical techniques, and their application to urban and environmental problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 642 Control of Gas and Vapor Pollutants From Industrial and Mobile Sources 3.0 Credits**
In this course, students will learn how different physical and chemical mechanisms can be used to prevent, separate, recover or destroy the gas/vapor air pollutants. The control mechanisms are studied in detail. Students then learn how to apply those mechanisms in the design of conventional, or new, devices and systems for control of gas/vapor air pollutants.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is PhD or Senior.
**Prerequisites:** ENVE 460 [Min Grade: D]

**ENVE 644 Design of Particulate Control Devices 3.0 Credits**
Students will learn how different mechanisms can control characteristics, formation, transport, separation and destruction of airborne particulate pollutants. Students learn how to apply the studied material in the first part of this course to design conventional or new devices and systems for control of particulate air pollutants.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVE 460 [Min Grade: D]

**ENVE 646 Advanced Solid Waste Systems 3.0 Credits**
Introduces and analyzes the newest advances in solid waste technology, with an emphasis on design, treatment, and processing techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 501 [Min Grade: C] and ENVR 546 [Min Grade: C] and ENVR 636 [Min Grade: C]

**ENVE 657 Incineration 3.0 Credits**
Covers destruction of solid and liquid hazardous wastes at high temperature in a combustion device, including requirements for destruction of toxic materials and control of discharges to the atmosphere.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 501 [Min Grade: C]

**ENVE 660 Chemical Kinetics in Environmental Engineering 3.0 Credits**
Covers chemical and biological kinetics, mass-transfer considerations and hydraulic regimes in water and wastewater treatment, and water quality management. Includes absorption and stripping of gases and volatile organics and applications to aeration and ozonation processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 661 Env Engr Op-Chem & Phys 3.0 Credits**
Provides a theoretical study of the chemical and physical unit operations of environmental engineering, including sedimentation, coagulation, precipitation, adsorption, oxidation-reduction, ion exchange, disinfection, membrane processes, and filtration.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVE 660 [Min Grade: C]

**ENVE 662 Enviro Engr Unit Oper-Bio 3.0 Credits**
Provides a systematic study of the microbiological and biochemical processes for the treatment of aqueous and solid wastes, including aerobic and anaerobic processes and composting.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVE 660 [Min Grade: C]

**ENVE 665 Hazardous Waste & Groundwater Treatment 3.0 Credits**
Covers principles of hazardous waste and groundwater treatment and in situ technologies. Presents application of processes, including solvent extraction, steam and air stripping, adsorption, ion exchange, oxidation, dechlorination, stabilization, wet air and supercritical oxidation, incineration, soil washing, and soil vapor extraction.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 660 [Min Grade: C]

**ENVE 681 Analytical and Numerical Techniques in Hydrology 3.0 Credits**
This course provides an introduction to some of the analytical and numerical methods that are widely used to solve problems in hydrology, including translating physical processes into partial differential equations and solving these problems using both analytical and numerical solution methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATH 200 [Min Grade: D] and ENGR 232 [Min Grade: D]

**ENVE 682 Subsurface Contaminant Transport 3.0 Credits**
This course covers principles governing contaminant movement in aquifers. It includes advection, dispersion, reactive transport, microbial and colloidal transport, matrix diffusion, density-coupled transport, and multiphase flow. It also emphasizes field-scale applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVE 681 [Min Grade: C]

**ENVE 683 Stochastic Subsurface Hydrology 3.0 Credits**
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVE 682 [Min Grade: C]

**ENVE 684 Water Resource Systems Analysis 3.0 Credits**
This course covers mathematical optimization techniques as applied to water resource systems. Example applications include water supply management, irrigation planning and operation, water quality management and ground water management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 702 Adv Enviro Instrumentatn 3.0 Credits**
Uses instrumental analysis to assess environmental quality.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 602 [Min Grade: C] and ENVR 604 [Min Grade: C]

**ENVE 726 Environmental Assessment 3.0 Credits**
Examines the National Environmental Policy Act of 1969 and its implemen-tation according to the regulations of the Council on Environmental Quality. Discusses air, water, noise, biological, cultural, and socioeconomic impacts. Includes methods of impact analysis and means to compare alternative actions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 727 Risk Assessment 3.0 Credits**
Covers quantitative relations between environmental exposures and effects. Includes computer methods for risk analysis and development of environmental guidelines and standards.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ENVE 750 Data-based Engineering Modeling 3.0 Credits**
This course covers empirical methods to understand and model engineering systems. Students will learn to develop evaluate statistical models and use three common statistical software packages, Excel, SPSS, and R.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Junior or Pre-Junior or Sophomore

**ENVE 761 Enviro Engr Unit Oper Lab 3.0 Credits**
Covers application of unit operations including filtration, adsorption, oxidation, coagulation, and biodegradation to the treatment of potable water, wastewater, and hazardous waste.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 661 [Min Grade: C] and ENVR 662 [Min Grade: C]

**ENVE 766 Waste Wtr Treat Plant Des 3.0 Credits**
Covers application of principles of environmental engineering unit operations to the treatment of municipal, industrial, and hazardous wastes by biological, physical, and chemical means. Includes applications of computers to the design process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ENVR 662 [Min Grade: C] and ENVR 751 [Min Grade: C]

**ENVE 767 Surface Water Mixing Processes 3.0 Credits**
This course covers the hydrodynamic mixing and transport processes in free-surface flows. Basic mixing processes including molecular diffusion, turbulent diffusion and dispersion are also covered. Emphasis will be on the solution of the advection-diffusion equation with various boundary conditions . Additional topics include boundary exchanges, non-ideal mixing in rivers, and analysis of jets and plumes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE or major is ENVE.
**Prerequisites:** CIVE 664 [Min Grade: C]

**ENVE 768 Sediment & Contamin Trnsport 3.0 Credits**
This course covers the transport of sediments and reactive solutes in surface waters as well as the classic theory for bed-load and suspended sediment transport. The interplay of stream flow, frictional resistance, and sediment transport is also covered. The biogeochemical processes that influence contaminant mobility and the integration of physical and chemical processes in contaminant transport models are also discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE or major is ENVE.
**Prerequisites:** CIVE 767 [Min Grade: C] or ENVE 767 [Min Grade: C]

**ENVE 865 Spec Topics Envr Engineering 12.0 Credits**
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Master of Engineering

*Master of Engineering (ME): 48.0 quarter credits*

## About the Program

This ME program is a highly customizable program primarily used for International and visiting students studying engineering at Drexel. This career-focused program is designed for working professionals and those seeking employment in a manufacturing-related industry, and may not be the best choice for those who wish to earn a PhD in engineering.
The ME program offers wide flexibility for those students who wish to combine technical and nontechnical study with hands-on experience in industry and laboratory research.

## Admission Requirements

In addition to meeting requirements for graduate admission, which include at least a 3.0 GPA for the last two years of undergraduate study and for any graduate study, applicants must hold a bachelor's degree in engineering from an accredited institution or an equivalent. Students whose background is in science or mathematics may be accepted to the program, but they will be required to take undergraduate engineering courses. Although the Graduate Record Examination (GRE) is not required for admission, it may be required of students interested in a teaching or research assistantship. Applicants whose native language is not English and who do not have previous degrees from a U.S. institution are required to submit scores of at least 550 on the Test of English as a Foreign Language (TOEFL).

## Degree Requirements

Students take a series of core and elective courses. Students work closely with and advisor to develop an individualized plan of study. A six-month period of career-related employment through Drexel's Graduate Co-op program is a requirement for full-time students. Students who are already employed as practicing engineers may apply to pursue the program on a part-time basis. A thesis is not required. The average time required to complete the master's degree is two years of full-time study or three years of part-time study.

## Degree Requirements

The degree requires a total of 48.0 credits, including at least 18.0 credits from an engineering discipline core. This core may be from any engineering department: Civil and Architectural, Chemical, Electrical and Computer, Materials, or Mechanical Engineering and Mechanics. (Please

refer to the appropriate departmental description in this catalog for more information about each department.) Students also complete 15.0 credits from the manufacturing core, which includes 6.0 credits in manufacturing and 9.0 credits of departmental manufacturing electives. Three credits of either engineering analysis or probability and statistics, 6.0 credits from either engineering management or the Bennett S. LeBow College of Business, and 6.0 credits of GCP round out the program.

## Curriculum

**Manufacturing Core Courses**

| MEM 687 | Manufacturing Processes I | 3.0 |
|---|---|---|
| MEM 689 | Computer-Aided Manufacturing | 3.0 |
| Departmental Manufacturing Electives (see below) | | 9.0 |
| Departmental Engineering Core | | 18.0 |
| Engineering Management/Business Requirements (see below) | | 6.0 |
| Engineering Analysis/Probability and Statistics Requirement | | 3.0 |
| Graduate Co-Op Program | | 6.0 |

**Departmental Manufacturing Elective Courses**

Select three of the following:

**Chemical Engineering**

| CHE 525 | Transport Phenomena I |
|---|---|
| CHE 554 | Process Systems Engineering |
| CHE 560 | Transport Phenomena in Biological Systems |
| CHE 562 | Bioreactor Engineering |
| CHE 564 | Unit Operations in Bioprocess Systems |

**Electrical and Computer Engineering**

| ECEC 541 | Robotic Computer Interface Controls I |
|---|---|
| ECEC 542 | Robotic Computer Interface Controls II |

**Materials Science and Engineering**

| MATE 570 | Materials Processing I |
|---|---|
| MATE 651 | Advanced Polymer Processing |

**Mechanical Engineering and Mechanics**

| MEM 688 | Manufacturing Processes II |
|---|---|
| MEM 717 | Heat Transfer in Manufacturing |
| MEM 727 | Fluid Dynamics in Manufacturing Processes |
| MEM 800 | Special Topics Mechanical Engineering |

**Business Core**

Select two of the following courses:

**LeBow College of Business**

| POM 620 | Management of Manufacturing Firms |
|---|---|
| POM 624 | Management of Service Firms |

**Engineering Management**

| EGMT 531 | Engineering Economic Evaluation & Analysis |
|---|---|
| EGMT 607 | Marketing: Identifying Customer Needs |
| EGMT 652 | Engineering Law |
| EGMT 680 | Special Topics in Engineering Management |

| **Total Credits** | **48.0** |
|---|---|

## Chemical Engineering Courses

**CHE 502 Mathematical Methods in Chemical Engineering 3.0 Credits**
Emphasizes formulation of differential and difference equations, both ordinary and partial, governing chemical engineering operations in the steady and unsteady state.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 513 Chemical Engineering Thermodynamics 3.0 Credits**
Examines thermodynamic principles from a classical viewpoint, including properties of materials, equations of state of mixtures, and chemical and phase equilibria of complex mixtures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 525 Transport Phenomena I 3.0 Credits**
Presents a unified treatment of transport rate theory, with emphasis on analogies among momentum, energy, and mass transfer, and continuum and molecular theories of matter.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 531 Fundamentals of Solar Cells 3.0 Credits**
This course focuses on the fundamentals of solar cells. It will cover semiconductor materials, basic semiconductor physics, optical and electronic phenomena, and case studies of crystalline silicon, thin film, and nanostructured photovoltaics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 534 Mass Transfer Operations I 3.0 Credits**
Theory and design of equilibrium stage operations. Separation processes for binary and multicomponent mixtures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 543 Kinetics & Catalysis I 3.0 Credits**
Covers chemical reaction kinetics as applied to chemical engineering. Introduces chemical kinetics and mechanisms and heterogeneous kinetics and catalysis. Includes design of ideal and non-ideal chemical reactors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 502 [Min Grade: C]

**CHE 554 Process Systems Engineering 3.0 Credits**
Covers the basic concepts of the systems engineering approach to the design and operation of processing plants. Includes methods for developing control strategies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 502 [Min Grade: C]

**CHE 556 Process Optimization 3.0 Credits**
Focuses on optimization of processes from the viewpoint of economic return.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 560 Transport Phenomena in Biological Systems 3.0 Credits**
Covers gas-liquid mass transfer in microbial systems, mass transfer in cells and biofilms, membrane transport, fluid mechanics of fermentation broth, power consumption in agitated vessels, heat transfer, and scale-up of mass transfer equipment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 561 Principles of Colloid Science 3.0 Credits**
This course focuses on fundamental principles of colloid science from a biological perspective. It will cover surface active agents, thermodynamics or self-assembly of surfactants, surface chemistry and physics of monolayers and bilayers, microstructures and phase behavior, specific biological colloids (micelles, liposomes, and lipoproteins), and colloidal stability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 562 Bioreactor Engineering 3.0 Credits**
Covers growth and product formation kinetics, batch and continuous stirred tank bioreactors, tower reactors, immobilized-cell reactors, and immobilized-enzyme reactors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 564 Unit Operations in Bioprocess Systems 3.0 Credits**
Covers liquid-liquid extractions, membrane separations, chromatographic separations, filtration, centrifugation, distillation, and leaching.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 566 Dynamics and Control of Biological Process Systems 3.0 Credits**
Dynamics of pH and temperature control systems, dynamics of bioreactors to feed upsets, substrate feed rate control, start-up of bioreactors, dynamics of multiple microbial populations, instrumentation of bioreactors, computer interfacing and control of bioreactors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 614 Chemical Engineering Thermodynamics II 3.0 Credits**
The second in a two-quarter sequence in thermodynamics for graduate students in Chemical and Biological Engineering. Students learn theory and application of statistical mechanics with emphasis on prediction of volumetric and thermal properties of pure fluids and mixtures, as well as phase equilibrium. Modern methods in applied statistical mechanics are covered, including Monte Carlo and molecular-dynamics simulations. Non-equilibrium statistical mechanics in terms of linear response theory applied to chemical kinetics is also covered. Students are evaluated on homework sets, two exams, and a term project.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CHE and program is PHD.
**Prerequisites:** CHE 513 [Min Grade: C]

**CHE 626 Transport Phenomena II 3.0 Credits**
Transport of mass, energy, and momentum of turbulent systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 631 Heat Transfer 3.0 Credits**
Advanced topics in heat conduction, convection, and radiation with application to design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 635 Mass Transfer Operations II 3.0 Credits**
Theory and design of continuous contact operations including fixed-bed and fluid-bed processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 644 Kinetics and Catalysis II 3.0 Credits**
Advanced topics in kinetics and catalysis including: diffusion and catalysis; optimization of chemical reaction systems; analysis and treatment of kinetic data.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 658 Advanced Process Design 3.0 Credits**
Covers flowsheet analysis and synthesis, batch process design and scheduling, project scheduling, and economic considerations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CHE 502 [Min Grade: C]

**CHE 670 Real-Time Microcomputer Applications 3.0 Credits**
Application of microcomputers in monitoring and control of external devices and processes. Topics include: digital input/output, real-time clock, analog-to-digital and digital-to-analog conversion, noise removal, signal processing, and data communications. Includes hands-on computer laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CHE 799 Independent Study in Chemical Engineering 9.0 Credits**
Provides advanced independent study in chemical engineering or related interdisciplinary fields.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CHE 800 Special Topics 0.5-9.0 Credits**
Covers selected advanced-level topics in chemical engineering. May be repeated for credit when topics vary.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CHE 898 Master's Thesis 9.0 Credits**
Requires fundamental research in chemical engineering. Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CHE 998 Ph.D. Dissertation 1.0-9.0 Credit**
Requires dissertation research in chemical engineering. Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Civil Engineering Courses

**CIVE 501 Model Analysis of Structures 3.0 Credits**
Open to advanced undergraduates. Covers application of models for the analysis and design of complex structures, including development of laws of similitude, methods of fabricating, and testing and instrumentation of models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 510 Prestressed Concrete 3.0 Credits**
Open to advanced undergraduates. Covers definitions and general principles, anchorage systems, and loss of prestress; analysis and design of simple beams for flexure, shear, bond, and bearing; partial prestressed and post-tensioned reinforcement; and continuous beams.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 520 Advanced Concrete Technology 3.0 Credits**
This course covers the mechanical, physical and chemical properties of concrete: characteristics of concrete in the fresh, setting and hardening states; high performance concrete. Factors influencing the mechanical performance of concrete are discussed as well as field testing methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is CIVE or major is EGEO.

**CIVE 530 Geotechnical Engineering for Highways 3.0 Credits**
Covers design if stable right-of-way, USDA classification, frost and swell expansion, capillary moisture retention, subgrade compaction, beam on elastic foundation pavement model, loads and resistance of buried pipes, subdrainage, basic slope stability and retaining structures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 531 Advanced Foundation Engineering 3.0 Credits**
Covers design of shallow foundations (footing and mats), deep foundations (piles, augered, drilled shafts) and retaining structures for stability and deformation performance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 560 Introduction to Coastal & Port Engineering 3.0 Credits**
Provides an overview of coastal engineering problems and their solution, including shoreline erosion, ocean waves and wave theories, wave generation, diffraction, refraction, harbor hydraulics, coastal currents, and tidal inlet hydraulics and sedimentation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 561 Introduction to Hydrology 3.0 Credits**
Covers climate and weather, precipitation, evaporation and transpiration, drainage basins, and hydrographs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGEO 700 [Min Grade: C]

**CIVE 562 Introduction to Groundwater Hydrology 3.0 Credits**
Covers the fundamentals of fluid flow in porous media, groundwater supply, pollution problems, well and aquifer hydraulics, and groundwater flow modeling.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 563 Coastal Processes 3.0 Credits**
This course provides a detailed presentation of hydraulic and sedimentary processes occurring in the coastal zone with a view toward applying knowledge of the processes to coastal erosion and shoreline stabilization problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 560 [Min Grade: C]

**CIVE 564 Sustainable Water Resource Engineering 3.0 Credits**
Objective is to enable students to incorporate sustainability concepts into the planning, design, and management of water resources, accomplished through critique of historical agricultural, industrial, and urban water infrastructure in the context of their ecological, social justice, and economic impacts. Global case studies featured and discussed. Also involves a research/design project with an actual "class client".
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Cannot enroll if classification is Freshman or Sophomore

**CIVE 565 Urban Ecohydraulics 3.0 Credits**
Will enable students to incorporate an understanding of ecohydrologic patterns and processes into the design of built landscapes and engineered infrastructure. Students will be introduced to techniques for analyzing and modeling rainfall-runoff processes and will learn how to develop ecosystem water budgets in urban contexts. Case studies and field trips will expose students to both ecosystem restoration and green infrastructure projects in the mid-atlantic region.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 320 [Min Grade: D] and CIVE 330 [Min Grade: D] and CIVE 430 [Min Grade: D]

**CIVE 567 Watershed Analysis 3.0 Credits**
This course focuses on land use change (LUC) and the hydrologic cycle in agricultural and forest (non-urban) watersheds. Using climate, hydrology, and agricultural models, students will investigate how changes in hydroclimatology and landscape-scale land cover affect surface water flow, runoff, and water quality in selected watersheds. The course will explore emerging topics pertaining to water and energy that course through rural watersheds, with the goal of interpreting data output from models into an environmental life cycle assessment (LCA) framework. LCA is a systems analysis framework that feeds information on life cycle environmental damages/consequences back into design and decision making. In this way, this course focuses specifically on watershed analysis models and how their output feed into desig.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 320 [Min Grade: B-] and CIVE 330 [Min Grade: B-] and CIVE 240 [Min Grade: B-]

**CIVE 585 Transportation Planning and Capacity 3.0 Credits**
Open to undergraduates. Covers prediction of travel demand; principles of highway and transit capacity; level-of-service concepts; uninterrupted and interrupted flow; traffic characterization by volume, speed, and density; operational analysis and design of freeways, highways, and urban streets; intermodal systems, intelligent transportation systems (its), and mass transit.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 586 Geometric Design of Highways 3.0 Credits**
Open to undergraduates. Covers classification of highway and transit systems with relation to function, funding, ownership, and design; characteristics of design vehicles, drivers, and traffic; elements of design including sight distance, horizontal alignment, and vertical alignment; cross-section and roadside design; and at-grade and separated intersections and interchanges.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 605 Advanced Mechanics Of Material 3.0 Credits**
Open to advanced undergraduates. Covers shear flow and shear center, unsymmetrical bending, torsion of non-circular and open sections, bending of curved beams, stress at a point, and failure theories.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**CIVE 615 Infrastructure Condition Evaluation 3.0 Credits**
This course covers the tools necessary for the inspection and evaluation of infrastructure. Non-destructive testing (NDT) techniques are introduced and applications and limitations of NDT techniques for a variety of structures are illustrated. Also covered are the policies for deter-mining the physical condition and maintenance needs for highway bridges.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is CIVE or major is EGEO.
**Prerequisites:** CIVE 250 [Min Grade: D] and CIVE 520 [Min Grade: C]

**CIVE 632 Advanced Soil Mechanics 3.0 Credits**
Consolidation magnitude and time rate of settlement, secondary compression, mitigating settlement problems, shear strength of cohesive and non-cohesive soils, critical state soil mechanics, undrainied pore pressure response, SHANSEP undrained strength.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 635 Slope Stability and Landslides 3.0 Credits**
Slope process and mass wasting; landslide characteristics, features and terminology; limit equilibrium slope stability analysis, including Bishop, Janbu, Spenser, Morgenstern-Price methods; effects of water on slop stability; dynamic (earthquake) stability analysis methods; introduction to rock slopes, slope stability investigations, and design and repair.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 636 Ground Modification 3.0 Credits**
This course covers the improvement of soil properties to meet project requirements, including surface and in situ technologies: compaction, densification, precompression, stabilization with admixtures, grouting and dewatering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 640 Environmental Geotechnics 3.0 Credits**
This course covers the analysis and control of subsurface exploration, groundwater remediation, pollutant-soil interaction and waste containment barriers and drains.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 650 Geosynthetics I 3.0 Credits**
Open to advanced undergraduates. Presents a basic description of the various products, relevant aspects of polymeric materials, and an overview of each category of geosynthetics. Covers geotextile testing and design on the basis of primary application function: separation, reinforcement, filtration, drainage, barrier, and combined.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**CIVE 651 Geosynthetics II 3.0 Credits**
Continues CIVE 650. Covers design and testing of geogrids for reinforcement applications and geonets for drainage applications. Presents geomembrane design and testing from an applications perspective in the areas of environmental, geotechnical, transportation, and hydraulic engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 650 [Min Grade: C]

**CIVE 652 Geosynthetics III 3.0 Credits**
Continues CIVE 651. Covers design and testing of geosynthetic clay liners as a hydraulic/gas barrier and geopipes as drainage materials in numerous application. Presents geocomposites in separation, reinforcement, filtration, drainage, and barrier applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 651 [Min Grade: C]

**CIVE 660 Hydrology-Stream Flow 3.0 Credits**
Covers precipitation, runoff, evaporation and transpiration, streamflow, floodflow, and minimum flow. Pays special attention to factors affecting water supply and quality.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.
**Prerequisites:** CIVE 561 [Min Grade: C]

**CIVE 662 Hydrodynamics I 3.0 Credits**
Covers theory of perfect fluids, Euler's equations of motion, continuity equation and energy equation, velocity potential and stream function, sources and sinks, circulation and vorticity, flow-around bodies and flow in channels, and jet flow.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 663 Hydrodynamics II 3.0 Credits**
Extends the theory of perfect fluids to cover fluid forces and moments on bodies, free streamline theory, and extension of vorticity theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 662 [Min Grade: C]

**CIVE 664 Open Channel Hydraulics 3.0 Credits**
Covers principles of flow in open channels, conservation laws, uniform flow, critical flow, gradually varied flow, backwater computations, channel design, and numerical computation of flows having a free surface.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if classification is Senior.

**CIVE 665 Computational Hydraulics I 3.0 Credits**
This course continues CIVE 664 to cover the application of mathematical and numerical techniques to model complex open channel hydraulic processes. At each stage the fundamental hydraulic principles are reviewed to assure proper construction of a modeling algorithm and to assist in interpretation of results.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE.
**Prerequisites:** CIVE 664 [Min Grade: C] and CIVE 330 [Min Grade: D] and CIVE 341 [Min Grade: D] and CIVE 430 [Min Grade: D]

**CIVE 666 Free Surface Flows 3.0 Credits**
This course extends the concepts of one-dimensional open channel flow to cover both the physical under-standing and the application of mathematical and numerical techniques to model very complex open channel hydraulics problems including transients, countercurrent flows and complex boundary conditions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE.
**Prerequisites:** CIVE 664 [Min Grade: C] and CIVE 665 [Min Grade: C]

**CIVE 701 Structural Analysis I 3.0 Credits**
Covers basic principles of structural analysis, including elastic deflection; elastic analysis of statically indeterminate structures by methods of virtual work, Castigliano's theorems, and moment distribution; and the Muller-Breslau principle and application to influence lines for continuous members and frames. Introduces numerical techniques.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 702 Structural Analysis II 3.0 Credits**
Covers matrix analysis of structures using finite elements, including elastic analysis of structures by influence coefficients, Argyris force method, direct stiffness method, and the displacement method. Introduces the finite-element method for planar structures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 701 [Min Grade: C]

**CIVE 703 Structural Analysis III 3.0 Credits**
Covers development of stiffness functions for planar and three-dimensional finite elements, and application to frame, plate, shell, and massive structures. Introduces the general application of finite elements to continuum problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 702 [Min Grade: C]

**CIVE 704 Behavior and Stability of Structural Members I 3.0 Credits**
Covers development of the basic differential equations of member behavior, including second-order effects, in-plane beam-column behavior, column buckling, elastic and inelastic behavior, energy methods, and approximate methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 705 Behavior and Stability of Structural Members II 3.0 Credits**
Covers general torsion of thin-walled open, closed, and combined open-and-closed cross-sections; lateral torsional buckling; biaxial bending; elastic and inelastic behavior; approximate methods; and frame buckling.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 704 [Min Grade: C]

**CIVE 710 Design and Structure of Integrity Building Systems 3.0 Credits**
Covers integration of design and building cycle, building envelope, structural morphology, composite structures, thermal and moisture design, fire and smoke, sound and vibration, building failure, and repair and restoration.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 711 Engineered Masonry I 3.0 Credits**
Covers masonry materials, structural behavior of masonry assemblages, and deformational characteristics of brick and block masonry; performance of load-bearing wall systems and design of unreinforced masonry elements; and special design and construction topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 712 Engineered Masonry II 3.0 Credits**
Covers fundamental concepts of reinforced masonry, reinforced wall design, column and pilaster design, seismic resistance of masonry structures, prestressed masonry, and applied design of low-and high-rise buildings.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 714 Behavior of Concrete Structures I 3.0 Credits**
Covers reinforced concrete members; relationship between results of research and current specifications for design of members subjected to axial loads, flexure, combined axial load and flexure, combined shear and flexure, long columns, bond and anchorage, and limit design; application to design of determinate and indeterminate reinforced concrete frames; and development of current code provisions for design of floor slabs in buildings.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 715 Behavior of Concrete Structures II 3.0 Credits**
Continues CIVE 714.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 714 [Min Grade: C]

**CIVE 717 Behavior of Metal Structures I 3.0 Credits**
Covers load and resistance factor design, including tension, bolted and welded connections, block-shear, compression, built-up compression members, lateral-torsional instability, light-gauge metal buckling and post-buckling strength, and behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 605 [Min Grade: C]

**CIVE 718 Behavior of Metal Structures II 3.0 Credits**
Covers load and resistance factor design, including design and behavior of metal structural members and connections, flexural members including plate girders, bracing and lateral-torsional buckling resistance, torsion and other combined loading, and composite beams and columns.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 717 [Min Grade: C]

**CIVE 719 Behavior of Metal Structures III 3.0 Credits**
Covers load and resistance factor design, including idealization and design of structures and their connections, frame bracing and sway, frame design philosophy, optimization, fatigue, and fracture.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 718 [Min Grade: C]

**CIVE 730 Experimental Soil Mechanics I 3.0 Credits**
Covers methods and techniques of soil testing, including interpretation and evaluation of test data, and fundamentals of soil behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: D]

**CIVE 731 Experimental Soil Mechanics II 3.0 Credits**
Continues CIVE 730.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: C]

**CIVE 732 Experimental Soil Mechanics III 3.0 Credits**
Continues CIVE 731.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 731 [Min Grade: C]

**CIVE 737 Seismic Geotechnics 3.0 Credits**
Introduction to earthquake hazards and seismology; strong ground motion parameters, deterministic and probabilistic seismic hazard analysis, influence of subsurface conditions and topography and ground motion, soil liquefaction, and brief coverage of seismic slop stability, design of retaining structures, and soil-structure interaction.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: C]

**CIVE 752 Coastal Structures 3.0 Credits**
This course briefly reviews the functional design of costal and port structures and deals in detail with forces on those structures. Forces caused by waves and currents, and mooring and vessel impacts are addressed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 563 [Min Grade: C]

**CIVE 754 Properties and Processes of Polymeric Construction Materials 3.0 Credits**
This course focuses on the uses and characteristics of polymeric materials used in civil and architectural engineering infrastructure. Also covered are micro-structure, physical and chemical properties and mechanical behavior. and the effects of manufacturing on the properties of the products.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is AE or major is CIVE or major is MATE.
**Prerequisites:** CIVE 250 [Min Grade: D] and TDEC 211 [Min Grade: D]

**CIVE 755 Durability of Polymeric Construction Materials 3.0 Credits**
This is a continuation of CIVE 754 and concentrates on protecting and predicting service lifetimes. It covers physical aging, mechanical stabilization and chemical degradation of polymeric materials and the products in which they are incorporated for field use. Covered in this course is the fundamental degradation mechanisms of different polymeric materials commonly used in Civil Engineering practice. Also covered are test methods and extrapolation methodologies for predicting long-term performance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 754 [Min Grade: C]

**CIVE 756 Evaluation of Polymeric Construction Materials 3.0 Credits**
This lab course is designed to integrate and extend the coverage of CIVE 754 and 755 so that students have a full concept of the behavior of polymeric construction materials. A series of thermal analysis and physical, chemical, and mechanical tests are included. The stress relaxation, stress cracking, oxidation, and applications of test results in infrastructure and environ-mental applications are discussed, including problems in comparative analysis of test results and their implications in design and specification.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 754 [Min Grade: D] and CIVE 755 [Min Grade: D]

**CIVE 767 Surface Water Mixing Processes 3.0 Credits**
This course covers hydrodynamic mixing and transport processes in free-surface flows. Basic mixing processes including molecular diffusion, turbulent diffusion, and dispersion are also covered. Emphasis will be on the solution of the advection-diffusion equation with various boundary conditions. Additional topics include boundary exchanges, non-ideal mixing in rivers, and analysis of jets and plumes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE or major is ENVE.
**Prerequisites:** CIVE 664 [Min Grade: C]

**CIVE 768 Sediment and Contaminate Transport 3.0 Credits**
This course covers the transport of sediments and reactive solutes in surface waters. Reviewed is the classic theory for bed-load and suspended sediment transport; interplay of stream flow, frictional resistance and sediment transport. Biogeochemical processes that influence contaminant mobility and integration of physical and chemical processes in contaminant transport models are also discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if major is CIVE or major is ENVE.
**Prerequisites:** ENVE 767 [Min Grade: C] or CIVE 767 [Min Grade: C]

**CIVE 790 Special Topics 9.0 Credits**
Covers selected advanced-level topics in civil engineering. May be repeated for credit if topics vary.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 799 Independent Study 12.0 Credits**
Independent study on a topic selected by the student. Independent study is supervised by a faculty member and guided by a plan of study.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 801 Dynamics of Structures I 3.0 Credits**
Covers formulation of equations of motion, including generalized single-degree-of-freedom systems, free vibration response, undamped and damped systems, harmonic analysis, resonance and vibration isolation, response to periodic loading, impulsive loading, response to general dynamic loading, non-linear structural response, and Rayleigh's method and other variational techniques. Introduces multi-degree-of-freedom systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 802 Dynamics of Structures II 3.0 Credits**
Covers formulation of multi-degree-of-freedom equations of motion, including evaluation of structural property matrices; elastic properties, mass properties, damping, and external loading; geometric stiffness; undamped free vibrations; analysis of dynamic response; practical vibration analysis; Stodola method; Holzer method; reduction of degrees of freedom; matrix iteration and other techniques; analysis of non-linear systems; variational formulation of the equations of motion; partial differential equations of motion; and free vibrations of beams.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 801 [Min Grade: C]

**CIVE 803 Dynamics of Structures III 3.0 Credits**
Covers distributed parameter dynamic systems, equations of motion, free and forced vibrations, analysis of structural response to earthquakes, seismological background, deterministic analysis of single-degree-of-freedom and multi-degree systems, multi-degree-of-freedom and distributive parameter systems, soil-structure interaction, non-linear response to earthquakes and current design code requirements, dynamics of complex structures, modeling, and use of large computer codes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 811 Plates and Shells I 3.0 Credits**
Covers analysis of circular, rectangular, and continuous plates by classical and approximate methods, including the folded plate theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 812 Plates and Shells II 3.0 Credits**
Covers the general theory of thin shells, cylindrical shells, surfaces of revolution, hyperbolic paraboloids, and other shells of double curvature.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 811 [Min Grade: C]

**CIVE 813 Plates and Shells III 3.0 Credits**
Covers buckling and vibration analysis, including application of finite-elements methods and anisotropic behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 812 [Min Grade: C]

**CIVE 831 Deep Foundations 3.0 Credits**
Covers topics including mat foundation design using plate theory, continuous beam design using beam-on-elastic foundation theory, and pile design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 833 Earth Retaining Structures 3.0 Credits**
Covers lateral earth pressure theories, analysis and design of temporary and permanent retaining structures, surcharge load, excavations, and loads on buried conduits.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 838 Soil Behavior 3.0 Credits**
Particle-scale behavior of soil and assemblages; clay mineralogy; soil formation, composition, structure and properties; soil water interaction; clay-water-electrolyte systems, adsorption-desorption and ion exchange; conduction phenomena; micromechanics; volume change behavior; strength and deformation behavior.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: C]

**CIVE 839 Geomechanics Modeling 3.0 Credits**
This course covers constitutive laws in goemechanics, including linear elastic, quasi-linear (hyperbolic) elastic, linear elastic-perfectly plastic and elasto-plastic models based on critical state soil mechanics. The finite element method is used to solve geotechnical boundary value problems incorporating different constitutive models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CIVE 632 [Min Grade: C]

**CIVE 898 Master's Thesis 0.5-20.0 Credits**
Involves investigation of an approved topic. Required of full-time master's degree students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CIVE 997 Research 1.0-12.0 Credit**
Research.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**CIVE 998 Ph.D. Dissertation 1.0-12.0 Credit**
Involves investigation of an approved topic. Required of Ph.D. students.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Elec Comp Engr-Computers Courses

**ECEC 500 Fundamentals Of Computer Hardware 3.0 Credits**
Covers computer organization and architecture; elements of computer hardware, processors, control units, and memories; hardware for basic mathematical operations; tradeoffs between speed and complexity; examples of embedded systems; microcontrollers; systems modeling.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 501 Computational Principles of Representation and Reasoning 3.0 Credits**
This course presents fundamentals of discrete mathematics as applied within the computer engineering and manufacturing environment. Students are given the theoretical background in representation and reasoning for a broad variety of engineering problems solving situations. Entity-relational techniques of representation are demonstrated to evolve into the object-oriented approach. Various search techniques are applied in the cases of representing engineering systems by using theory of automata techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 502 Principles of Data Analysis 3.0 Credits**
This course presents theoretical methods and techniques of model development applicable within the computer engineering design and manufacturing environment. Students are given the theoretical background in data analysis (including "data mining"). Emphasis is on hybrid systems and discrete events systems. Various methods of recognizing regularities in data will be presented. Elements of the theory of clustering and classification will be dealt with for the paradigm of software and hardware problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 503 Principles of Decision Making 3.0 Credits**
This course presents theoretical fundamentals and engineering techniques of decision making and problem solving applicable within the computer engineering design and manufacturing environment. Students are given the theoretical background in optimization methods for a broad variety of situation. Elements of the theory of planning and on-line control of systems are presented within the scope of software and hardware computer design and control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 511 Combinational Circuit Design 3.0 Credits**
Representing arithmetic. Logic and syntax data for machine processing. Switching algebra: Boolean and multiple values. Identification and classification of functions. Realizing completely specified and incompletely specified Boolean functions. Issues in designing large communication/control Boolean functions. Fault and testing of Boolean function.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 512 Sequential Circuit Design 3.0 Credits**
Finite automata and their realization by sequential machines, capabilities, transformation, and minimization of finite automata, linear finite automata. Clocked pulsed and level mode sequential circuits. Malfunctions in sequential circuits: hazards, races, lockouts, metastability. Issues of state assignment. Evolution of memory elements design: ROM vs. RAM vs. associative memory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 511 [Min Grade: C]

**ECEC 513 Design for Testability 3.0 Credits**
Economics vs. Complexity vs. Strategy of Testing; Fault Models; Test Generation; Testability Analysis & Designing Testable Circuits; Testing Microprocessors, Memories and Computer Components; Test Data Compression; Fault Tolerant Hardware; Reliably vs. Availability; Redundancy and Error Correcting Codes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 511 [Min Grade: C] and ECEC 512 [Min Grade: C]

**ECEC 520 Dependable Computing 3.0 Credits**
Fundamental design issues involved in building reliable, safety-critical, and highly available systems. Topics include testing and fault-tolerant design of VLSI circuits, hardware and software fault tolerance, information redundancy, and fault-tolerant distributed systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 541 Robotic Computer Interface Controls I 3.0 Credits**
Covers sensors, actuators, mechanical components of robots, kinematics, inverse kinematics, dynamics, and equations of motion.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 542 Robotic Computer Interface Controls II 3.0 Credits**
Covers the robot control problem, including PD, PID, position, force and hybrid controllers, resolved rate and acceleration control, and multiprocessor architecture.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECES 641 [Min Grade: C] and ECES 643 [Min Grade: C] and ECEC 541 [Min Grade: C]

**ECEC 543 Robotic Computer Interface Controls III 3.0 Credits**
Covers non-linear control techniques, FLDT, and advanced topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 542 [Min Grade: C]

**ECEC 571 Introduction to VLSI Design 3.0 Credits**
This is an introductory course where systematic understanding, design and analysis of digital VLSI integrated circuits will be covered. The course will begin with a review of CMOS transistor operation and semiconductor processes. Logic design with CMOS transistor and circuit families will be described. Specifically, layout, design rules, and circuit simulation will be addressed. Performance metrics will be analyzed in design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 572 Custom VLSI Design & Analysis I 3.0 Credits**
This is the first of two courses offered on Custom VLSI circuit and systems design and analysis. An understanding of VLSI integrated circuits is achieved through circuit design and analysis. This course focuses exclusively on high performance digital CMOS VLSI circuit and systems design, although some topics on mixed-signal circuits are also addressed. Design and analysis of VLSI integrated circuits will be covered from the circuits and systems design perspectives. First, a thorough analysis of interconnect networks is presented. The second part of the class focuses on synchronization of high performance ICs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 571 [Min Grade: C]

**ECEC 573 Custom VLSI Design & Analysis II 3.0 Credits**
This is the second of two courses offered on Custom VLSI circuit and systems design and analysis. An understanding of VLSI integrated circuits is achieved through circuit design and analysis. This course focuses exclusively on high performance digital CMOS VLSI circuit and systems design, although some topics on mixed-signal circuits are also addressed. The primary focus is on-chip power management. Power generation techniques are discussed and different power converters are analyzed. Power distribution networks are presented with a focus on the different distribution architectures and output impedance characteristics. Techniques to reduce power supply noise are also provided. A secondary focus examines substrate noise in mixed-signal systems and techniques to reduce substrate noise.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 571 [Min Grade: C]

**ECEC 574 ASIC Design I 3.0 Credits**
This course will focus exclusively on digital CMOS Application Specific Integrated Circuit (ASIC) systems design and automation. The ASIC physical design flow, including logic synthesis, floorplanning, placement, clock tree synthesis, routing and verification will be presented. These back-end physical design flow steps will also be covered through hands-on practice using industrial VLSI CAD tools. Contemporary design practices will be reviewed and presented in experiments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 575 ASIC Design II 3.0 Credits**
Design and analysis of VLSI integrated circuits will be covered from a systems design perspective. System timing, arithmetic building block and memory block design processes will be presented. Design tasks in a quarter-long, small-complexity processor design project will cover the back-end of the IC design flow range, from RTL synthesis to timing and power analysis. Projects will be performed in a hierarchical group, similar to an industrial setting, with other graduate and undergraduate students.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 572 [Min Grade: C]

**ECEC 600 Fundamentals of Computer Networks 3.0 Credits**
Fundamentals design principles of ATM, Internet and local area networks; protocol layers and the Internet Architecture; medium access protocols; application protocols and TCP/IP utilities; basic principles and virtual circuit switching; naming and addressing; flow and congestion control protocols; routing algorithms; Quality-of-Service in computer networks; security issues in networks.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 621 High Performance Computer Architecture 3.0 Credits**
Maximizing single processor performance. Concepts and techniques for design of computer systems. Processor design, instruction set architecture design and implementation, memory hierarchy, pipelines processors, bus bandwidth, processor/memory interconnections, cache memory, virtual memory, advanced I/O systems, performance evaluation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 622 Parallel Computer Architecture 3.0 Credits**
Advanced techniques of computer design. Use of parallel processing to achieve high performance levels. Fine and coarse grained parallelism. Multiple CPU parallelism, through multiprocessors, array and vector processors. Dataflow architectures and special purpose processors. Design implications of memory latency and bandwidth limitations. Speedup problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 621 [Min Grade: C]

**ECEC 623 Advanced Topics in Computer Architecture 3.0 Credits**
This course teaches advanced concepts of modern computer architecture and introduces the current challenges faced by computer architects. These challenges include power consumption, transistor variability, and processor heterogeneity. Students develop their research skills through a self directed research project with a final presentation and conference style writeup.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 621 [Min Grade: C]

**ECEC 631 Principles of Computer Networking 3.0 Credits**
Principles of circuit switching, packet switching and virtual circuits; protocol layering; application layer protocols for e-mail and web applications; naming and addressing; flow control and congestion avoidance with TCP; Internet Protocol (IP); routing algorithms; router architectures; multicast protocols; local area network technologies and protocols; issues in multimedia transmissions; scheduling and policing; Quality-of-Service and emerging Internet service architectures; principles of cryptography.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 632 Performance Analysis of Computer Networks 3.0 Credits**
Covers probability theory and its applications to networks, random variable and random processes; Markov chains, multi-dimensional Markov chains; M/M/1, M/M/m, M/M/m/m, M/G/1 and G/G/1 queueing systems and their applications in computer networks; analysis of networks of queues: Kleinrock Independence Approximation; Time-reversibility and Burke's theorem; Jackson's theorem; the phenomenon of long-range dependence and its implications in network design and traffic engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 631 [Min Grade: C]

**ECEC 633 Advanced Topics in Computer Networking 3.0 Credits**
perspectives in the areas of switch/router architectures, scheduling for best-effort and guaranteed services, QoS mechanisms and architectures, web protocols and applications, network interface design, optical networking, and network economics. The course also includes a research project in computer networking involving literature survey, critical analysis, and finally, an original and novel research contribution.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 631 [Min Grade: C] and ECEC 632 [Min Grade: C]

**ECEC 654 Knowledge Engineering I 3.0 Credits**
Covers conceptual modeling, including an overview of knowledge representation. Includes semantic networks, reduced semantic networks, logic of incomplete knowledge bases, extensional semantic networks, and applications of conceptual models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 655 Knowledge Engineering II 3.0 Credits**
Covers expert systems, including language and tools of knowledge engineering. Includes reasoning about reasoning, design and evaluation, heuristics in expert systems, expert systems for decision support, and expert systems in conceptual design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 654 [Min Grade: C]

**ECEC 656 Knowledge Engineering III 3.0 Credits**
Covers information-intensive systems, including information representation in autonomous systems. Includes clauses and their validation; clustering in linguistic structures; linguistic and pictorial knowledge bases; discovery in mathematics, including am; and methods of new knowledge generation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 655 [Min Grade: C]

**ECEC 661 VLSI Design 3.0 Credits**
Covers CMOS design styles, techniques, and performance; VLSI computer hardware, arithmetic units, and signal processing systems; and cat tools for layout design and simulation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 662 VLSI Array Processors I 3.0 Credits**
Covers VLSI testing, including design for testability and parallel computer architectures; signal and image processing algorithms and mapping algorithms onto array structures; and systolic array processors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 661 [Min Grade: C]

**ECEC 663 VLSI Array Processors II 3.0 Credits**
Covers wavefront array processors; matching hardware to arrays; hardware design, systems design, and fault-tolerant design; and implementations and VLSI design projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 662 [Min Grade: C]

**ECEC 671 Electronic Design Automation for VLSI Circuits I 3.0 Credits**
This course focuses on the electronic design automation problems in the design process of VLSI integrated circuits. In this first quarter of the course, algorithms, techniques and heuristics structuring the foundations of contemporary VLSI CAD tools are presented. Boolean algebra, graph theory, logic minimization and satisfiability topics are presented.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ECEC 672 Electronic Design Automation for VLSI Circuits II 3.0 Credits**
This course focuses on the electronic design automation problems in the design process of VLSI integrated circuits. In this second quarter of the course, physical VLSI design steps of technology mapping, floor planning, placement, routing and timing and presented individual and team-based small-to-medium scale programming projects are assigned.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 671 [Min Grade: C]

**ECEC 673 Deep Sub-Micron Integrated Circuit Design 3.0 Credits**
This course focuses on the design challenges of digital VLSI integrated circuits in deep sub-micron manufacturing technologies. Automation challenges and high-performance circuit design techniques such as low-power and variation-aware design are presented. The course material is delivered in a lecture format structured on recent presentations, articles, and tutorials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** ECEC 671 [Min Grade: C]

**ECEC 690 Special Topics Computer Engineering 9.0 Credits**
Covers special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 697 Research in Computer Engineering 1.0-12.0 Credit**
Research in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 699 Supervised Study in Computer Engineering 9.0 Credits**
Supervised study in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 890 Advanced Special Topics in Computer Engineering 1.0-9.0 Credit**
Covers advanced special topics of interest to students and faculty.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 891 Advanced Topics in Computer Engineering 0.5-9.0 Credits**
Advanced topics in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 898 Master's Thesis in Computer Engineering 1.0-12.0 Credit**
Master's thesis in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 997 Dissertation Research in Computer Engineering 1.0-12.0 Credit**
Graded Ph.D. dissertation in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**ECEC 998 Ph.D. Dissertation in Computer Engineering 1.0-12.0 Credit**
Ph.D. dissertation in computer engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Materials Engineering Courses

**MATE 500 Structure and Properties of Metals 3.0 Credits**
Covers crystallography, crystal defects, dislocation mechanisms, phase transformations, recovery and recrystallization, diffusional processes, and strengthening mechanisms.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 501 Structure and Properties of Polymers 3.0 Credits**
Covers step and free radical polymers, copolymerization, molecular weight characteristics, polymer morphology, thermodynamics, viscoelasticity, yielding and crazing, and Boltzmann and T-T superpositions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 502 Structure and Properties of Ceramic and Electronic Materials 3.0 Credits**
Covers bonding; crystal structure; defects; diffusion; electrical conductivity; and mechanical, electrical, dielectric, magnetic, and thermal properties.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 503 Introduction to Materials Engineering 3.0 Credits**
This course provides an introductory overview of materials science and engineering at the graduate level. The fundamental linkages between processing, structure and properties will be addressed with emphasis on micro- and nano-structural impacts on properties.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 505 Phase Equilibria 3.0 Credits**
Covers thermodynamic concepts of phase equilibria, including unary, binary, and ternary systems; pressure effects; and relationships between phase diagrams and structure.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 506 Diffusion 3.0 Credits**
Covers atomic migration in solids, self-diffusion, concentration gradients, mathematical analysis of diffusion, and applications of numerical methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 507 Kinetics 3.0 Credits**
Covers nucleation phenomena in homogeneous and heterogeneous metallic and ceramic systems, strain energy analysis, composition fluctuation analysis, growth and solution kinetics of second phases, coarsening processes, martensitic transformations, and crystallization of glass.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 510 Thermodynamics of Solids 3.0 Credits**
Covers classical thermodynamics, introduction to statistical mechanics, solution theory, thermodynamics of interfaces and crystal defects, and phase diagrams and reaction equilibrium.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 512 Introduction to Solid State Materials 3.0 Credits**
This course is a graduate level introduction to solid-state materials. The effects of crystal structure and bonding on properties will be discussed. Quantum theory of solids will be used to elucidate the electronic transport, magnetic, dielectric and optical properties of solid state materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 514 Structure, Symmetry, and Properties of Materials 3.0 Credits**
Structure–property relationships form a cornerstone for performance-engineering in nearly all materials. Condensed matter systems, including inorganic or organic materials, are defined by their internal structure— the distribution of atoms, defects, and large scale domains with preferred microstructures. This class aims to familiarize materials science students with the real space and k-space structural description of both ideal (defect free) and realistic (imperfect) crystalline materials and the properties derived from the underlying point and transitional symmetry.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 503 [Min Grade: C]

**MATE 515 Experimental Technique in Materials 3.0 Credits**
Covers electron microscopy techniques, scanning transmission and Auger analysis, x-ray diffraction, x-ray wavelength dispersive and energy dispersive analysis, thermal analysis, statistics and error analysis, and design of experiments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 525 Introduction to Composite Materials 3.0 Credits**
Covers classification and definition of composite materials; properties of fibers, matrices, and their interfaces; structural geometry of reinforcing materials; formation and testing of composites; and properties and analysis of composite materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 530 Solidification Processing I 3.0 Credits**
Covers principles of solidification processing, heat flow during solidification, thermodynamics and kinetics of nucleation and growth, solute redistribution, interfacial stability and morphology, transport phenomena: continuum treatments and structural effects, and rapid solidification.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 531 Solidification Processing II 3.0 Credits**
The technology of solidification processing is covered in this course; clean metal processing; crystal growth; squeeze casting; thixo-and compo-casting; diffusion solidification and rheocasting; continuous casting processes, VM, VAR, ESR, and VADER processing; structural control via MDH; rapid solidification processes (RSP); microgravity casting.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 535 Numerical Engineering Methods 3.0 Credits**
Covers numerical solution of non-linear equations, linear systems, and integration of ordinary differential equations. Introduces finite differences and finite elements. Provides a user's perspective of finite elements, element selection, convergence, and error estimation. Applications to heat transfer, diffusion, stress analysis, and coupled problems. Maple and ABAQUS (a commercial non-linear finite element program) are used in this course. A term project using ABAQUS is required. Emphasis is placed on materials engineering examples.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 536 Materials Seminar Series 1.0 Credit**
MSE hosts visitors from materials and materials-related academic departments, national laboratories and industry to visit and interact with students and to present a seminar. Students will interact with visitors. Lectures on other selected topics: safety and health, ethics in science & engineering research, and writing and presentation skills.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 12 times for 12 credits

**MATE 540 Polymer Morphology 3.0 Credits**
Covers crystallography, crystallization, single crystals, bulk crystallization, orientation, amorphous polymers, and experimental techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 541 Introduction to Transmission Electron Microscopy and Related Techniques 3.0 Credits**
This course covers fundamentals of electron optics, electron-specimen interaction, and transmission electron microscopy (TEM). Elastic (high resolution and in situ TEM) and inelastic scattering techniques (energy dispersive spectroscopy, electron energy loss speciroscopy) are reviewed. An introduction to scanning electron microscopy ( SEM), focused ion beam (FIB), and sample preparation is provided.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 542 Nuclear Fuel Cycle & Materials 3.0 Credits**
This course encompasses the nuclear fuel cycle, including extraction, enrichment, transmutation in a nuclear reactor, reprocessing, waste processing, repository performance, materials for nuclear reactors, mechanical and thermal performance will be discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 543 Thermal Spray Technology 3.0 Credits**
Thermal spray technology and coatings provides "solutions" to a large number of surface engineering problems - wear, corrosion, thermal degradation. This course will [i] be of interest and use to students majoring in materials, mechanical, chemical, electrical & environmental engineering; [ii] provide a thorough grounding and understanding of thermal spray processes, their principles and applications; [iii] integrate this knowledge with practical engineering applications and current industrial surfacing practice.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 544 Nanostructured Polymeric Materials 3.0 Credits**
This course is designed to address the role of polymer science in Nanotechnology. Topics that will be covered include block copolymer templated self assembly, polymer thin and thick films, LBL, self assembly, soft lithography and polymer nanocomposites.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 501 [Min Grade: C]

**MATE 545 Fracture of Polymeric Materials 3.0 Credits**
Theoretical strength; defects; brittle fracture;fracture surfaces; fracture mechanics; creep failure; fatigue failure; environmental stress cracking; composite failure; crazing; impact and high-speed failure.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 560 Powder Metallurgy I 3.0 Credits**
Covers commercial and near-commercial methods of powder making, material and process variables, atomization mechanisms, powder properties and characterization, powder compaction, and properties in the green state.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 561 Powder Metallurgy II 3.0 Credits**
Covers powder consolidation: pressing and sintering; preform forging, rolling, extrusion, and hot isostatic pressing; innovative powder processing techniques, including spray forming; and structure-property relationships in press and sinter and fully dense materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 563 Ceramics 3.0 Credits**
This course deals with the structure and bonding of ceramics. The fundamental role of point defects on electric and diffusional properties is discussed. Sintering, both solid and liquid phase, is explored. What affects strength, creep, subcritical crack growth and fatigue of ceramics is elucidated. Glasses and their properties are examined.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 565 Crystal Mechanics I 3.0 Credits**
Covers crystal plasticity, texture development, continuum aspects of dislocations, interaction and intersection of dislocations, dislocation multiplication, dislocations in crystalline solids, and dislocation boundaries and configurations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 566 Crystal Mechanics II 3.0 Credits**
Covers Peierls-Nabarro stress, thermally activated flow, work hardening, creep, superplasticity, ductile and brittle fracture, and fatigue.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 570 Materials Processing I 3.0 Credits**
Covers metal deformation processes: slab and deformation work analyses; slip line theory; and upper bound analysis applied to upsetting, drawing, extrusion, rolling, and deep drawing.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MATE 571 Materials Processing II 3.0 Credits**
Manufacture of objects from powder--atomization, compaction, sintering, and liquid phase consolidation techniques; deformation processing of powder preforms; manufacture of shapes by high-strength cold deformation-preferred orientation, substructure, strengthening mechanisms.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MATE 572 Materials for High Temperature and Energy 3.0 Credits**
This graduate level introduction to high temperature materials and materials used for energy applications, deals with metals and ceramics that are used in systems that produce or store energy, such as power generation facilities, solid oxide fuel cells, batteries, photovollaics, thermoelectric generators and supercapacitors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 573 Electronic, Magnetic and Optical Characterization of Energy Materials 3.0 Credits**
This course will examine the selection criteria for component materials in each of these applications and cover how critical properties – electronic conductivity, mobility, ionic conductivity, magnetization, optical absorption, Seebeck coefficient – are measured.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 576 Recycling of Materials 3.0 Credits**
This course will examine the selection criteria for recycling component materials. Recycling involves both reusing materials for energy applications and reprocessing materials into new products.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 580 Special Topics in Materials Engineering 0.5-9.0 Credits**
Covers selected advanced-level topics. May be repeated for credit if topics vary.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MATE 582 Materials for Energy Storage 3.0 Credits**
The course will address principles of operation of electrochemical energy storage devices and describe materials used in those devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 583 Environmental Effects on Materials 3.0 Credits**
Environmental degradation is explored with focus on electrochemical corrosion reactions in metals and alloys due to atmospheric, aqueous, chemical or elevated temperature exposure. In addition, high temperature degradation of ceramics and degradation of polymers due to exposure to heat, light and chemicals will be addressed. The role of these environmental effects during service and the impact on performance and reliability will be explored.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 585 Nanostructured Carbon Materials 3.0 Credits**
Covers advanced carbon materials ranging from diamond to fullerenes and nanotubes. Structure, properties and applications will be discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 602 Soft Materials 3.0 Credits**
This course is designed to introduce the field of Soft Materials to senior undergraduate and graduate students. Topics that will be covered include Polymers, Gels, Colloids, Amphiphiles and Liquid Crystals.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 605 Computer Simulation of Materials and Processes I 4.0 Credits**
Simulation of equilibrium and transport properties of materials by Monte Carlo and molecular dynamics methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 610 Mechanical Behavior of Solids 3.0 Credits**
Covers stress and strain, three-dimensional nomenclature, hydrostatic and deviatoric stresses, isotropic and anisotropic elasticity and plasticity, viscoelasticity, crack growth, and fracture.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 651 Advanced Polymer Processing 3.0 Credits**
Covers continuum mechanics; heat transfer; application to extrusion, calendering, coating, injection molding, film blowing, rotational molding, and fiber spinning; powder processing; design; and equipment selection.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 661 Biomedical Materials I 3.0 Credits**
This course covers biocompatibility; implantable devices; survey of materials properties; corrosion;; cardiovascular applications; orthopedic applications; kidney dialysis; artificial heart and lung devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 662 Biomedical Materials II 3.0 Credits**
This course covers phase equilibria; strengthening of materials; dental cast alloys; denture base materials; adhesives and sealants; porcelain and glasses; dental materials laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 699 Independent Study and Research 0.5-9.0 Credits**
Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MATE 702 Natural Polymers 3.0 Credits**
This course provides an introduction to natural and biomimetic polymers with an interdisciplinary view of biology, chemistry and macromolecular science. An understanding of natural building blocks and methods by which nature carries out polymer synthesis and modification reactions is coupled with insights into DNA; structural proteins; polysaccharides; and a wide variety of renewable resources.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 501 [Min Grade: C]

**MATE 897 Research 1.0-12.0 Credit**
Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is MATE or major is MSE.

**MATE 898 [WI] Master's Thesis 1.0-12.0 Credit**
Hours and credits to be arranged. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is MATE or major is MSE.

**MATE 998 Ph.D. Dissertation 1.0-12.0 Credit**
Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is MATE or major is MSE.

# Mechanical Engr Mechanics Courses

**MEM 503 Gas Turbines & Jet Propulsion 3.0 Credits**
Covers fundamentals of thermodynamics and aerothermodynamics, and application to propulsion engines; thermodynamic cycles and performance analysis of gas turbines and air-breathing propulsion systems, turbojet, turboprop, ducted fan, ramjet, and ducted rocket; theory and design of ramjets, liquid and solid rockets, air-augmented rockets, and hybrid rockets; aerodynamics of flames, including the thermodynamics and kinetics of combustion reactions; supersonic combustion technology and zero-g propulsion problems; and propulsion systems comparison and evaluation for space missions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 504 HVAC Equipment 3.0 Credits**
Covers performance of air handlers, pumps, direct expansion systems, chillers, cooling towers, and similar equipment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 505 HVAC Controls 3.0 Credits**
Covers control theory and application to heating, ventilating, air conditioning, including pneumatic, fluidic, and electronic controls.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 517 Fundamentals of Nanomanufacturing 3.0 Credits**
This course introduces conventional methods that emerged from microelectronics and nonconventional or alternative approaches as applied to fabricate nanometer-scale biological and solid-state devices; Preliminary concepts for nanofabrication; Conventional lithographic methods; Nonconventional methods such as nanoimprint lithography and chemical and biological approaches; Cell culturing for application in biology; The safe development and use of advanced nanotechnological manufacturing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (MEM 417 [Min Grade: C] and ENGR 201 [Min Grade: C] and ENGR 202 [Min Grade: C]) or PHYS 201 [Min Grade: C]

**MEM 518 Introduction to Nanoscale Metrology 3.0 Credits**
Highlights the most innovative and powerful developments in nano/microscale diagnostics; Reviews conventional and non-conventional micro- and nanofabrication, preliminary concepts for nanoscale metrology; Covers optical diagnostics for microfluidics and nanofluidics, scanning electron microscopy, transmission electron microscopy, atomic force microscopy, ionic current blockage measurement, mass spectroscopy and UV-Vis spectroscopy, and laser induced fluorescence.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 530 Aircraft Flight Dynamics & Control I 3.0 Credits**
Covers development of dynamic models, linearization, aerodynamic coefficients, control derivatives, longitudinal and lateral modes, and open-loop analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 540 Control Applications of DSP Microprocessors 3.0 Credits**
Most of the control systems today are digital and implemented using microprocessors. In this course, the students will learn how to employ the state-of-the-art DSP microprocessors to perform analog-to-digital conversion, digital-to-analog conversion, digital signal processing, decision making, and feedback control action to achieve precise regulation/ tracking, disturbance reduction, and robust stability/ performance for physical systems. In addition to lectures by the instructor, the course will feature eight hands-on lab projects centered on the design and microprocessor implementation of digital controllers for MIMO (multi-input-multi-output) electro-mechanical systems. Cross-listed with undergraduate course MEM 459.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 545 Solar Energy Fundamentals 3.0 Credits**
This course focuses on basic theories of solar radiation, solar thermal energy, and photovoltaics. Students will learn basic radiation heat transfer, solar radiation, solar thermal collection and storage, passive and active solar heating/cooling, physics of photovoltaic cells, and characteristics and types of solar cells.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 345 [Min Grade: D] or PHYS 201 [Min Grade: D]

**MEM 569 Introduction to Composite Materials I 3.0 Credits**
Introduces anisotropic elasticity, lamina stiffness and compliance, plane-stress and plane-strain, stress-strain relations of a lamina, testing methods, engineering elastic constants, failure criteria, and micromechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 570 Introduction to Composite Materials II 3.0 Credits**
Covers laminated plate theory, stiffness and compliance of laminated plates, effect of laminate configuration on elastic performance, and review of research topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 569 [Min Grade: C]

**MEM 571 Introduction to Robot Technology 3.0 Credits**
Covers robot configuration; components, actuators, and sensors; vision; and control, performance, and programming. Includes lectures and laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 572 Mechanics of Robot Manipulators 3.0 Credits**
Covers homogeneous transformation, direct and inverse kinematic manipulators, velocities and acceleration, static forces, and manipulators' dynamics, via Lagrange and Newton-Euler formulations. Includes lectures and laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 666 [Min Grade: C]

**MEM 573 Industrial Application of Robots 3.0 Credits**
Covers path planning and workspace determination, robot accuracy and repeatability measurements, robot call design, application engineering and manufacturing, material transfer, processing operations, and assembly and inspection. Includes lectures and laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 574 Introduction to CAM 3.0 Credits**
Examines the basic elements used to integrate design and manufacturing processes, including robotics, computerized-numerical controlled machines, and CAD/CAM systems. Covers manufacturability considerations when integrating unit process elements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 591 Applied Engr Analy Methods I 3.0 Credits**
Covers effective methods to analyze engineering problems. This module focuses on analytical and computational methods for problems tractable with vectors, tensors and linear algebra. Uses symbolic/numerical computational software. Examples drawn from thermal fluid sciences, mechanics and structures, systems and control, and emerging technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 592 Applied Engr Analy Methods II 3.0 Credits**
Covers effective methods to analyze engineering problems. This module focuses on computational and analytical methods for complex variables and ordinary differential equations. Uses symbolic/numerical computational software. Examples drawn from thermal fluid sciences, mechanics and structures, systems and control, and emerging technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 591 [Min Grade: C]

**MEM 593 Applied Engr Analy Methods III 3.0 Credits**
Covers effective methods to computationally and analytically solve engineering problems. This module focuses on solution methods for partial differential equations, Fourier analysis, finite element analysis and probabilistic analysis. Uses symbolic/numerical computational software. Examples drawn from mechanical and civil engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 592 [Min Grade: C]

**MEM 601 Statistical Thermodynamics I 3.0 Credits**
Covers probability theory; statistical interpretation of the laws of thermodynamics; systems of independent particles; systems of dependent particles; kinetic theory of dilute gases; quantum mechanics; energy storage and degrees of freedom; and thermochemical properties of monatomic, diatomic, and polyatomic gases.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 602 Statistical Thermodynamics II 3.0 Credits**
Covers analysis of monatomic solids, theory of liquids, chemical equilibrium, kinetic and thermochemical description of rate processes, transport phenomena, and spectroscopy.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 601 [Min Grade: C]

**MEM 603 Advanced Thermodynamics 3.0 Credits**
Covers reformulation of empirical thermodynamics in terms of basic postulates; presentation of the geometrical, mathematical interpretation of thermodynamics; Legendre transforms; requirements for chemical and phase equilibrium; first-and second-order phase transitions; Onsager reciprocal relations; and irreversible thermodynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 611 Conduction Heat Transfer 3.0 Credits**
Covers conduction of heat through solid, liquid, and gaseous media; advanced analytical methods of analysis, including integral transform and Green's functions, the use of sources and sinks, and numerical and experimental analogy methods; and variational techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 612 Convection Heat Transfer 3.0 Credits**
Covers convective heat transfer without change of phase or constitution, fundamental equations, exact solutions, application of the principle of similarity and the boundary-layer concept to convective heat transfer, similarity between heat and momentum transfer, and heat transfer in high-velocity flows.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 613 Radiation Heat Transfer 3.0 Credits**
Covers radiation heat transfer between surfaces and within materials that absorb and emit. Formulates and applies methods of analysis to problems involving radiation alone and radiation combined with conduction and convection.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 617 Introduction to Microfabrication 3.0 Credits**
This course focuses on the fundamentals of microfabrication technologies. The materials, principles, and applications of silicon-based microfabrication technologies such as photolithography, wet/dry etching, deposition techniques, surface micromachining, and polymer micromachining will be covered. This course also includes two lab sessions through which students will have a hands-on experience in microfabrication.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 619 Microfluidics and Lab-on-a-Chip 3.0 Credits**
The course explores applications of microfluidic phenomena and lab-on-a-chip technology. The topics include fluid behavior in microchannels, electrokinetic manipulation, micro-scale separation/surface sciences, transducer effects, and microactuators. Students will also have a hands-on experience through laboratory sessions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 417 [Min Grade: C] or MEM 617 [Min Grade: C]

**MEM 621 Foundations of Fluid Mechanics 3.0 Credits**
Covers kinematics and dynamics of fluid motion; Lagrangian and Eulerian description of motion; transport theorem; continuity and momentum equations (Navier-Stokes equations); vorticity vector and equation; three-dimensional, axisymmetric, and two-dimensional complex potential flows; constitutive equations of a viscous fluid; dynamic similarity; Stokes flow; and similarity analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 622 Boundry Layers-Laminar & Turbulent 3.0 Credits**
Covers laminar boundary layers; approximate integral method; three-dimensional laminar boundary layer and boundary-layer control; transient boundary-layer flows; the integral momentum equation; origins of turbulence; transition to turbulent flow; Reynolds-averaged equations; Reynolds stress; measurement of turbulent quantities; study of turbulent wall bounded flows, including pipe flow, flow over a flat plate, and flow over a rotating disk; and boundary layer in a pressure gradient.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 621 [Min Grade: C]

**MEM 630 Linear Multivariable Systems I 3.0 Credits**
State space representation, continuous time and discrete time systems, similarity transformation, invariant subspaces, state response, stability, controllability, observability, Kalman decomposition, spectral and singular value decompositions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 631 Linear Multivariable Systems II 3.0 Credits**
Pole assignment, output feedback, linear quadratic regulator, observer design, stochastic processes, state response to white noise, Kalman filter, linear quadratic Gaussian controller, evaluation of closed loop system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 632 Linear Multivariable Systems III 3.0 Credits**
Model reduction: approximation of transfer functions, modal truncations, oblique projections, component cost analysis, internal balancing; controller reduction: observer-based controller parametrization, Riccati balancing, q-COVER theory, optimal projections.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 633 Robust Control Systems I 3.0 Credits**
Covers linear spaces and linear operators; Banach and Hilbert spaces; time-domain spaces; frequency-domain spaces; singular value decomposition; EISPACK, LINPACK, and MATLAB, including internal stability; coprime factorization over the ring of polynomial matrices; matrix fraction description; properties of polynomial matrices; irreducible mfds; Smith-McMillan form; poles and zeros; canonical realizations; and computation of minimal realizations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 634 Robust Control Systems II 3.0 Credits**
Covers the structure of stabilizing controllers; coprime factorization over the ring of proper stable rational matrices; algebraic Riccati equation; state space computation of coprime factorization; yvb controller parametrization; linear fractional transformation; state space structure of proper stabilizing controllers; formulation of control problem, H, and H optimization problem; model matching problem; tracking problem; robust stabilization problem; inner-outer factorization; and Sarason's H interpolation theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 633 [Min Grade: C]

**MEM 635 Robust Control Systems III 3.0 Credits**
Covers Hankel-norm approximations, balanced realizations, two-block H optimization, generalized multivariable stability margins, structured and non-structured stability margins, structured singular values, robust stabilization and performance, and recent developments in robust control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 634 [Min Grade: C]

**MEM 636 Theory of Nonlinear Control I 3.0 Credits**
Provides a comprehensive introduction to the geometric theory of non-linear dynamical systems and feedback control. Includes stability, controllability, and observability of non-linear systems; exact linearization, decoupling, and stabilization by smooth feedback; and zero dynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 637 Theory of Nonlinear Control II 3.0 Credits**
Covers systems with parameters, including bifurcation and stability; static bifurcation; local regulation of parameter-dependent non-linear dynamics; tracking; limit cycles in feedback systems; perturbation methods; frequency domain analysis; and applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 636 [Min Grade: C]

**MEM 638 Theory of Nonlinear Control III 3.0 Credits**
Covers high gain and discontinuous feedback systems, including sliding modes, applications, and advanced topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 637 [Min Grade: C]

**MEM 639 Real Time Microcomputer Control I 3.0 Credits**
Covers discrete-time systems and the Z-transform, sampling and data reconstruction, the pulse transfer function, discrete state equations, time-domain analysis, digital simulation, stability, frequency-domain analysis, Labview programming, and data acquisition and processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 640 Real Time Microcomputer Control II 3.0 Credits**
Covers design of discrete-time controllers, sampled data transformation of analog filter, digital filters, microcomputer implementation of digital filters, Labview programming techniques, using the daq library, writing a data acquisition program, and Labview implementation of pid controllers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 639 [Min Grade: C]

**MEM 646 Fundamentals of Plasmas I 3.0 Credits**
Introduces the fundamentals of plasma science and modern industrial plasma applications in electronics, fuel conversion, environmental control, chemistry, biology, and medicine. Topics include quasi-equilibrium and non-equilibrium thermodynamics, statistics, fluid dynamics and kinetics of plasma and other modern high temperature and high energy systems and processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 647 Fundamentals of Plasmas II 3.0 Credits**
Continues the development of the engineering fundamentals of plasma discharges applied in modern industrial plasma applications in electronics, fuel conversion, environmental control, chemistry, biology, and medicine. Topics include quasi-equilibrium and non-equilibrium thermodynamics, statistics, fluid dynamics of major thermal and non-thermal plasma discharges, operating at low, moderate and atmospheric pressures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 646 [Min Grade: C]

**MEM 648 Applications of Thermal Plasmas 3.0 Credits**
Introduces applications of modern thermal plasma processes focused on synthesis of new materials, material treatment, fuel conversion, environmental control, chemistry, biology, and medicine. Topics include: thermodynamics and fluid dynamics of high temperature plasma processes, engineering organization of specific modern thermal plasma technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 649 Application of Non-Thermal Plasmas 3.0 Credits**
Application of modern non-thermal plasma processes focused on synthesis of new materials, material treatment, fuel conversion, environmental control, chemistry, biology, and medicine. Topics include: non-equilibrium thermodynamics and fluid dynamics of cold temperature plasma processes, engineering organization of specific modern non-thermal plasma technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 660 Theory of Elasticity I 3.0 Credits**
Summarizes mechanics of materials courses. Covers vector and tensor analysis, indicial notation, theory of stress, equilibrium equations, displacements and small strains, compatibility, and strain energy; formulation of the governing equations and the appropriate boundary conditions in linear elasticity, and uniqueness of the solutions; elementary three-dimensional examples and two-dimensional theory; stress functions; solutions in Cartesian and polar coordinates; and Fourier series.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 661 Theory of Elasticity II 3.0 Credits**
Covers two-dimensional problems by the method of Muskhelishvili, torsion problem, stress function and solutions by means of complex variables and conformal mapping, three-dimensional solutions for straight beams, energy theorems, virtual work and their applications, and Rayleigh-Ritz method.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 660 [Min Grade: C]

**MEM 662 Theory of Elasticity III 3.0 Credits**
Covers use of Fourier series and Green's functions for plane problems; three-dimensional problems in terms of displacement potentials; use of the Galerkin vector and the Boussinesq-Papkovitch-Neuber functions; fundamental solutions to the Kelvin, Boussinesq, Cerruti, and Mindlin problems; and elastic contact. Introduces non-linear elasticity.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 661 [Min Grade: C]

**MEM 663 Continuum Mechanics 3.0 Credits**
Covers kinematics, Eulerian, and Lagrangian formulations of deformation; theory of stress; balance principles; continuum thermodynamics; and constitutive relations in fluids and solids.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 664 Introduction to Plasticity 3.0 Credits**
Reviews stress and strain deviators, invariants and distortional energy, principal and octahedral stresses and strains, Tresca and von Mises yield criteria, yield surface and Haigh-Westergaard stress space, Lode's stress parameter, subsequent yield surface, Prandtl-Reuss relations, work hardening and strain hardening, stress-strain relations from Tresca criteria, incremental and deformation theories, the slip-line field, slip-line equations for stress, velocity equations and geometry of slip-line field, limit analysis, simple truss, bending of beams, lower and upper bound theorems, and plasticity equations in finite-element methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 660 [Min Grade: C]

**MEM 665 Time-Dependent Solid Mechanics 3.0 Credits**
Part a: Covers elastodynamics, including plane, cylindrical, and spherical waves; characteristics; the acoustic tensor; polarizations and wave speeds; transmission and reflection at plane interfaces; critical angles and surface waves; and waveguides and dispersion relationships. Part b: Covers linear viscoelasticity, including relaxation modulus and creep compliance, hereditary integrals, Laplace transform, correspondence principle, creep buckling and vibrations, viscoplasticity, creep, strain-rate effects, shear bands, and shock waves.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 660 [Min Grade: C]

**MEM 666 Advanced Dynamics I 3.0 Credits**
Covers analytical statics (principle of virtual work), Lagrange's equations, conservation laws, stability analysis by perturbation about steady state, Jacobi first integral, ignoration of coordinates, classification of constraints, solution of constrained dynamical problems by constraint embedding (elimination) or constraint adjoining (Lagrange multipliers), generalized impulse and momentum, and formulation and solution of non-holonomic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 667 Advanced Dynamics II 3.0 Credits**
Covers vector dynamics in three dimensions, including a detailed study of rotational kinematics, motion of the mass center and about the mass center for a system of particles and a rigid body, moments of inertia, three-dimensional dynamical problems, and comparison between Lagrangian techniques and the vector methods of Euler and Newton. Includes vibrations, Euler's angles, motion of a gyroscope, and motion of an axially symmetric body under no force other than its weight.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 666 [Min Grade: C]

**MEM 668 Advanced Dynamics III 3.0 Credits**
Covers central forces, effect of the earth's rotation, Foucault's pendulum, variational methods, Hamilton's principle, state space techniques for the integration of equations of motion, and numerical integration of equations of motion on microcomputers through the CSMP program. Depending on student interest, includes either Hamiltonian dynamics (canonical equations, contact transformations, Hamilton-Jacobi theory) or rigid body kinematics of complex dynamical systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 667 [Min Grade: C]

**MEM 670 Theory of Plates and Shells 3.0 Credits**
Covers elements of the classical plate theory, including analysis of circular and rectangular plates, combined lateral and direct loads, higher-order plate theories, the effects of transverse shear deformations, and rotatory inertia; matrix formulation in the derivation of general equations for shells; and membrane and bending theories for shells of revolution.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 671 Mechanical Vibrations I 3.0 Credits**
Free and forced responses of single degree of freedom linear systems; two degree of freedom systems; multiple degree of freedom systems; the eigenvalue problem; modal analysis; continuous systems; exact solutions; elements of analytical dynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 672 Mechanical Vibrations II 3.0 Credits**
Continuous systems; approximate solutions; the finite element method; nonlinear systems; geometric theory, perturbation methods; random vibrations; computational techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 673 Ultrasonics I 3.0 Credits**
Basic elements of ultrasonic nondestructive evaluation, wave analysis, transducers, transform techniques, A,B,C,M,F and Doppler imaging, medical imaging, multiple element arrays, real-time imaging, calibration.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 674 Ultrasonics II 3.0 Credits**
Basic elements of guided wave analysis, oblique incidence reflection factor, critical angle reflectivity, surface waves, lamb waves, plate waves, dispersion, phase and group velocity, experimental techniques for guided waves.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 675 Medical Robotics I 3.0 Credits**
Use of robots in surgery, safety considerations, understanding robot kinematics, analysis of surgeon performance using a robotic devices, inverse kinematics, velocity analysis, acceleration analysis, various types of surgeries case study.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 676 Medical Robotics II 3.0 Credits**
Force and movement for robot arms, robot dynamics, computer vision, vision based control, combining haptics, vision and robot dynamics in a cohesive framework for the development of a medical robotic system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 675 [Min Grade: C]

**MEM 677 Haptics for Medical Robotics 3.0 Credits**
Introduction to haptics, physiology of touch, actuators, sensors, non-portable force feedback, portable voice feedback, tactile feedback interfaces, haptic sensing and control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 678 Nondestructive Evaluation Methods 3.0 Credits**
This course covers the tools necessary for the inspection and evaluation of materials and infrastructures. Most relevant methods used for Non-Destructive Evaluation (NDE) of structural components will be discussed. Physical principles of continuum mechanics, electrical engineering, acoustics and elastic wave propagation underlying the NDE methods will be covered. Sensor data acquisition and digital signal processing will be addressed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 681 Finite Element Methods I 3.0 Credits**
Covers formulation of finite element methods for linear analysis of static and dynamic problems in solids, structures, fluid mechanics, heat transfer, and field problems; displacement-based, hybrid, and stress-based methods; variational and weighted residual approaches; effective computational procedures for solution of finite element equations in static and dynamics analyses; and pre-processing and post-processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 682 Finite Element Methods II 3.0 Credits**
Covers formulation of advanced finite element methods for non-linear analysis of static and dynamic problems in solids, structures, fluid mechanics, heat transfer, and field problems; material non-linearity; large displacement; large rotation; large strain; effective solution procedures for non-linear finite element equations in static and dynamic analyses; and effective finite element methods for eigenvalue problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 681 [Min Grade: C]

**MEM 684 Mechanics of Biological Tissues 3.0 Credits**
Covers composition and structure of tendons, ligaments, skin, and bone; bone mechanics and its application in orthopedics; viscoelasticity of soft biological tissues; models of soft biological tissues; mechanics of skeletal muscle; and muscle models and their applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 685 Mechanics of Human Joints 3.0 Credits**
Covers the structure of human joints, including experimental and analytical techniques in the study of human joint kinematics; applications to the design of artificial joints and to clinical diagnosis and treatments; stiffness characteristics of joints and their applications to joint injuries; and prosthetic design and graft replacements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 686 Mechanics of Human Motion 3.0 Credits**
Examines experimental and analytical techniques in human motion analysis and human locomotion; interdeterminacy of muscle force distribution in human motion; modeling and simulation of bipedal locomotion; energetics, stability, control, and coordination of human motion; and pathological gait.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 687 Manufacturing Processes I 3.0 Credits**
Introduces basic manufacturing process technology and the mechanical properties of metals and plastics. Covers dimensional and geometry tolerancing; surface finishing; material removal processes and machine tools; processing of polymers and reinforced plastics, including general properties of plastic materials and forming, shaping, and processing of plastics; and CNC machining and programming. Combines lectures and laboratory work.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 688 Manufacturing Processes II 3.0 Credits**
Covers processing of polymers and reinforced plastics, including general properties of plastic materials and forming, shaping, and processing of plastics; CNC machining and programming; casting processes; sheet-metal forming processes; bulk deformation processes; and computer integrated manufacturing systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 687 [Min Grade: C]

**MEM 689 Computer-Aided Manufacturing 3.0 Credits**
Covers development of software and hardware for computer-aided manufacturing systems, basic elements used to integrate the manufacturing processes, and manufacturability studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 699 Independent Study and Research 0.5-9.0 Credits**
Offers independent study and research in mechanical engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 701 Physical Gas Dynamics I 3.0 Credits**
Reviews equilibrium kinetic theory of dilute gases. Covers non-equilibrium flows of reacting mixtures of gases, flows of dissociating gases in thermodynamics equilibrium, flow with vibrational or chemical non-equilibrium, non-equilibrium kinetic theory, flow with translational non-equilibrium, and equilibrium/non-equilibrium radiation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 602 [Min Grade: C]

**MEM 705 Combustion Theory I 3.0 Credits**
Covers thermochemistry, including the relationship between heats of formation and bond energies, heat capacities and heats of reaction, chemical equilibrium and the equilibrium constant, calculation of adiabatic flame temperature and composition of burned gas, free energy and phase equilibrium, classical chemical kinetics, and chain reaction theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 706 Combustion Theory II 3.0 Credits**
Covers laminar flame propagation in premixed gases, detonation and deflagration, heterogeneous chemical reactions, burning of liquid and solid fuels, and diffusion flames.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 705 [Min Grade: C]

**MEM 707 Combustion Theory III 3.0 Credits**
Covers advanced topics in combustion, including combustion-generated air pollution, incineration of hazardous wastes, supersonic combustion, propellants and explosives, and fires.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 706 [Min Grade: C]

**MEM 711 Computational Fluid Mechanics and Heat Transfer I 3.0 Credits**
Covers classification of fluid flow and heat transfer phenomena, including time-dependent multidimensional heat conduction and finite-difference and finite-element formulations; convection and diffusion; upwind, exponential, and hybrid schemes; and boundary-layer-type fluid flow and heat transfer problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 712 Computational Fluid Mechanics and Heat Transfer II 3.0 Credits**
Covers basic computational methods for incompressible Navier-Stokes equations, including vorticity-based methods and primitive variable formulation; computational methods for compressible flows; inviscid and viscous compressible flows; finite-element methods applied to incompressible flows; and turbulent flow models and calculations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 711 [Min Grade: C]

**MEM 714 Two-Phase Flow & Heat Transfer 3.0 Credits**
Covers selected topics in two-phase flow, with emphasis on two-phase heat transfer problems, basic conservation equations for two-phase flows, nucleation, bubble dynamics, pool boiling, forced convective boiling, condensation heat transfer, two-phase flow equipment design, tube vibration and flow instability in two-phase flows, and fouling in heat transfer equipment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 717 Heat Transfer in Manufacturing 3.0 Credits**
Covers heat conduction fundamentals, including phase change problems (casting, welding, and rapid solidification processes) and cooling controls of rolling, forging, and extrusion processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 611 [Min Grade: C]

**MEM 721 Non-Newtonian Fluid Mechanics and Heat Transfer 3.0 Credits**
Covers the stress-strain rate relationship, simple flow, general constitutive and conservation equations, generalized Newtonian models, molecular theories, rheological property measurements, plane Couette flow, hydrodynamic theory of lubrication, helical flow, boundary layer flows, pipe flows, natural convection, thin film analysis, drag reduction phenomenon, and biorheology.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 622 [Min Grade: C]

**MEM 722 Hydrodynamic Stability 3.0 Credits**
Introduces stability, including discrete and continuous systems. Covers linear theory; instability of shear flows, spiral flows between concentric cylinders and spheres, thermoconductive systems, and viscous flows; global stability and non-linear theories; and time periodic and non-periodic flows, attractors, and bifurcation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 622 [Min Grade: C]

**MEM 723 Vortex Interactions and Complex Turbulent Flow 3.0 Credits**
Nonlinear vertex motion and interaction; motion of point vortices; generation and interaction of vortex rings and counter-rotating vortex pairs; vortex impulse, energy, pairing, bifurcation, and bursting; study of free and separating turbulent flows: mixing layers, wakes, jets, and buoyant plumes; recirculation behind bluff bodies and backsteps; longitudinal and lateral vortex waves and shear layers; sweeps and bursts in turbulent boundary layers; characteristics of turbulence: entrainment and molecular mixing, effects of buoyancy, rotation, acceleration, and heat release; the 3-D turbulent energy cascade and the 2-D inverse cascade.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 725 Compressible Fluid Dynamics 3.0 Credits**
Reviews one-dimensional flows. Covers steady flow of a compressible fluid; two-and three-dimensional subsonic, transonic, supersonic, and hypersonic flow; normal and oblique shock waves; wave reflections; oblique shock wave interactions and generation vorticity; compressible boundary layers; and shock boundary-layer interactions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 621 [Min Grade: C]

**MEM 727 Fluid Dynamics in Manufacturing Processes 3.0 Credits**
Covers transport of slurries, molten metals, and polymers; hydrodynamics in forming processes; resin flow model in polymer composites; shaped charge jet technology; separation and filtration; coating; lubrication; and melt-spinning process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 730 Control of Flexible Space Structures I 3.0 Credits**
Covers modeling of FSS including PDE description and finite element modeling, model errors, model reduction, component cost analysis, modal cost analysis, stability of mechanical systems, gyroscopic and non-gyroscopic systems, and rate and position feedback.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 731 Control of Flexible Space Structures II 3.0 Credits**
Covers probability theory, stochastic processes, Kalman filter, LQG compensators, controller reduction, CCA theory, balancing reductions, and applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 730 [Min Grade: C]

**MEM 733 Applied Optimal Control I 3.0 Credits**
Covers necessary conditions from calculus of variations, equality and inequality constraints, fixed and free final time problems, linear-quadratic control, bang-bang control, and application to problems in flight mechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 734 Applied Optimal Control II 3.0 Credits**
Covers neighboring extremals and the second variation, perturbation feedback control, sufficient conditions, numerical solution methods, and application to problems in flight mechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 733 [Min Grade: C]

**MEM 735 Advanced Topics in Optimal Control 3.0 Credits**
Covers singular arc control, model following control, variable structure control, singular perturbation methods, differential games, and applications.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Prerequisites:** MEM 734 [Min Grade: C]

**MEM 760 Mechanical Composite Materials I 3.0 Credits**
Covers anisotropic elastic moduli, stress-strain relations of a lamina, failure criteria of a lamina, introduction to micromechanics, laminated plate theory, residual stresses, and strength of laminates.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 660 [Min Grade: C]

**MEM 761 Mechanical Composite Materials II 3.0 Credits**
Covers anisotropic plates and shells, boundary value problem in anisotropic heterogeneous elasticity, vibrations and buckling of laminated plates, and testing methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 760 [Min Grade: C]

**MEM 762 Mechanical Composite Materials III 3.0 Credits**
Covers classical failure criteria for orthotropic materials, fracture in laminates, three-dimensional stress analysis, simulation of delamination and transverse cracks, fatigue damage, and cumulative damage models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 761 [Min Grade: C]

**MEM 770 Theory of Elastic Stability 3.0 Credits**
General stability criteria; beam column; the elastica; energy methods; torsional stability; combined torsion and flexure; lateral buckling of beams in pure bending; buckling of rings; curved bars and arches.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 777 Fracture Mechanics I 3.0 Credits**
Covers fundamental mechanics of fracture, including linear elastic crack mechanics, energetics, small-scale yielding, fully plastic crack mechanics, creep crack mechanics, fracture criteria, mixed mode fracture, stable quasi-static crack growth (fatigue crack growth and environmentally induced crack growth), toughness and toughening, and computational fracture mechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 782 Impact and Wave Propagation I 3.0 Credits**
Governing equations for elastic waves; longitudinal waves in a bar; transverse in a flexible string; flexural waves in a Bernoulli-Euler beam; flexural waves in a Timoshenko beam; Rayleigh surface waves; Pochhammer-Chree waves in circular cylinders; reflection of plane waves at a plane boundary.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 783 Impact and Wave Propagation II 3.0 Credits**
Spherical and cylindrical waves in unbounded medium; method of Laplace transform; method of characteristics; flexural waves in a Timoshenko plate; viscoelastic and viscoplastic waves; dispersion and phase velocity; natural frequency in free vibration.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 784 Impact & Wave Propagation III 3.0 Credits**
Governing equations for unsteady, nonisentropic fluid flows; shock waves; method of characteristics for nonlinear system; numerical integration along characteristics; impact and vibration of shell topics in wave propagation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 800 Special Topics Mechanical Engineering 0.5-9.0 Credits**
Covers topics of current interest to faculty and students; specific topics for each term will be announced prior to registration. May be repeated for credit if topics vary.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 891 Topics in Advanced Engineering I 2.0 Credits**
Linear systems; control theory; vibrations and eigenvalue problems; systems dynamics; Fourier transformation; flight dynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 892 Topics in Advanced Engineering II 2.0 Credits**
Separation of variables; thermodynamics; heat transfer; fluid mechanics; boundary layer theory; elasticity; finite element methods. Solid mechanics; aeroelasticity.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 893 Topics in Advanced Engineering III 2.0 Credits**
Basic probability and statistics; communication theory; sampled data system; digital and optical processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 894 Engineering Mathematics 3.0 Credits**
Application of matrices, linear algebra, and complex analysis to engineering problems. Ordinary and partial differential equations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 897 Research 1.0-12.0 Credit**
Supervised research in Mechanical Engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 898 Master's Thesis 1.0-20.0 Credit**
Master's thesis.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 998 Ph.D. Dissertation 1.0-12.0 Credit**
Ph.D. dissertation.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Master of Science in Construction Management

*Master of Science: 45.0 quarter credits*

## About the Program

The Master of Science in Construction Management program gives professionals the opportunity to develop the multidisciplinary skills required of effective construction managers. The program focuses on training professionals to meet the challenge of increasing owner demands, tighter project delivery times and increasing regulation. The program provides the leadership skills professionals need to navigate the many daily challenges construction organizations face in successfully managing construction operations.

Three concentrations are available: construction project management, real estate, and sustainability and green construction.

## Program Goals

The program is designed to increase the students' breadth and depth of knowledge in the principles and practices of construction management. The program serves as an excellent platform to develop senior management for the region's construction industry.

Graduates of the Master of Science in Construction Management program will:

- exhibit strong technical and managerial skills
- apply scientific methodologies to problem solving
- think critically
- exercise creativity and inject innovation into the process
- operate at the highest level of ethical practice
- employ principles of transformational leadership

**Concentrations**
Three concentrations are available:

***Construction Project Management***
This concentration provides the knowledge and skills required to successfully manage complex construction projects. Topics include he hard skills of project management, such as estimating and budgeting, time management, and planning. Other topics include managerial and legal aspects of construction contract administration, international construction practices,strategic planning, quality management, and productivity analysis.

***Real Estate***
In this concentration students explore the knowledge and skills required to create, maintain, and build environments for living, working and entertainment purposes. Relevant issues include project finance, real estate as investments, design and construction, operations, development law, environmental remediation, public policy, market analysis, and architecture.

***Sustainability and Green Construction***
Sustainable development means integrating the decision-making process across the project team, so that every decision is made with an eye to the greatest long-term benefits. Currently, in the Leadership in Energy and Environmental Design (LEED) green building rating system, the construction process represents a significant portion of the effort required to achieve high performance building programs.This concentration is intended to explore these concepts in detail.

For additional information, view the College of Engineering's Construction Management (http://drexel.edu/engineering/programs/undergrad/ Construction%20Management) web page.

## Admissions Requirements

Admission to the program requires:

- A bachelor's degree in construction management or engineering, or a baccalaureate business or non-technical degree.
- A completed application
- Official transcripts from all universities or colleges and other post-secondary educational institutions (including trade schools) attended. Potential students must supply transcripts regardless of the number of credits earned or the type of school attended. If a potential student does not list all post-secondary institutions on his or her application, and these are listed on transcripts received from other institutions, processing of the application will be delayed until the remaining transcripts have been submitted.
- GPA of 3.0 or higher
- Two letters of recommendation (professional or academic)
- Up-to-date resume
- 500 word essay on why the applicant wishes to pursue graduate studies in this program
- International Students must submit a TOEFL score indicating a minimum of 600 (paper exam) or 250 (CBT exam). For more information regarding international applicant requirements, view the International Students Admissions Information (http://drexel.edu/isss/ NewStudent.html) page.

Visit the Graduate Admissions (http://www.drexel.edu/grad/programs/ coe/construction-management) website for more information about requirements and deadlines, as well as instructions for applying online.

## Degree Requirements

The Master of Science in Construction Management curriculum includes a core of 5 required courses (15.0 credits), a concentration, and 6.0 credits of culminating experience. The culminating experience includes a capstone project in construction management.

**Core Foundation Courses**

| | | |
|---|---|---|
| CMGT 501 | Leadership in Construction | 3.0 |
| CMGT 505 | Construction Accounting and Financial Management | 3.0 |

| CMGT 510 | Construction Control Techniques | 3.0 |
|---|---|---|
| CMGT 512 | Cost Estimating and Bidding Strategies | 3.0 |
| CMGT 515 | Risk Management in Construction | 3.0 |
| **Concentrations** | | 15.0-24.0 |

Students pursue a concentration in one of the following areas:

**Construction Management Project Management Concentration**

| CMGT 525 | Applied Construction Project Management |
|---|---|
| CMGT 528 | Construction Contract Administration |
| CMGT 530 | Equipment Applications and Economy |
| CMGT 532 | International Construction Practices |
| CMGT 538 | Strategic Management in Construction |
| CMGT 540 | Schedule Impact Analysis |
| CMGT 548 | Quality Management and Construction Performance |
| CMGT 550 | Productivity Analysis and Improvement |

**Real Estate Concentration**

Select eight of the following:

| CMGT 535 | Community Impact Analysis |
|---|---|
| REAL 568 | Real Estate Development |
| REAL 571 | Advanced Real Estate Investment & Analysis |
| REAL 572 | Advanced Market Research & Analysis |
| REAL 573 | Sales & Marketing of Real Estate |
| REAL 574 | Real Estate Economics in Urban Markets |
| REAL 575 | Real Estate Finance |
| REAL 576 | Real Estate Valuation & Analysis |
| REAL 577 | Legal Issues in Real Estate Development |

**Sustainability and Green Construction Concentration**

| CMGT 535 | Community Impact Analysis |
|---|---|
| CMGT 545 | Sustainable Principles & Practices |
| CMGT 546 | Sustainable Technologies |
| CMGT 547 | LEED Concepts |
| CMGT 558 | Community Sustainability |
| **Culminating Experience** | | 6.0 |
| CMGT 696 | Capstone Project in Construction Management I |
| CMGT 697 | Capstone Project in Construction Management II |
| **Total Credits** | | **45.0** |

The certificate in construction management has been designed for professionals to develop the multidisciplinary skills required of effective construction managers.

Students have the option of completing this 18.0 credit certificate in construction management as a stand-alone professional development credential, or as a step toward the MS in Construction Management program.

The admissions process for this program is the same as for the MS in Construction Management.

Depending on the experience and background of individual students, a prerequisite course of CMGT 501 "Leadership in Construction" may be required, or, at the discretion of the faculty, can be waived.

**Requirements**

| CMGT 510 | Construction Control Techniques | 3.0 |
|---|---|---|
| CMGT 512 | Cost Estimating and Bidding Strategies | 3.0 |

| CMGT 515 | Risk Management in Construction | 3.0 |
|---|---|---|
| CMGT 525 | Applied Construction Project Management | 3.0 |
| CMGT 528 | Construction Contract Administration | 3.0 |
| CMGT 538 | Strategic Management in Construction | 3.0 |
| **Total Credits** | | **18.0** |

This graduate certificate seeks to produce professionals with the knowledge, skills, and perspective required to be successful in the real estate development process and the industry as a whole. Students explore the knowledge and skills required to create, maintain, and build environments for living, working and entertainment purposes.

Relevant issues include project finance, real estate as investments, design and construction, operations, development law, environmental remediation, public policy, market analysis, and architecture.

Students wising to complete this certificate in the context of a master's degree should consider the MS in Construction Management with a concentration in Real Estate.

**Requirements**

| REAL 568 | Real Estate Development | 3.0 |
|---|---|---|
| REAL 571 | Advanced Real Estate Investment & Analysis | 3.0 |
| REAL 572 | Advanced Market Research & Analysis | 3.0 |
| REAL 575 | Real Estate Finance | 3.0 |
| REAL 577 | Legal Issues in Real Estate Development | 3.0 |
| Select one of the following: | | 3.0 |
| REAL 573 | Sales & Marketing of Real Estate | |
| REAL 574 | Real Estate Economics in Urban Markets | |
| REAL 576 | Real Estate Valuation & Analysis | |
| **Total Credits** | | **18.0** |

The architectural, engineering, and construction community faces the daunting task of providing a built environment which is in harmony with the natural environment—meeting the current needs of society without jeopardizing the ability of future generations to meet their needs. Sustainable development means integrating the decision-making process across the project team, so that every decision is made with an eye to the greatest long-term benefits.

The certificate in Sustainability and Green Construction is a flexible, part-time post-baccalaureate program, focused on the sustainable aspects of the construction process. Students have the opportunity to complete all requirements within one and a half years.

Currently, in the Leadership in Energy and Environmental Design (LEED) green building rating system, the construction process represents a significant portion of the effort required to achieve high performance building programs.This certificate program is intended to explore these concepts in detail. Credits from this certificate will transfer toward a Masters of Science in Construction Management .

**Requirements**

| CMGT 535 | Community Impact Analysis | 3.0 |
|---|---|---|
| CMGT 545 | Sustainable Principles & Practices | 3.0 |
| CMGT 546 | Sustainable Technologies | 3.0 |
| CMGT 547 | LEED Concepts | 3.0 |
| CMGT 558 | Community Sustainability | 3.0 |
| **Total Credits** | | **15.0** |

# Construction Management Faculty

Jeffrey Beard, PHD, MGTPRO *(Georgia Institute of Technology)*. Associate Clinical Professor. Project delivery methodologies; Systems decomposition for civil and industrial projects; Service Life Predictors for the Built Environment and its Components; Design and Construction Entrepreneurship; History of Urban Engineering and ConstructionHistory of Urban Engineering and Construction.

Douglas Carney, MBA, AIA, LEED, AP *(Eastern University)*. Assistant Clinical Professor. Architecture; Contract management; Master planning; Site analysis; Feasibility and zoning studies; Space needs and program development.

Charles Cook, PhD *(New York University)*. Assistant Clinical Professor. Construction management; project management; leadership and teambuilding; oral and written communication.

Edward Keeter, PhD *(Texas A&M University)*. Associate Clinical Professor. Integrated project management; Construction risk management; Construction management; Management of field operations.

Robert Muir, PhD, PE *(Drexel University) Program Director*. Associate Clinical Professor. Construction management; value engineering; management of field operations; planning and scheduling; project management; heavy and industrial construction.

Richard Sievert, PhD, PMP, CFM *(Northwestern University)*. Assistant Clinical Professor. Project management and construction management; value engineering; cost reduction and waste minimization; facilities planning and management; marketing and selling professional services; quality management, engineering and construction business administration.

## Courses

**CMGT 501 Leadership in Construction 3.0 Credits**
This course is intended to introduce students to value-based, effective leadership principles and practices across the construction industry. Topics include prevailing theory, leadership traits & styles, emotional intelligence, motivation, collaborative environs and alliances, and change.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 505 Construction Accounting and Financial Management 3.0 Credits**
This course presents the principles of accounting for construction projects. Topics include techniques of cost accounting and financial analysis employed by the construction practitioners. Specific topics include accounting principles to track and manage labor, material, equipment, overhead and other construction resources. Topics specific to construction include contract revenue, financial reporting, and tax considerations for conductors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 510 Construction Control Techniques 3.0 Credits**
This course addresses the knowledge and skill sets required to successfully plan and control complex construction projects. Topics include procurement and contracts, pre-bid planning, contract budgets and cash flow, and planning case studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 512 Cost Estimating and Bidding Strategies 3.0 Credits**
This is an advanced course in construction estimating addressing competitive bidding strategies. Topics include profit objectives, analyzing the competition, and determining optimum combo of price, cost and volume.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 515 Risk Management in Construction 3.0 Credits**
This course presents risk management techniques and practices specific to construction projects. Students will gain an understanding of the risks stemming from technical and business sources related to the construction process, and to identify, quantify, and develop the appropriate response strategies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 525 Applied Construction Project Management 3.0 Credits**
This course presents the knowledge and skills required to successfully manage complex construction projects. Topics include the project management hard skills such as estimating and budgeting, time management, and planning.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CMGT 501 [Min Grade: C]

**CMGT 528 Construction Contract Administration 3.0 Credits**
This course introduces the managerial and legal aspects of construction contract administration. The student is introduced to basic concepts of contract law employed in construction and the rules of interpretation. Topics include changes and change orders, disputes, differing site conditions, and defective documents.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 530 Equipment Applications and Economy 3.0 Credits**
This course provides an in-depth treatment of heavy construction equipment applications and covers the associated management practices. The application topics include techniques used to analyze and estimate equipment productivity, equipment selection, and optimization. The course includes a strong emphasis in equipment economics including owning and operating costs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 532 International Construction Practices 3.0 Credits**
This course provides an introduction to the strategic issues relating to the business of construction on a global scale. The course is intended to provide students with the knowledge of current best practices by construction organizations in America, Europe and Asia.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 535 Community Impact Analysis 3.0 Credits**
This course provides an overview of community impact assessment, including the benefits of conducting such an assessment. It also provides general guidelines for conducting a community impact assessment, including types of impacts that should be addressed during the process and related issues.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 538 Strategic Management in Construction 3.0 Credits**
This course presents concepts in strategic management within construction organizations. Topics include clients/constructors/competencies, portfolio management, and marketing strategies for construction firms.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 540 Schedule Impact Analysis 3.0 Credits**
This is an advanced course that deals with the legal aspects of construction schedules. Topics include time impact analysis, applying CPM techniques to contract claims, and calculating delay damages.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CMGT 510 [Min Grade: C]

**CMGT 545 Sustainable Principles & Practices 3.0 Credits**
This course addresses the fundamentals of green building concepts and practices underlying sustainable construction from the perspective of the LEED Green Building rating system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 546 Sustainable Technologies 3.0 Credits**
This course addresses sustainable technologies in the built environment and is presented as a whole building design system. The course is organized into three major categories-Design Guidance, Project Management, and Operations & Maintenance.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 547 LEED Concepts 3.0 Credits**
This course addresses the fundamental concepts and practices underlying the LEED green building rating system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 548 Quality Management and Construction Performance 3.0 Credits**
This course covers quality management of construction processes. Topics include designing and implementing quality management plans, establishing a quality management system and Information technology in quality management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CMGT 501 [Min Grade: C]

**CMGT 550 Productivity Analysis and Improvement 3.0 Credits**
The focus of this course is construction productivity measurement and improvement. Topics include roles of the individual stakeholders, quantifying labor and equipment productivity, and techniques to improve job site productivity.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 558 Community Sustainability 3.0 Credits**
This course provides clear direction to students how to design cities and developments that are sustainable and reduce environmental harm.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 696 Capstone Project in Construction Management I 3.0 Credits**
The capstone project is completed independently over two quarters under the direction of full-time Construction Management faculty and is intended to reinforce the knowledge and skills acquired through graduate study.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**CMGT 697 Capstone Project in Construction Management II 3.0 Credits**
The capstone project is completed independently over two quarters under the direction of full-time Construction Management faculty and is intended to reinforce the knowledge and skills acquired through graduate study.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** CMGT 696 [Min Grade: C]

# Master of Science in Engineering Technology

## About the Program

*Master of Science 45.0 quarter credits*
The Master of Science in Engineering Technology offers courses focused on the technologies used in today's modern emerging industries. The program is designed to provide specialized engineering technology education to those who currently hold an accredited baccalaureate degree in engineering technology or a related field. The flexibility of the program permits students to select a combination of courses relevant to their individual career goals or to provide the foundation for further advanced study. Courses will be delivered in several modes; face-to-face, on-line, or real-time videoconferencing.

The primary goal of the Master of Science in Engineering Technology is to develop advanced-level practitioners in resolving technical problems through the application of engineering principles and technology.

The program can be pursued in either a full- or part-time basis and permits students to select a combination of courses relevant to individual career goals in technology**.** The program is also designed to provide the foundation for further advanced study and allows practicing professionals the opportunity to update knowledge and skills based on the latest technological developments in the industrial environment and therefore advance in their chosen careers.

## Program Goals

Graduates of the Master of Science in Engineering Technology will be expected to:

- Apply scientific and technological concepts to solving technological problems.
- Apply concepts and skills developed in a variety of technical and professional disciplines including computer applications and networking, materials properties and production processes, and quality control to improve production processes and techniques.
- Plan, facilitate, and integrate technology and problem solving techniques in the leadership functions of the industrial enterprise system.
- Engage in applied technical research in order to add to the knowledge of the discipline and to solve problems in an industrial environment.
- Apply theories, concepts, and principles of related disciplines to develop the communication skills required for technical-managers.

For additional information, view the College of Engineering's Engineering Technology program (http://drexel.edu/engtech) web page.

## Admission Requirements

Applicants must have a 3.0 grade point average in their undergraduate or upper division (junior and senior year) coursework.

International students who have their undergraduate degree from a country whose language is not English can be admitted with a Test of English as a Foreign Language (TOEFL) test score of 550 or better. For more information regarding international applicant requirements, view the International Students Admissions Information (http://drexel.edu/isss/NewStudent.html) page.

In addition to the general Drexel graduate admission requirements, applicants must provide a preliminary proposal of their intended plan of study, which should include a general set of objectives, an outline of the courses to be taken, and identification of a master's project topic to be pursued.

### Prerequisite courses
The following prerequisite courses must be completed at the undergraduate level with a minimum grade of C:

- Calculus 1
- Calculus 2
- Physics 1 (algebra-based)
- Physics 2 (algebra-based)
- DC/AC Circuit Analysis
- Digital Electronics
- Industrial Materials
- Statistics

Visit the Graduate Admissions (http://www.drexel.edu/grad/programs/coe/engineering-technology) website for more information about requirements and deadlines, as well as instructions for applying online.

## Degree Requirements

Candidates for the MS in Engineering Technology must complete a minimum of 45.0 quarter credits. A minimum grade of B is required in all core courses and no more than two C grades in electives.

Of the 45.0 quarter credits required for the degree, 30.0 must be earned at Drexel University, including 24.0 credits of Engineering Technology (ET) courses. A maximum of 15.0 transfer credits may be allowed for graduate courses taken at other institutions, if they are appropriate to the student's plan of study.

| Core Courses | | |
|---|---|---|
| ET 605 | Materials for Emerging Technologies | 3.0 |
| ET 610 | Networks for Industrial Environments | 3.0 |
| ET 615 | Rapid Prototyping and Product Design | 3.0 |
| ET 619 | Programmable Devices and Systems | 3.0 |
| ET 620 | Microsystems and Microfabrication | 3.0 |
| ET 725 | Sensors and Measurement Systems | 3.0 |
| ET 732 | Modern Energy Conversion Technologies | 3.0 |
| PRST 503 | Ethics for Professionals | 3.0 |
| PRST 504 | Research Methods & Statistics | 3.0 |
| **Electives** | | 9.0 |
| Select three of the following: | | |
| ET 635 | Engineering Quality Methods | |
| ET 675 | Reliability Engineering | |
| ET 730 | Lean Manufacturing Principles | |
| ET 755 | Sustainable and Green Manufacturing | |
| PROJ 501 | Introduction to Project Management | |
| PRST 512 | Computing for Professionals | |
| **Capstone Course** | | 9.0 |
| ET 775 | Master's Project and Thesis in Engineering Technology (3-credit course, taken 3 times.) | |
| **Total Credits** | | **45.0** |

## Engineering Technology Faculty

Richard Chiou, PhD *(Georgia Institute of Technology)*. Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Yalcin Ertekin, PhD *(University of Missouri-Rolla)*. Associate Clinical Professor. High speed machining with micromachining applications, machining process optimization and condition monitoring using multiple sensors, FEA simulation with 3D solid modeling applications, rapid prototyping and reverse engineering, quality and reliability improvement through statistically designed experiments, neural networks and data mining and Taguchi methods, CNC machine tool calibration characterization of cold fastening, clinching and self-pierced riveting processes, non-invasive surgical tool design, student learning enhancement using online simulation tools.

Vladimir Genis, PhD *(Kiev State University, Ukraine) Department Head, Engineering Technology*. Professor. Ultrasound wave propagation and scattering, ultrasound imaging, electronic instrumentation, piezoelectric transducers, and engineering education. Designed and developed diagnostic and therapeutic equipment for medical applications and electronic systems and techniques for defense-related and industrial applications.

Irina Ciobanescu Husanu, PhD *(Drexel University)*. Assistant Professor. Microgravity combustion, thermal-fluid science with applications in micro-combustion, fuel cells and research of alternative and green fuels, energy conversion and renewable energy, industrial experience in aerospace engineering areas (theoretical analysis, numerical simulations and

experimental investigations), design and testing of propulsion systems, mechanical instrumentation, and developing industrial applications of aircraft engines.

Michael Mauk, PhD, PE *(University of Delaware).* Assistant Clinical Professor. Rapid prototyping, microfluidics, alternative energy including solar energy and photovoltaics, semiconductor materials science, nanotechnology.

Warren Rosen, PhD *(Temple University).* Assistant Clinical Professor. Computer networks; optical networks; high-performance switching; lightweight protocols.

# Courses

**ET 605 Materials for Emerging Technologies 3.0 Credits**
General properties of metals, ceramics and polymers are presented. Focus shifts to technologies - photo and fuel cells in the energy industry. Topic include: the chemical process that converts fuel to elec,tricity directly, light energy that converts to electrical energy, band model for optical materials, and materials for the optical and electronic industries.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 610 Networks for Industrial Environments 3.0 Credits**
An in-depth review of high-performance wired and wireless networks for industrial control, communications, and computing. The emphasis is on understanding current and newly emerging network architectures, protocols and technologies from the point of view of performance, reliability, and cost. Industry standard modeling and simulation tools are also reviewed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 615 Rapid Prototyping and Product Design 3.0 Credits**
This course will introduce concepts and methods for rapid prototyping, including their technical basis, and unified principles common to almost all rapid prototyping technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 619 Programmable Devices and Systems 3.0 Credits**
A review of programmable devices and systems for industrial and embedded applications. Field-Programmable Gate Arrays, microcontrollers, and Programmable Logic Controllers are compared with respect to suitability, performance, and cost in industrial and embedded environments. Industry standard modeling and development tools will be introduced and used to predict performance and reliability.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 620 Microsystems and Microfabrication 3.0 Credits**
Microsystems and microfabrication covers the principles of design, structure, and operation, as well as fabrication technologies for microsystems including microelectronics, sensors, MEMS, micro-optics, and microfluidics (lab-on-a-chip).
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 635 Engineering Quality Methods 3.0 Credits**
Six Sigma concepts and methods are covered with emphasis on its framework, statistical tools and practical implementations. Students will gain a working knowledge of Six Sigma approaches and techniques for applications to both manufacturing and services.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 675 Reliability Engineering 3.0 Credits**
This course will introduce the foundations and applications of reliability engineering including basic probability models for component and system failure, with emphasis on practical applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 725 Sensors and Measurement Systems 3.0 Credits**
This course provides a foundation in sensors and measurement systems including data acquisition for quality control. It covers general concepts, measuring devices, and the manipulation, transmission and recording of data.expanded coverage of sensors, and the use of computer tools in measurement & data acquisition for quality control. Measurement techniques related to micro- and nano-technologies are also discussed, reflecting the growing importance of these technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 730 Lean Manufacturing Principles 3.0 Credits**
Lean is a generic process management philosophy, developed initially for manufacturing and derived mainly from the Toyota Production System (TPS), Just-in-Time (JIT) operations theory, and earlier sources dating from the work of Taylor, Ford, and others or work methods, mass production, and automation. Lean is an integral part of today's modern manufacturing enterprises.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 732 Modern Energy Conversion Technologies 3.0 Credits**
This course introduces new energy conversion technologies, with an emphasis on solid-state devices, distributed systems with storage, and alternative energy sources including solar, waste heat, wind, biomass, and hydrogen. Solid-state energy conversion devices including solar cells, thermoelectrics, thermionics, thermophotovoltaics and light-emitting diodes, as well as solid-state refrigerators, will be described and analyzed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 755 Sustainable and Green Manufacturing 3.0 Credits**
This course covers environmental considerations in engineering product and process design, reduction of environmental impact by design, recycling, material selection, demanufacturing and remanufacturing and trade-offs.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**ET 775 Master's Project and Thesis in Engineering Technology 3.0 Credits**

Involves the study and investigation of a research or development topic in the area of the student's interest. Requires the topic and solution to be reported in a thesis under the direction of a faculty advisor. Can be repeated for credit.

**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 3 times for 9 credits

# Master of Science in Project Management

*Master of Science 45.0 quarter credits*

## About the Program

The Master of Science in Project Management, a part-time online program, is designed to equip professionals with the fundamental competencies expected of project managers in virtually any field. The course content is mapped to the internationally recognized Project Management Institute's A Guide to the Project Management Body of Knowledge (PMBOK® Guide).

Modern project management is a field that began in the 1950s in the defense industry. In the 1980s, the field gained critical mass in a broad range of industries, including, but not limited to building/construction, IT/systems development, defense, engineering, film and video, financial services, healthcare, and government contracting. Most work environments today are "projectized." Organizations are using project management concepts, tools, and techniques to achieve their objectives and gain a competitive advantage.

For additional information, visit the Master of Science in Project Management (http://drexel.edu/projmgt) page.

## Admission Requirements

### Recommended Prerequisites

The following undergraduate courses or their equivalent are recommended:

- Financial Accounting Foundations
- Introduction to Finance
- Organizational Behavior
- Introduction to Business Statistics

### Admission Requirements

- Completed Application Form
- Bachelor's degree from a regionally accredited institution
- Undergraduate GPA of 3.0 or higher (graduate degree GPAs will be considered along with the undergraduate GPA). Applicants with a cumulative GPA below 3.0 may be considered.
- Official transcripts from all universities or colleges and other post-secondary educational institutions (including trade schools) attended. Instead of hard copy transcripts, you may email official electronic transcripts issued by a post-secondary institution directly to Drexel University Online (customerservice@drexel.com) . All transcripts must be supplied, regardless of the number of credits earned or the type of school attended. If all post-secondary institutions are not listed on the application, and then listed on transcripts received from other institutions, application processing will be delayed until the remaining transcripts are submitted. Use Drexel's Transcript Lookup Tool (http://www.drexel.com/tools/transcript.aspx) to assist you in contacting your previous institutions.

- Two letters of recommendation, professional or academic. Drexel University Online now accepts electronic letters of recommendation (http://www.drexel.edu/apply/recommend) . If a recommender prefers to submit an original, hard copy letter of recommendation, please remind the recommender that it must be signed and submitted in a sealed envelope signed across the flap by the recommender.
- Personal Essay, between 500-750 words, describing your interest in the program. Specifically, discuss the following:
  - How the program relates to your previous educational activities
  - If changing course, why are you moving in a new direction with your educational goals
  - How the program relates to your current line of work
  - How you plan to apply the program to your future goals
- Resume
- International Students must submit a TOEFL score of 550 or higher. For more information regarding international applicant requirements, view the International Students Admissions Information (http://drexel.edu/isss/NewStudent.html) page.
- An interview may be requested.

Visit the Graduate Admissions (http://www.drexel.edu/grad) website for more information about requirements and deadlines, as well as instructions for applying online.

## Degree Requirements

The Master of Science in Project Management requires completion of 45 credit hours (quarter) of study. The curriculum includes a core of 10 required courses (30 credits), a culminating capstone project experience integrating the knowledge and skills acquired during the program (PROJ 695 (https://nextcatalog.drexel.edu/graduate/schooloftechnologyandprofessionalstudies/projectmanagement) , 3.0 credits) and 12.0 credits of electives.

**Electives**
Students may use electives to increase project management, creativity, communication, or leadership skills or to develop areas of specialization. Any appropriate graduate course offered in the University can serve as an elective if the student has sufficient background to take the course. In addition, the program will offer its own elective courses including special topics (PROJ 690 (https://nextcatalog.drexel.edu/graduate/schooloftechnologyandprofessionalstudies/projectmanagement) ). Qualified students may also pursue independent study (PROJ 699 (https://nextcatalog.drexel.edu/graduate/schooloftechnologyandprofessionalstudies/projectmanagement) ) for elective credit in special cases.

**Curriculum**

| Core Courses | | |
|---|---|---|
| PROJ 501 | Introduction to Project Management | 3.0 |
| PROJ 502 | Project Planning & Scheduling | 3.0 |
| PROJ 510 | Project Quality Management | 3.0 |
| PROJ 515 | Project Estimation & Cost Management | 3.0 |
| PROJ 520 | Project Risk Assessment & Management | 3.0 |
| PROJ 530 | Managing Multiple Projects | 3.0 |
| PROJ 535 | International Project Management | 3.0 |

| PROJ 540 | Project Procurement Management | 3.0 |
| PROJ 603 | Project Leadership & Teamwork | 3.0 |
| PROJ 645 | Project Management Tools | 3.0 |
| **Free Electives** | | 12.0 |
| **Capstone Project** | | |
| PROJ 695 | Capstone Project in Project Management | 3.0 |
| **Total Credits** | | **45.0** |

# Project Management Faculty

Frank T. Anbari, PhD, PE, PMP *(Drexel University) Director of Project Management program.* Clinical Professor. Transportation engineering; project scheduling; project cost management; earned value management; project quality management; project leadership; project management education; Six Sigma.

Victor Sohmen, PhD *(University of Queensland) Project Management Program.* Associate Clinical Professor. Extensive international experience in teaching, research, publication, and practice in diverse areas of: general management; project management; cost engineering; pedagogy; curriculum development; distance learning technology; research methodology; cross-cultural studies; and international business.

# Interdepartmental Faculty

John Via, EngD *(Southern Methodist University) Director, Systems Engineering Program.* Teaching Professor. Head, Engineering Management; Associate Dean, Online Engineering Programs

# Courses

**PROJ 501 Introduction to Project Management 3.0 Credits**
This course will prepare students to manage scheduling, supply management, project team recruiting, resource allocation, time/cost tradeoffs, risk assessment, task coordination, team-building, progress monitoring, and post-project assessment through a comprehensive overview of project management. Case studies are used to illustrate the principles and tools of project management as a process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PROJ 502 Project Planning & Scheduling 3.0 Credits**
This course will prepare students to master concepts in project planning, scheduling and control. Project scheduling methods are covered including: critical path systems, critical chain scheduling, statistical analysis, Program Evaluation Review Technique, linear resource leveling, and legal ramifications on contracted projects.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 510 Project Quality Management 3.0 Credits**
Quality management is related to project management. Examines basic quality concepts and explores the three sub-processes of quality management: quality planning, quality assurance, and quality control as they relate to project management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 515 Project Estimation & Cost Management 3.0 Credits**
This course will provide an overview of project financial and economic principles involved in product and system development. It is intended to familiarize project managers with methods in project accounting, budgeting, cost estimation, financial management, design optimization, and economics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 520 Project Risk Assessment & Management 3.0 Credits**
Examines the risk factors throughout every phase of a project. Looks at the overall project planning process, explores the use of high-level risk assessment tools, and describes key ideas for project risk planning. Models for risk analysis, assessment, and classification are presented.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 525 E-Tools for Project Management 3.0 Credits**
This course will examine the use of electronic tools as a means of creating a virtual workplace. Issues related to the use of the e-tools for collaboration and decision making for project management will be explored.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 530 Managing Multiple Projects 3.0 Credits**
Examines the complex and simultaneous management principles and techniques required to manage multiple projects. Emphasis is placed on a theory and practice of project management that is rigorous and disciplined, yet flexible.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 535 International Project Management 3.0 Credits**
Examines the uniqueness and adaptations of project management when operating in an international context. Details the investigation of cultural, legal, and regulatory environments as the context of international project management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 540 Project Procurement Management 3.0 Credits**
Examines role of procurement in project management including processes and activities needed to acquire products, services and results required to accomplish a project from outside the project organization. Planning, conducting administering and closing procurements are course components as are relevant legal and ethical issues, contract capacity, authority, public and private bidding processes and dispute resolution methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 603 Project Leadership & Teamwork 3.0 Credits**
Examines project leadership skills required for building and maintaining successful, high-performance project teams. Prepares project managers to facilitate teamwork through good management and wise leadership.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 645 Project Management Tools 3.0 Credits**
Examines theories relating to project management software acceptance, use of project management tools, and how tools relate to project success. Develops in-depth skills in a widely-used project management software package, and provides exposure to other selected project management tools for successful collaboration in collocated and virtual project teams.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if program is MS.
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 650 Project Stakeholder Management 3.0 Credits**
Examines theories and processes required to identify the individuals, groups, organizations, and other stakeholders that could impact or be impacted by a project. Also covers analyzing stakeholder expectations and their influence on the project, and developing strategies for engaging project stakeholders in effective project decisions to ensure successful project outcomes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Restrictions:** Can enroll if program is MS.
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 690 Special Topics in Project Management 0.5-12.0 Credits**
Provides courses in topics of current interest to faculty and students. Topic for study must be approved in advance of registration by the program advisor, the supervising faculty, and the associate dean. May be repeated for credit if topic varies.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Prerequisites:** PROJ 501 [Min Grade: C]

**PROJ 695 Capstone Project in Project Management 3.0 Credits**
Provides an opportunity for the student to successfully integrate knowledge and skills acquired during their master's program in project management. Students will evaluate the project management practices in an organization and create a report that identifies strengths and weaknesses in an organization and recommend strategies for improvement.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PROJ 502 [Min Grade: C] and PROJ 510 [Min Grade: C] and PROJ 515 [Min Grade: C] and PROJ 520 [Min Grade: C] and PROJ 525 [Min Grade: C] and PROJ 530 [Min Grade: C] and PROJ 535 [Min Grade: C] and PROJ 603 [Min Grade: C]

**PROJ 699 Independent Study in Project Management 1.0-9.0 Credit**
Provides individual study or research in project management under faculty supervision. Course may be repeated for credit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 9 times for 9 credits
**Prerequisites:** PROJ 501 [Min Grade: C]

# Master of Science in Property Management

*Master of Science: 45.0 quarter credits*

## About the Program

The only online program of its kind in the nation, Drexel's Master of Science in Property Management provides an education forum for professionals who are challenged with tightening markets; pipelines of new development; doing more with less; increased owner demands; evolving environmental laws; and optimum decision-making for maximum property performance. The rigorous curriculum is designed to challenge and engage students. Students have access to courses anytime, anywhere.

The Master of Science in Property Management is a part-time program with a structured plan of study. Students complete core foundation courses and select elective courses that align with their personal interests and professional goals. The curriculum stresses strategic decision-making and critical thinking through research and analysis. Students review best practice cases and discuss the latest industry strategies and benchmarks. All students participate in a culminating project which focuses on current issues and trends.

For additional information, visit the Master of Science in Property Management (http://www.drexel.edu/engmgmt/propmgt/academics/ms) page.

## Admission Requirements

- Completed application
- Current resume or CV
- Bachelor's degree from a regionally accredited institution
- Undergraduate GPA of 3.0 or higher out of a 4.0 scale. Graduate degree GPAs will be considered along with the undergraduate GPA. Applicants with a cumulative GPA below 3.0 with extensive related experience and current industry credentials (e.g. CPM$^{®}$) may be considered.
- Official transcripts from all universities or colleges and other post-secondary educational institutions attended. Instead of hard copy transcripts, you may email official electronic transcripts issued by a post-secondary institution directly to Drexel University Online (customerservice@drexel.com) . All transcripts must be supplied, regardless of the number of credits earned or the type of school attended. If all post-secondary institutions are not listed on the application, and then listed on transcripts received from other institutions, application processing will be delayed until the remaining transcripts are submitted. Use Drexel's Transcript Lookup Tool (http://www.drexel.com/tools/transcript.aspx) to assist you in contacting your previous institutions.
- Two letters of recommendation, professional or academic. Drexel University Online now accepts electronic letters of recommendation (http://www.drexel.edu/apply/recommend) . If a recommender prefers to submit an original, hard copy letter of recommendation, please remind the recommender that it must be signed and submitted in a sealed envelope signed across the flap by the recommender.
- An essay of at least 1,000 words describing your interest in the program. Your essay should include discussion of the following:
  - The degree's connection to your Bachelor's degree and/or other graduate coursework

- The extent your past experiences (personal and professional) will enhance your classroom engagement, complement your coursework, and strengthen your performance
  - The program's relationship to current employment and potential for career growth
  - Your plan to apply the degree to future goals
  - If this is a change to your academic plans and/or career, explain the catalyst and your expectations
- International students must submit a TOEFL score indicating a minimum of 600 (paper exam) or 250 (CBT exam). For more information regarding international applicant requirements, view the International Students Admissions Information (http://drexel.edu/isss/NewStudent.html) page.
- An interview may be requested

Visit the MS in Property Management Online Application (http://www.drexel.com/online-degrees/business-degrees/ms-property-management/apply.aspx) page for more information about requirements and deadlines, as well as instructions for applying online.

# Degree Requirements

### Core Courses

| | | |
|---|---|---|
| CMGT 535 | Community Impact Analysis | 3.0 |
| PRMT 602 | Residential Property Marketing | 3.0 |
| PRMT 603 | Property Asset Management | 3.0 |
| PRMT 610 | Facilities Management | 3.0 |
| PRMT 625 | Property Financial Analysis & Strategies | 3.0 |
| PRMT 630 | Rental Property Law | 3.0 |
| PRMT 640 | Property Security Emergency & Risk Management | 3.0 |
| PRMT 645 | Property Management Technology Strategies | 3.0 |
| PRST 504 | Research Methods & Statistics | 3.0 |
| REAL 568 | Real Estate Development | 3.0 |
| REAL 572 | Advanced Market Research & Analysis | 3.0 |

### Electives

| | | |
|---|---|---|
| Select two of the following: | | 6.0 |
| PRMT 650 | Retail Property Marketing & Management | |
| PRMT 655 | Affordable Housing Management | |
| PRMT 660 | Student Housing Marketing & Management | |
| PRMT 665 | Military Housing Marketing & Management | |
| PRMT 670 | Housing for Later Life | |
| PRMT 675 | Commercial Property Management | |
| PRMT 680 | Special Topics in PRMT | |
| REAL 574 | Real Estate Economics in Urban Markets | |

### Culminating Experience

| | | |
|---|---|---|
| PRMT 695 | Capstone in Property Management I | 3.0 |
| PRMT 696 | Capstone in Property Management II | 3.0 |
| **Total Credits** | | **45.0** |

# Property Management Faculty

Kimberly Mitchell, PhD *(Virginia Polytechnic Institute and State University) Director, Property Management Program.* Associate Teaching Professor. Multi-family real estate operations, sustainability, affordability, and policy; asset management; real estate development.

# Courses

**PRMT 602 Residential Property Marketing 3.0 Credits**
This course covers strategies to successfully market residential properties. Discussions include acquiring and retaining tenants, motivating renters, packaging amenities, selling techniques, advertising media, and online marketing. Students will review best practices advertising campaigns and analyze marketing plans from regional residential housing developments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 603 Property Asset Management 3.0 Credits**
This course focuses on increasing property values by creating strategies to maximize return by providing excellent customer service, designing systems to provide utilities in an effective manner, creating value-added services to enhance the tenants' experiences, and managing the day-to-day operations of properties effectively.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 610 Facilities Management 3.0 Credits**
This course focuses on the strategic role property managers play in facilities management. Property managers must be aware of all operational issues and are active participants in making strategic facilities decisions including in-house or outsourcing services, service specifications, managing service providers, and creative method of addressing sustainable development issues.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 625 Property Financial Analysis & Strategies 3.0 Credits**
This course focuses on the importance of financial analysis to the strategic decision-making process employed by property managers including cash flow, tax implications, and risks of various projects. Decision-making models, lease valuation, and sensitivity analysis are employed in real situation. Current marketing conditions are discussed including alternative financing choices, cost of funds, tax incentive development options, and capitalization rates.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 630 Rental Property Law 3.0 Credits**
The focus of this course is the legal framework within which a property manager makes strategic decisions. Lease provisions for a variety of property types are analyzed and a significant portion of the course deals with Fair Housing Law, the Americans with Disabilities Act, HUD regulations, and state housing statutes. Strategies to reduce legal exposure are discussed. The course features major cases.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 640 Property Security Emergency & Risk Management 3.0 Credits**
This course focuses on risk aversion strategies employed by property managers to protect tenants, employees, community members, and owners. The course includes analysis of best practice strategies featuring property developments with superior emergency planning systems, security systems, communication strategies, and environmental response plans. Students review the insurance strategy for a major property development and discuss state and federal laws.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 645 Property Management Technology Strategies 3.0 Credits**
This course focuses on the use of technology to effectively manage and market property. Successful strategies employing technology to gain operating efficiencies, increase employee and tenant communications, optimize rent management, increase tenant retention, and maximize security systems are featured. Best practice examples of integrated technology stems are reviewed and students perform a technology audit.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 650 Retail Property Marketing & Management 3.0 Credits**
Explores strategies to market and manage retail properties. A variety of retail properties are analyzed such as shopping centers, malls, small strip centers, mixed-use properties, and retail entertainment destinations. Topics include tenant mix, advertising, promotion, leases, maintenance, technology integration, retail development and rehabilitation, and retail as an amenity for residential tenants.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 655 Affordable Housing Management 3.0 Credits**
This course focuses on successful strategies to manage affordable housing. The major issues impacting development are discussed including HUD regulations, rental property law, development financing, green development concerns, and specialized amenities including childcare, assisted living facilities, and pharmacies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 660 Student Housing Marketing & Management 3.0 Credits**
This course focuses on successful strategies for marketing and managing student housing. The main variables influencing decisions are explored including federal and state laws, town-gown relations, emergency management, security and communications planning, advertising design and placement, rent management opportunities, and constraints, and awareness of student issues and current cases.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 665 Military Housing Marketing & Management 3.0 Credits**
Strategies to successfully market and manage military housing are the central focus of this course. Military housing requires specialized study in a variety of areas including federal laws, emergency management, security and communications, military regulations, Department of Defense initiatives and regulations, and specialized amenities especially childcare, family entertainment, and healthcare.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 670 Housing for Later Life 3.0 Credits**
This course features strategies to successfully manage and market housing for later life. A range of housing choices is explored and emphasis is placed on specialized lifestyle activities, unique amenity wants and related health service needs of the tenants. Emphasis is placed on legal, operational, marketing, and financial issues. Private equity investment into nursing homes is discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 675 Commercial Property Management 3.0 Credits**
This course focuses on the strategic management of commercial property. A variety of commercial properties are featured including office buildings, medical office buildings, industrial properties, warehouses, and mixed-use corporate campuses. Operational issues are discussed and commercial property is analyzed as an investment including the development process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 677 Commercial Property Leasing 3.0 Credits**
This course covers leasing processes for office, retail and industrial properties. Students will evaluate preliminary documents that set the stage for rental agreements, including landlord lease packages, tenant requests for proposals and letters of intent. Relative bargaining positions of key stakeholders and model lease clauses resolving principal issues are evaluated.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**PRMT 680 Special Topics in PRMT 0.5-12.0 Credits**
Covers special topics of interest in Property Management. This course can be repeated for credit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 18 times for 9 credits

**PRMT 695 Capstone in Property Management I 3.0 Credits**
This culminating course provides an overview of major issues facing property managers today and requires the completion of a comprehensive community analysis of property development. The research protocol and methods to be used in PMGT 696 are presented and students submit a research topic for approval.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 602 [Min Grade: C] and PRMT 603 [Min Grade: C] and PRMT 625 [Min Grade: C] and PRMT 630 [Min Grade: C] and PRMT 640 [Min Grade: C] and PRMT 645 [Min Grade: C] and REAL 572 [Min Grade: C]

**PRMT 696 Capstone in Property Management II 3.0 Credits**
This culminating experience requires the completion of a research project focusing on a topic relevant to today's property managers. The project will be completed in a systematic manner using research and management tools. Students demonstrate their abilities to conduct thorough research, analyze and interpret data, evaluate results, and make conclusions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** PRMT 602 [Min Grade: C] and PRMT 603 [Min Grade: C] and PRMT 625 [Min Grade: C] and PRMT 630 [Min Grade: C] and PRMT 640 [Min Grade: C] and PRMT 645 [Min Grade: C] and PRMT 695 [Min Grade: C] and REAL 572 [Min Grade: C]

**PRMT 697 Property Management Practicum 1.0-3.0 Credit**
This course provides students an opportunity for experience in the field of property management. Students will secure their own relavent practicum placement. Work will be supervised by a professional with appropriate property management experience. Students will complete an ongoing project.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 3 times for 3 credits
**Restrictions:** Can enroll if major is PRMT.

**PRMT 699 Independent Study in Property Management 1.0-6.0 Credit**
Provides individual study or research in Property Management under faculty supervision. This course may be repeated for credit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 11 times for 12 credits
**Restrictions:** Can enroll if major is PRMT.

# Master of Science in Systems Engineering

*Master of Science in Systems Engineering (MSSYSE): 48.0 quarter credits*

## About the Program

The Master of Science in Systems Engineering is an online curriculum integrating systems and financial management and planning. The degree enables engineering leaders to perform, lead, and manage systems development throughout the life cycle, from conceptual development and engineering design through the operation and sustainment phases.

Elective courses for the curriculum:

- Include models relevant to sustainable, high performance systems and topics related to living, learning, effectiveness, power, influence, networking, and systems thinking as they relate to effective systems engineering
- Expose students to model-based system development using SysML and DODAF, also covering major aspects of the systems domain.
- Teach SE processes and skills to integrate user needs, manage requirements, conduct technological evaluation, and build elaborate system architectures, assess risk and establish financial and schedule constraints.
- Prepare students to intelligently manage and contribute to any engineering challenge, from concept development, technology assessment, and architecture selection, to proposal development, stimulating and challenging as they consider sustainability-oriented projects and become serious systems engineering managers and practitioners.

## Program Outcomes

Graduates of the Drexel University Master of Science in Systems Engineering will be competent in their ability to:

- develop and implement models and tools to enhance and optimize complex systems;
- develop and manage processes relevant to complex systems development;
- architect, design, implement, integrate, verify, validate, support and decommission complex systems;
- use systems engineering tools and practices to identify and execute effective technical solutions;
- manage system-intensive projects within cost and schedule constraints;
- consider financial elements in all complex systems solutions.

## Certificate Opportunity

A student may first complete a Certificate as an individual pursuit or as a gateway to the full Master of Science in Systems Engineering. A student may apply for admission to the Masters of Science in Systems Engineering degree program at any point in a certificate series. Upon admission, graduate courses successfully completed in the certificate series may be applied toward the Master's degree as applicable. Certificate opportunities include:

- Certificate in Systems Design and Development
- Certificate in Systems Engineering Analysis
- Certificate in Systems Engineering Fundamentals
- Certificate in Systems Engineering Integrated Logistics
- Certificate in Systems Reliability Engineering

## Admission Requirements

### Degree and GPA Requirement

A bachelor's degree in an Engineering discipline from an ABET-accredited college or university is required. A bachelor's degree in science (Physics, Mathematics, Computer Science, etc.) can also acceptable. Applicants with degrees in sciences may be required to take a number of undergraduate or post-baccalaureate courses. An undergraduate degree earned abroad must be deemed equivalent to a U.S. bachelor's degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required.

### GRE Requirement

The GRE General Test is only required of applicants for full-time studies; part-time applicants do not need to take the GRE. For those taking the GRE, a minimum score of approximately 1200 is recommended. Official documents of the exam must be submitted directly to the Graduate Admissions Office. Unofficial photocopies will not be accepted. The GRE can be waived for students who have successfully completed a Master's degree or a Drexel certificate in the systems curriculum.

### TOEFL Requirement

For students whose native language is not English and who do not hold a degree from a U.S.institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum of 600 (paper-based), 250 (computer-based), or 100 (internet-based). Official documents of this exam must be submitted directly to the Graduate Admissions Office. Unofficial photocopies will not be accepted.

### Other Requirements

- Submission of an application
- Official, sealed college transcripts
- An essay
- Two or more letters of recommendation

# Degree Requirements

The master of science in systems engineering degree requires 48.0 credits, including 36.0 credits in required core courses and 12.0 graduate elective credits. These electives may be taken in other colleges at Drexel consistent with the plan of study and any required prerequisites.

Students may take their required elective credits from any graduate-level course(s) in engineering, business, or another college for which they have adequate preparation and can obtain approvals from the college and the systems engineering program.

All candidates are encouraged to discuss areas of interest with the program advisor and to develop a proposed plan of study during the early stages of the program.

Note: Specific course requirements will be waived for students who have taken equivalent courses elsewhere.

**Engineering Management Required Courses**

| | | |
|---|---|---|
| EGMT 531 | Engineering Economic Evaluation & Analysis | 3.0 |
| EGMT 571 | Managerial Statistics | 3.0 |
| EGMT 572 | Statistical Data Analysis | 3.0 |
| EGMT 573 | Operations Research | 3.0 |
| EGMT 685 | Systems Engineering Management | 3.0 |

**Systems Engineering Required Courses**

| | | |
|---|---|---|
| EGMT 688 | Systems Engineering Analysis I | 3.0 |
| EGMT 690 | Systems Engineering Analysis II | 3.0 |
| SYSE 510 | Systems Engineering Process | 3.0 |
| SYSE 520 | Sustainment and Integrated Logistics | 3.0 |
| SYSE 521 | Integrated Risk Management | 3.0 |
| SYSE 533 | Systems Integration and Test | 3.0 |

**Capstone in Systems Engineering**

| | | |
|---|---|---|
| SYSE 598 | Capstone in Systems Engineering | 3.0 |
| **Electives** | | **12.0** |

Complete four of the following:

| | | |
|---|---|---|
| SYSE 511 | Systems Engineering Tools | |
| SYSE 522 | Supply Chain Systems Engineering | |
| SYSE 523 | Systems Reliability Engineering | |
| SYSE 524 | Systems Reliability, Availability & Maintainability Analysis | |
| SYSE 525 | Statistical Modeling & Experimental Design | |
| SYSE 530 | Systems Engineering Design | |
| SYSE 531 | Systems Architecture Development | |
| SYSE 532 | Software Systems Engineering | |
| EGMT 635 | Visual System Mapping | |
| EGMT 650 | Engineering Leadership | |
| ECES 511 | Fundamentals of Systems I | |
| ECES 512 | Fundamentals of Systems II | |
| ECES 513 | Fundamentals of Systems III | |
| ECES 521 | Probability & Random Variables | |
| ECES 522 | Random Process & Spectral Analysis | |
| ECES 523 | Detection & Estimation Theory | |
| ECES 811 | Optimization Methods for Engineering Design | |
| ECEP 501 | Power System Analysis | |
| ECEP 502 | Computer Analysis of Power Systems | |
| ECEP 503 | Synchronous Machine Modeling | |
| ECEP 610 | Power System Dynamics | |
| ECEP 611 | Power System Security | |
| ECEP 612 | Economic Operation of Power Systems | |
| SYSE 898 | Master's Thesis in Systems Engineering [**] | |
| **Total Credits** | | **48.0** |

[*]   Electives from other engineering disciplines and/or Drexel colleges may be considered with review and approval by the advisor.

[**]   If a student decides to pursue the Master's Thesis option, the student will complete the 11 core courses, one elective course and nine thesis credits. Advisor/Director consultation and approval is required if a student is interested in waiving core courses when pursuing the Master's Thesis option.

## Dual Degree Opportunity

Students may pursue the Master of Science in Systems Engineering as part of a dual degree option with approval from the graduate advisors of both programs. Students may transfer as many as 15 credits from one program to the other, usually in the form of electives, and are therefore required to complete a minimum of 63 graduate credits in order to complete a dual master's degree program (the actual credit total may be higher, depending on each department's core requirements). Examples of permissible dual pursuits could include MS SYSE/MS EE and MS SYSE/ MS Finance.

## Secondary Master's Degree Pursuit Opportunity

Students with a previously completed master's degree may pursue a second master's degree in a different major without the need to go through the admission process again or to complete another 45 credits of graduate coursework. Because the student has already completed a master's degree at Drexel, he or she may transfer up to 15 credits from the first into the second master's degree program, depending upon, departmental requirements in the new major, and may, therefore, complete the second master's degree with a minimum of 33 new graduate credits.

Readmission into the second master's degree program is requested through the new departmental graduate advisor, with final approval by the Graduate Studies Office. During the term in which the student expects to complete the second master's degree, he/she must file an application for degree form through DrexelOne.

## Career Opportunities

The MS Systems Engineering prepares students to become effective systems engineers, leaders, managers and future executives. With a systems engineering background, students are able to tackle a wide array of engineering challenges from the entire systems life cycle, including concept development, technology assessment, architecture selection, and proposal development.

Systems engineers are highly valued in industry because their skills complement those in traditional engineering fields. Whereas other engineering disciplines usually focus deeply in only one area, systems engineers must integrate all of those areas into a comprehensive and effective system. This is a versatile skill-set that allows for a flexible career path, as systems engineering expertise is sought by a wide range of industries such as healthcare, defense, communications, aerospace,

government, transportation, finance, and more. Drexel University's MS Systems Engineering will prepare students from any of these fields to lead large, complex projects in their organizations.

# Systems Engineering Faculty

Kevin Gazzara, DM *(University of Phoenix)*. Adjunct Professor. Senior Partner in Magna Leadership Solutions LLC.

Richard Grandrino, MBA *(Drexel University)*. Teaching Faculty. Program Manager for advanced logistics operations at Lockheed Martin, MS2.

Stephen Mastro, PhD *(Drexel University)*. Adjunct Professor. Expertise in advanced sensor and control technologies for condition-based maintenance, damage control, and automation.

Miray Pereira, MBA *(Rutgers University)*. Adjunct Professor. Manages a team of consultants responsible for development, facilitation and implementation of fundamental demand management systems and capabilities for DuPont, most recently with the DuPont Safety & Protection Platform in strategic planning, mergers & acquisitions.

Walter Sobkiw, BS *(Drexel University)*. Adjunct Professor. Systems Engineer for the Wyle Aerospace Group.

Fernando Tovia, PhD *(University of Arkansas)*. Adjunct Professor. Expertise in core quantitative analysis, strategic planning, supply chain management and manufacturing systems.

John Via, EngD *(Southern Methodist University) Director, Systems Engineering Program*. Teaching Professor. Head, Engineering Management; Associate Dean, Online Engineering Programs

# Interdepartmental Faculty

Stephen Smith, PhD *(Drexel University)*. Adjunct Professor. Development of online learning and distance teaching/learning techniques for engineering.

# Courses

### SYSE 510 Systems Engineering Process 3.0 Credits
This course covers the complete system engineering process, touching on the many facets of engineering systems from needs and requirements generation to production and construction to operation. Engineering involves application of science to perform a myriad of technical processes including development, manufacturing, and maintenance, sustainment and operation of systems. Engineering education is concerned with cognitive, hardware, and software tools to attack technical problems. Engineers are normally introduced to component level problems before proceeding to more complex ones. Systems engineering covers a higher level system concept, applying well tested engineering practices to address processes critical to most large engineering efforts, and optimizing them for effectiveness and financial success.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

### SYSE 511 Systems Engineering Tools 3.0 Credits
This course focuses on teaching a variety of tools and applications. Stochastic modeling and simulation tools used for systems engineering analysis are covered. Course provide a comprehensive understanding of use of tools as well as modeling and simulation concepts to perform simulation analysis of physical and conceptual systems. Systems engineering has great potential for solving problems related to physical, conceptual and esoteric systems. The power of systems engineering relies on the ability to conduct elaborate analysis in an attempt to employ the most optimal integrated system. This approach requires understanding of tools for conducting requirements analysis, analysis of alternatives and systems architectural design. Students will learn how to apply "state of the art" tool.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 571 [Min Grade: C] and EGMT 572 [Min Grade: C] and EGMT 573 [Min Grade: C]

### SYSE 520 Sustainment and Integrated Logistics 3.0 Credits
Logistics activities are critical integrating functions in any type of business. Annual expenditures on logistics in the United States alone are equivalent to approximately 10% of US Gross domestic product. Logistics expenditures represent an even larger percentage of the world economy. Thus, achieving state-of the –art excellence in logistics functions, and attaining the inherit cost reductions associated with outstanding logistics efforts is very important in terms of competitiveness and profitability. This course discusses traditional methods and contemporary topics associated with logistics and global sustainment. It also introduces methodologies and tools for achieving affordable integrated logistics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 571 [Min Grade: C]

### SYSE 521 Integrated Risk Management 3.0 Credits
Will expose students to various methodologies for the evaluation of strategic alternatives to allow analysis and organizational visibility of the underlying assessment of risk, communication and organizational debate of the decision choices among plausible strategic alternatives. Assessment of uncertainty, identification of risk variables, formulation of mitigation plans and real options will be covered. The role of financial analytics to provide consistent criteria and illustrate the impact of alternative decisions and uncertain market scenarios will be discussed. Provide understanding of most sensitive factors that influence risk for each strategy or project allows an organization to select a risky strategy that meets the risk tolerance of the enterprise and leverages vale of future gains.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 571 [Min Grade: C] and EGMT 531 [Min Grade: C]

**SYSE 522 Supply Chain Systems Engineering 3.0 Credits**
Covers the concepts and methods used for designing, modeling, and managing the supply chain as a strategy that organizations use to be competitive in the global marketplace. The course has broad applications for different types of industries such as manufacturing, service, and retailing. Includes both practical and analytical approaches used for managing supply chain. Students in this course will apply industrial and systems engineering tools to design, analyze, and optimize the supply chain such as, mathematical optimization, inventory management, transportation and network location, facilities planning and material handling. More advanced topics are interrelated such as: value of information sharing in the supply chain, customer value, strategic alliances, international issues and decision support systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 572 [Min Grade: C] and (EGMT 574 [Min Grade: C] or EGMT 690 [Min Grade: C])

**SYSE 523 Systems Reliability Engineering 3.0 Credits**
The course focuses in modeling and analysis of systems reliability using probability models. The primary reason for modeling reliability systems is to improve the reliability and availability of a product or a system. The course covers three major aspects of reliability: reliability models, analysis of failure and repair distributions, and finally preventive maintenance and warranty models. Upon completion of the course, students will be able to apply reliability models for a product or system during its life-cycle: design, production, and warranty.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 572 [Min Grade: C] and EGMT 573 [Min Grade: C]

**SYSE 524 Systems Reliability, Availability & Maintainability Analysis 3.0 Credits**
Introduction to systems reliability, maintainability and availability analysis (RM&A) for systems. The course has an application to all phases of the systems engineering process including requirements definition through systems design and development. Introduces design for sustainability of systems during the life cycle of operation. Discusses RM&A and modeling, trade off analysis and cost-effective maintenance concepts for optimization of reliability and availability of a system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 571 [Min Grade: C]

**SYSE 525 Statistical Modeling & Experimental Design 3.0 Credits**
This course focuses on statistical modeling to systems engineering problems; relationships between experimental measurements using regression and correlation theory and analysis of variance models; design of experiments with one and more than one levels; emphasis on inherent variability of systems and processes; response surface methodology, control chart techniques and statistical process control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 572 [Min Grade: C]

**SYSE 530 Systems Engineering Design 3.0 Credits**
Course introduces the student to the design of complex systems. Specific topics include needs analysis, conceptual physical and implementation architectures, technology quality and fundamentals of great system designs, selecting system designs, system and design requirements, system element designs, system design verification and validation, and sustainability design.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 688 [Min Grade: C]

**SYSE 531 Systems Architecture Development 3.0 Credits**
System architecture development is the most important activity in a complex system solution: pick the wrong architecture and the final system may not work, be overcome by displacement technology, or never be implemented because of cost, complexity, or other issues. Course Topics include architecture frameworks, architecture drivers, selection criteria, depiction, generic alternatives, trade studies, architecture selection, open closed architectures, vendor independence and technology choices, and architecture information products.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 688 [Min Grade: C]

**SYSE 532 Software Systems Engineering 3.0 Credits**
Many of our systems today are extremely software intensive. This course introduces software intensive systems engineering. This course is for software and non-software engineers. Topics from the systems perspective include capability maturity models (CMM, CMMI, SE CMM), systems and software interaction, deriving allocating software requirements, traceability, certification needs, mission critical software, software safety, software fault tolerance, human software interface, system and software architectures, reuse and breakthrough software, software interface management, software maintainability, software testability, technology considerations, software change control and configuration management, software quality, software integration verification and validation, software planning and management.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 688 [Min Grade: C]

**SYSE 533 Systems Integration and Test 3.0 Credits**
The systems engineering process applies well tested engineering practices to address the processes which are critical to most large engineering efforts, and optimizing them for effectiveness and financial success. The process covers the complete engineering system evolution from needs and requirements generation to production and construction and operation. Throughout the systems engineering process, various disciplines of engineering as well as various forms of information and technology need to be integrated, and the effectiveness of each step of the process ascertained. This course will address the processes, methods, and tools to integrate, test and evaluate the myriad of engineering information, technology, and products that are encountered throughout the systems engineering process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**SYSE 598 Capstone in Systems Engineering 3.0 Credits**
The capstone course is completed independently or within a group class setting over a full quarter term. The capstone course is the culmination of the student's academic and professional experience, and it will be completed under the direction of a Systems Engineering faculty member. Over the course of the term, students will apply the knowledge gained during their tenure in the program to create a Capstone Project. This project will integrate the skills necessary for analyzing issues, thinking creatively, working collaboratively, and presenting impactful ideas. The Capstone Project should be one of the most comprehensive and applied works a student completes in his or her academic career.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** EGMT 571 [Min Grade: C] and EGMT 572 [Min Grade: C] and EGMT 573 [Min Grade: C] and EGMT 685 [Min Grade: C] and EGMT 531 [Min Grade: C] and EGMT 688 [Min Grade: C] and EGMT 690 [Min Grade: C] and SYSE 510 [Min Grade: C] and SYSE 520 [Min Grade: C] and SYSE 521 [Min Grade: C] and SYSE 533 [Min Grade: C]

**SYSE 680 Special Topics in Systems Engineering 3.0 Credits**
Study of topic of interest to student and/or faculty member as approved by offering unit.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**SYSE 699 Independent Study in Systems Engineering 3.0 Credits**
The purpose of the Independent Study (IS) is for a student to find a supervisor for his/her research with the hope of identifying a thesis topic, or for studying a topic in depth that is not covered by a course. The agreement between the student and faculty member should be formalized by completing the Independent Study form and forwarding it to the advisor for Systems Engineering. The Independent Study form should outline what reading is required and include a schedule of deliverables for the student to follow. Independent Study counts for 3 credit hours delivered over a full academic term via Drexel's Online Learning Management System, Blackboard Learn and requires the student to meet with their faculty advisor for a minimum of 3 hours per week. The student and the professor must both sign the form before s.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**SYSE 898 Master's Thesis in Systems Engineering 1.0-9.0 Credit**
The thesis option is intended to familiarize a student with the techniques for guiding an entire project and to develop a student's creativity in solving real problems. An academic research thesis generally involves more than an industrial project in that the goal is not merely to solve the specific problem but also to understand its relevance to previous work and to the discipline in which one is working. It is expected that the thesis work will represent an advance in understanding of the state-of-the-art and that it will be suitable for publication in an engineering journal or for inclusion as part of a more comprehensive publication. The thesis generally takes a considerable amount of time and effort, with successful completion of the entire process taking more than a year's time. The study and investig.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

# Certificate in Systems Design and Development

*Certificate Level: Graduate*

*Admission Requirements: Bachelor's degree in engineering or other science*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 15.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Estimated Time to Completion: 3 years*
*Financial Aid Eligibility: Not aid eligible*

## About the Program

The courses in this certificate focus on teaching students engineering design and management of large complex systems including software intensive systems. These courses will expose the students to the systems engineering design body of knowledge and allow them to develop systems skills in stimulating and challenging environments that will prepare them to be industry leaders who can make a significant difference. Upon completion of this certificate the students will be able to design, lead and manage any systems engineering effort regardless of size, complexity, technologies, or engineering emphasis.

## Admission Requirements
### Degree and GPA Requirement

A bachelor's degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor's degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. Applicants with degrees in the sciences may be required to take a number of undergraduate or post-baccalaureate courses. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required.

### TOEFL Requirement

For students whose native language is not English and who do not hold a degree from a US institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum of 600 (paper-based), 250 (computer-based) or 100 (internet-based). Official documents of this exam must be submitted directly to the Graduate Admissions Office. Unofficial photocopies will not be accepted.

### Other Requirements

- Submission of an application
- Official, sealed college transcripts
- An essay
- Two or more letters of recommendation

## Requirements

| | | |
|---|---|---|
| EGMT 685 | Systems Engineering Management | 3.0 |
| EGMT 688 | Systems Engineering Analysis I | 3.0 |
| SYSE 530 | Systems Engineering Design | 3.0 |
| SYSE 531 | Systems Architecture Development | 3.0 |
| SYSE 532 | Software Systems Engineering | 3.0 |
| **Total Credits** | | **15.0** |

# Certificate in Systems Engineering Analysis

*Certificate Level: Graduate*
*Admission Requirements: Bachelor's degree in engineering or other science*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 15.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Estimated Time to Completion: 3 years*
*Financial Aid Eligibility: Not aid eligible*

## About the Program

This courses in this certificate focus on teaching students statistical analysis and the use of mathematical models to solve a variety of problems. The courses are structured to discuss theory, process and application. The primary emphasis is application as the objectives of the courses are to provide students with skills to model problems, determine a quantitative solution and to perform sensitivity analysis. Theory and process are also studied so students learn how the models work by understanding the underlying theory associated with a particular model. Understanding of theory also enforces skills to conduct sensitivity analysis and helps answer "what if" type questions. Upon successful completion of this Certificate, students will be able to formulate mathematical models and solve quantitative problems.

Any students interested in decision sciences or advanced mathematical modeling and analysis should consider pursuing this certification.

## Admission Requirements

### Degree and GPA Requirement

A bachelor's degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor's degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. Applicants with degrees in the sciences may be required to take a number of undergraduate or post-baccalaureate courses. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required.

### TOEFL Requirement

For students whose native language is not English and who do not hold a degree from a US institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum of 600 (paper-based), 250 (computer-based) or 100 (internet-based). Official documents of this exam must be submitted directly to the Graduate Admissions Office. Unofficial photocopies will not be accepted.

### Other Requirements

- Submission of an application
- Official, sealed college transcripts
- An essay
- Two or more letters of recommendation

## Requirements

| | | |
|---|---|---|
| EGMT 571 | Managerial Statistics | 3.0 |
| EGMT 572 | Statistical Data Analysis | 3.0 |
| EGMT 573 | Operations Research | 3.0 |
| EGMT 690 | Systems Engineering Analysis II | 3.0 |
| SYSE 525 | Statistical Modeling & Experimental Design | 3.0 |
| **Total Credits** | | **15.0** |

# Certificate in Systems Engineering Fundamentals

*Certificate Level: Graduate*
*Admission Requirements: Bachelor's degree in engineering or other science*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Estimated Time to Completion: 3 years*
*Financial Aid Eligibility: Not aid eligible*

## About the Program

This certificate focuses on teaching students the process and the art of systems engineering. Students will learn systems engineering tools and skills to integrate user needs, manage requirements, conduct technological evaluation and build elaborate system architectures. The courses devote particular attention to knowledge, skills, mindset and leadership qualities needed to be a successful systems engineering leader in the field.

Any students working or interested in the field of systems engineering should consider pursuing and completing this certificate.

## Admission Requirements

### Degree and GPA Requirement

A bachelor's degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor's degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. Applicants with degrees in the sciences may be required to take a number of undergraduate or post-baccalaureate courses. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required.

### TOEFL Requirement

For students whose native language is not English and who do not hold a degree from a US institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum of 600 (paper-based), 250 (computer-based) or 100 (internet-based). Official documents of this exam must be submitted directly to the Graduate Admissions Office. Unofficial photocopies will not be accepted.

### Other Requirements

- Submission of an application
- Official, sealed college transcripts

- An essay
- Two or more letters of recommendation

## Requirements

| | | |
|---|---|---|
| EGMT 571 | Managerial Statistics | 3.0 |
| EGMT 572 | Statistical Data Analysis | 3.0 |
| EGMT 573 | Operations Research | 3.0 |
| EGMT 685 | Systems Engineering Management | 3.0 |
| EGMT 688 | Systems Engineering Analysis I | 3.0 |
| EGMT 690 | Systems Engineering Analysis II | 3.0 |
| **Total Credits** | | **18.0** |

# Certificate in Systems Engineering Integrated Logistics

*Certificate Level: Graduate*
*Admission Requirements: Bachelor's degree in engineering or other science*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Estimated Time to Completion: 3 years*
*Financial Aid Eligibility: Not aid eligible*

## About the Program

The courses in this certificate focus on teaching students to understand, analyze and enhance the performance of complex and dynamic global supply chains. The certificate is structured with three quantitative courses: EGMT 571, EGMT 572, and EGMT 573, that will provide the students with mathematical and statistical tools to analyze and evaluate the supply chain.

In addition, the certificate offers three courses: EGMT 690, SYSE 520, SYSE 522 and that will allow the students to understand the dynamic and complex nature of global supply chains from a systems engineering perspective, as well as to implement the quantitative tools learned during the first three courses to efficiently manage the supply chain. Students will evaluate and analyze diverse types of supply chains through case studies, and analyze and discuss the best practices in supply chains across the world.

All affiliate courses may be applied to the Master of Science in Systems Engineering and the Master of Science in Engineering Management .

## Admission Requirements

### Degree and GPA Requirement

A bachelor's degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor's degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. Applicants with degrees in the sciences may be required to take a number of undergraduate or post-baccalaureate courses. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required.

### TOEFL Requirement

For students whose native language is not English and who do not hold a degree from a US institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum of 600 (paper-based), 250 (computer-based) or 100 (internet-based). Official documents of this exam must be submitted directly to the Graduate Admissions Office. Unofficial photocopies will not be accepted.

### Other Requirements

- Submission of an application
- Official, sealed college transcripts
- An essay
- Two or more letters of recommendation

## Requirements

| | | |
|---|---|---|
| EGMT 571 | Managerial Statistics | 3.0 |
| EGMT 572 | Statistical Data Analysis | 3.0 |
| EGMT 573 | Operations Research | 3.0 |
| EGMT 690 | Systems Engineering Analysis II | 3.0 |
| SYSE 520 | Sustainment and Integrated Logistics | 3.0 |
| SYSE 522 | Supply Chain Systems Engineering | 3.0 |
| **Total Credits** | | **18.0** |

# Certificate in Systems Reliability Engineering

*Certificate Level: Graduate*
*Admission Requirements: Bachelor's degree in engineering or other science*
*Certificate Type: Graduate Certificate*
*Number of Credits to Completion: 18.0*
*Instructional Delivery: Online*
*Calendar Type: Quarter*
*Estimated Time to Completion: 3 years*
*Financial Aid Eligibility: Not aid eligible*

## About the Program

The courses in this certificate focus on teaching students to design for sustainability and reliability of systems during the life cycle of operation. Students will take the first three courses that will teach them the analytical tools required to perform reliability and maintainability modeling and analysis. Then, the students will take three courses that focus on systems reliability, maintainability and availability analysis (RM&A) for systems. The courses have an application to all phases of the systems engineering process including requirements definition through systems design and development. The students will learn the process that starts with RM&A in the initial phases of development, conducting trade off analysis during the system development phase to optimize reliability and availability of the system. The students will also learn to improve the reliability and availability of a product or a system by modeling and analysis of systems reliability using probability models.

Upon completion of the courses, students will be able to understand RM&A and modeling, apply reliability models for a product or system during its life-cycle: design, production, and warranty, as well as how to conduct trade off analysis to enhance availability and reliability of the

system and development of maintenance concepts that are cost effective and support sustainment of the system.

## Admission Requirements
### Degree and GPA Requirement

A bachelor's degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor's degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. Applicants with degrees in the sciences may be required to take a number of undergraduate or post-baccalaureate courses. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required.

### TOEFL Requirement

For students whose native language is not English and who do not hold a degree from a US institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum of 600 (paper-based), 250 (computer-based) or 100 (internet-based). Official documents of this exam must be submitted directly to the Graduate Admissions Office. Unofficial photocopies will not be accepted.

### Other Requirements

- Submission of an application
- Official, sealed college transcripts
- An essay
- Two or more letters of recommendation

### Requirements

| EGMT 571 | Managerial Statistics | 3.0 |
|---|---|---|
| EGMT 572 | Statistical Data Analysis | 3.0 |
| EGMT 573 | Operations Research | 3.0 |
| EGMT 688 | Systems Engineering Analysis I | 3.0 |
| SYSE 523 | Systems Reliability Engineering | 3.0 |
| SYSE 524 | Systems Reliability, Availability & Maintainability Analysis | 3.0 |
| **Total Credits** | | **18.0** |

# Materials Science and Engineering

*Master of Science in Materials Science and Engineering (MSMSE): 45.0 quarter credits*
*Doctor of Philosophy: 90.0 quarter credits*

## About the Program

The graduate program in Materials Science and Engineering aims to provide an education which encompasses both the breadth and depth of the most recent knowledge base in the materials science and engineering fields in a format suitable for individuals seeking careers in academia and/or industry.

In addition, the program provides students with research training through their courses and thesis research at the MS and PhD levels.

The graduate student body reflects a broad spectrum of undergraduate backgrounds. Because of the expansion into interdisciplinary areas, qualified physical and biological science graduates may also join the program. Non-engineering graduates are required to take MATE 503-Introduction to Materials Engineering.

Graduate work in materials science and engineering is offered both on a regular full-time and on a part-time basis. The General (Aptitude) Test of the Graduate Record Examination (GRE) is required for applicants pursuing full-time study.

**Career Opportunities**
Graduates go on to careers in engineering firms, consulting firms, law firms, private industry, business, research laboratories, academia, and national laboratories. Materials scientists and materials engineers find employment in such organizations as Hewlett-Packard, Intel, IBM, 3M, DuPont, Lockheed-Martin, Johnson and Johnson, Merck, AstraZeneca, Arkema, Army Research Laboratory, Los Alamos National Laboratory, Air Products, Micron, Xerox, Motorola, Monsanto, Corning, and Eastman Kodak.

For more information about Materials Science and Engineering, visit the Department of Materials Science and Engineering (http://www.materials.drexel.edu) web page.

## Admission Requirements

Applicants must meet the graduate requirements for admission to Drexel University. The graduate student body reflects a broad spectrum of undergraduate backgrounds. Because of the expansion into interdisciplinary areas, qualified non-MSE engineering, physical and biological science graduates may also join the program.

For specific information on how to apply to this program, visit Drexel University's Materials Science and Engineering Graduate Admissions (http://www.drexel.edu/grad/programs/coe/materials-science-engineering) page.

## Master of Science in Materials Science and Engineering

The 45.0 quarter credits required for the MS degree include two required core courses on MATE 510-Thermodynamics of Solids and MATE 512-Introduction to Solid State Materials. Students choose four additional core courses.

**Thesis Options**
All full-time students are required to undertake a 9.0 credit thesis on a topic of materials research supervised by a faculty member. MS students can select the Non-thesis Option if carrying out research is not possible, in which case, the thesis may be replaced by either (a) a 6.0 credit Thesis Proposal and 3.0 credit coursework, or (b) 9.0 credits of coursework.

All students are required, during their first year, to propose an advisor supported research thesis topic or literature survey for approval by the department. Students are urged to make a choice of topic as early as possible and to choose appropriate graduate courses in consultation with their advisor.

The program is organized so that part-time students may complete the degree requirements in two to four years. Full-time students may complete the program in two years.

**MS to PhD Program**

There is no general exam required for MS students. If an MS student wishes to continue for a PhD then: (a) the student must be admitted to the PhD program (there is no guarantee that an MS student will be admitted to the PhD program), and (b) the student must take the Candidacy Exam during the first term after being admitted to the PhD program.

**Materials Science and Engineering (MSMSE) Core Courses** [*]

| | | |
|---|---|---|
| Required core courses: | | |
| MATE 510 | Thermodynamics of Solids | 3.0 |
| MATE 512 | Introduction to Solid State Materials | 3.0 |
| Select four additional core courses from the following: | | 12.0 |
| MATE 501 | Structure and Properties of Polymers | |
| MATE 507 | Kinetics | |
| MATE 515 | Experimental Technique in Materials | |
| MATE 535 | Numerical Engineering Methods | |
| MATE 610 | Mechanical Behavior of Solids | |
| MATE 661 | Biomedical Materials I | |
| Any additional related courses if approved by the graduate advisor/ thesis advisor (such as MATE 514 and MATE 573) | | |
| **Optional Core Courses** [**] | | 18.0 |
| **Thesis and Alternatives** | | 9.0 |
| 9.0 credits MS thesis OR 6.0 credits of thesis proposal (literature review) + 3.0 credit course OR 9.0 credits of electives | | |
| **Total Credits** | | **45.0** |

[*]  PhD candidates must achieve a minimum B- grade in each of the core courses. Waiver of any of the 6 core courses must be approved by the MSE Department Graduate Advisor and the student's Thesis Advisor in Advance.

[**]  Of the 18 technical elective credits, at least 9 credits must be taken as Materials Science and Engineering (MATE) courses, while the rest may be taken within the College of Engineering, College of Arts and Sciences, or at other colleges if consistent with the student's plan of study (and given advance written approval by his/her advisor). At least 9 of these 18 technical electives must be exclusive of independent study courses or research credits.

# PhD in Materials Science and Engineering Requirements

The graduate school requires at least 90.0 credits for the PhD degree in Materials Science and Engineering. An MS degree is not a prerequisite for the PhD degree, but does count as 45.0 credits toward the 90.0 credit requirement. Students entering the department at the BS level must satisfy the course requirements for the MS degree.

Students choose a doctoral thesis topic after consultation with the faculty. Students are urged to consider and select topics early in their program of study. An oral thesis presentation and defense are scheduled at the completion of the thesis work.

Doctoral program students must pass a candidacy examination within the first eighteen months. The candidacy exam consists of a seminar presentation by the student, followed by an oral examination covering the materials found in the core courses as well as the subject matter presented in the seminar. Six months later, doctoral candidates present a thesis proposal outlining their research study. Approximately six months before the full defense of their PhD thesis, doctoral candidates should prepare and present a pre-defense seminar.

For more information, visit the Department of Materials Science and Engineering (http://www.materials.drexel.edu) web page.

# Facilities

**Biomaterials and Biosurfaces Laboratory**

This laboratory contains 10 kN biaxial and 5 kN uniaxial servo-hydraulic mechanical testing machines, a Fluoroscan X-ray system, a microscopic imaging system, a spectra fluorometer, a table autoclave, centrifuge, vacuum oven, $CO_2$ incubators, biological safety cabinet, thermostatic water baths, precision balance and ultrasonic sterilizer.

**Nanobiomaterials and Cell Engineering Laboratory**

This laboratory contains fume hood with vacuum/gas dual manifold, vacuum pump and rotary evaporator for general organic/polymer synthesis; gel electrophoresis and electroblotting for protein characterization; bath sonicator, glass homogenizer and mini-extruder for nanoparticle preparation; centrifuge; ultrapure water conditioning system; precision balance; pH meter and shaker.

**Ceramics Processing Laboratory**

This laboratory contains a photo-resist spinner, impedance analyzer, Zeta potential meter, spectrofluorometer, piezoelectric d33 meter, wire-bonder, and laser displacement meter.

**Dynamic Characterization Laboratory**

This laboratory contains metallographic sample preparation (sectioning, mounting and polishing) facilities; inverted metallograph; microhardness tester; automated electropolishing for bulk and TEM sample preparation; SEM tensile stage for EBSD; magneto-optical Kerr effect (MOKE) magnetometer.

**MAX Phase Ceramics Processing Laboratory**

This laboratory contains a vacuum hot-press; cold isostatic press (CIP) and hot isostatic press (HIP) for materials consolidation and synthesis; precision dilatometer; laser scattering particle size analyzer; impedance analyzer, creep testers, and assorted high temperature furnaces.

**Mechanical Testing Laboratory**

This laboratory contains mechanical and closed-loop servo-hydraulic testing machines, hardness testers, impact testers, equipment for fatigue testing, metallographic preparation facilities and a rolling mill with twin 6" diameter rolls.

**Mesoscale Materials Laboratory**

This laboratory contains instrumentation for growth, characterization, device fabrication, and design and simulation of electronic, dielectric, ferroelectric and photonic materials. Resources include physical and chemical vapor deposition and thermal and plasma processing of thin films, including oxides and metals, and semiconductor nanowire growth. Facilities include pulsed laser deposition, atomic layer deposition, chemical vapor deposition, sublimation growth, and resistive thermal evaporation. Variable-temperature high-vacuum probe station and optical cryostats including high magnetic field, fixed and tunable-wavelength laser sources, several monochromators for luminescence and Raman scattering spectroscopies, scanning electron microscopy with electron beam lithography, and a scanning probe microscope.

**Nanomaterials Laboratory**

This laboratory contains instrumentation for testing and manipulation of materials under microscope, high-temperature autoclaves, Sievert's apparatus; glove-box; high-temperature vacuum and other furnaces for the synthesis of nano-carbon coatings and nanotubes; electro-spinning system for producing nano-fibers.

**Oxide Films and Interfaces Laboratory**

This laboratory contains an oxide molecular beam epitaxy (MBE) thin film deposition system; physical properties measurement system for electronic transport and magnetometry measurements from 2 – 400K, up to 9 T fields; 2 tube furnaces.

**Powder Processing Laboratory**

This laboratory contains vee blenders, ball-mills, sieve shaker + sieves for powder classification, several furnaces (including one with controlled atmosphere capability); and a 60-ton Baldwin press for powder compaction.

**Soft Matter Research and Polymer Processing Laboratories**

These laboratories contain computerized thermal analysis facilities including differential scanning calorimeters (DSC), dynamic mechanical analyzer (DMA) and thermo-gravimetric analyzer (TGA); single-fiber tensile tester; strip biaxial tensile tester; vacuum evaporator; spincoater; centrifuge; optical microscope with hot stage; liquid crystal tester; microbalance; ultrasonic cleaner; laser holographic fabrication system; polymer injection molder and single screw extruder.

**Natural Polymers and Photonics Laboratory**

This laboratory contains a spectroscopic ellipsometer for film characterization; high purity liquid chromatography (HPLC) system; lyophilizer; centrifuge; refractometer; electro-spinning system for producing nano-fibers.

**X-ray Tomography Laboratory**

This laboratory contains a high resolution X-ray tomography instrument and a cluster of computers for 3D microstructure reconstruction; mechanical stage, a positioning stage and a cryostage for in-situ testing. For more information on departmental facilities, please visit the Department's Facilities web page (http://www.materials.drexel.edu/research/facilities) .

**Centralized Research Facilities**

The Department of Materials Science & Engineering relies on Core Facilities within the University for materials characterization and micro- and nano-fabrication. These facilities contain state-of-the-art materials characterization instruments, including environmental and variable pressure field-emission scanning electron microscopes with Energy Dispersive Spectroscopy (EDS) for elemental analysis, and Orientation Image Microscopy (OIM) for texture analysis; a Transmission Electron Microscope (TEM) with STEM capability and TEM sample preparation equipment; a dual beam focused ion beam (FIB) system for nano-characterization and nano fabrication; a femtosecond/ terahertz laser Raman spectrometer; visible and ultraviolet Raman micro spectrometers with a total of 7 excitation wavelengths for non-destructive chemical and structural analysis and Surface Enhanced Raman (SERS); a Fourier Transform Infrared (FTIR) spectrometer with a microscope and full array of accessories; a Nanoindenter; an X-ray Photoelectron Spectrometer (XPS)/Electron Spectroscopy for Chemical Analysis (ESCA) system; and X-Ray Diffractometers (XRD), including small angle/wide angle X-Ray scattering (SAX/WAX).

More details of these instruments, information how to access them and instrument usage rates can be found on the Core Facilities web page (http://crf.coe.drexel.edu) .

# Materials Science and Engineering Faculty

Michel Barsoum, PhD *(Massachusetts Institute of Technology) A. W. Grosvenor Professor*. Professor. Processing and characterization of novel ceramics and ternary compounds, especially the MAX and 2-D MXene phases.

Hao Cheng, PhD *(Northwestern University)*. Assistant Professor. Drug delivery, molecular self-assembly, cell-nanomaterial interactions, regenerative medicine and cell membrane engineering.

Yury Gogotsi, PhD *(Kiev Polytechnic Institute) Director, A. J. Drexel Nanotechnology Institute*. Distinguished University & Trustee Chair Professor. Nanomaterials; carbon nanotubes; nanodiamond; graphene; MXene; materials for energy storage, supercapacitors, and batteries.

Richard Knight, PhD *(Loughborough University) Associate Department Head and Undergraduate Advisor*. Teaching Professor. Thermal plasma technology; thermal spray coatings and education; plasma chemistry and synthesis.

Christopher Y. Li, PhD *(University of Akron)*. Professor. Soft and hybrid materials for optical, energy, and bio applications; polymeric materials, nanocomposites, structure and properties.

Michele Marcolongo, PhD, PE *(University of Pennsylvania) Department Head*. Professor. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Steven May, PhD *(Northwestern University)*. Assistant Professor. Synthesis of complex oxide films, superlattices, and devices; materials for energy conversion and storage; magnetic and electronic materials; x-ray and neutron scattering.

Ekaterina Pomerantseva, PhD *(Moscow State University, Russia)*. Assistant Professor. Solid state chemistry; electrochemical characterization, lithium-ion batteries, energy generation and storage; development and characterization of novel nanostructured materials, systems and architectures for batteries, supercapacitors and fuel cells.

Caroline L. Schauer, PhD *(SUNY Stony Brook) Graduate Advisor*. Associate Professor. Polysaccharide thin films and nanofibers.

Wei-Heng Shih, PhD *(Ohio State University)*. Professor. Colloidal ceramics and sol-gel processing; piezoelectric biosensors, optoelectronics, and energy harvesting devices; nanocrystalline quantum dots for bioimaging, lighting, and solar cells.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering*. Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces; scanning probe microscopy; laser spectroscopy, including Raman scattering.

Mitra Taheri, PhD *(Carnegie Mellon University) Hoeganeas AssociateProfessor of Metallurgy*. Associate Professor. Development of the ultrafast Dynamic Transmission Electron Microscope (DTEM) for the study of laser-induced microstructural evolution/phase transformations

in nanostructured materials; use of various *in-situ* Transmission Electron Microscopy techniques.

Garritt Tucker, PhD *(Georgial Institute of Technology)*. Assistant Professor. Computational materials science and engineering; microstructural evolutiona nd material behavior in extreme environments; interfacial-driven processes for improving material functionality; multi-scale physics modeling.

Christopher Weyant, PhD *(Northwestern University)*. Associate Teaching Professor.

Antonios Zavaliangos, PhD *(Massachusetts Institute of Technology) A.W. Grosvenor Professor*. Professor. Constitutive modeling; powder compaction and sintering; pharmaceutical tableting, X-ray tomography.

## Interdepartmental Faculty

Jason B. Baxter, PhD *(University of California, Santa Barbara)*. Associate Professor. Solar cells, semiconductor nanomaterials, ultrafast spectroscopy.

Adam K. Fontecchio, PhD *(Brown University) Associate Dean for Undergraduate Affairs; Associate Director, Expressive and Creative Interactive Technologies (EXCITE) Center*. Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Alexander Fridman, DSc, PhD *(Moscow Institute of Physics and Technology) Mechanical Engineering and Mechanics, John A. Nyheim Endowed University Chair Professor, Director of the Drexel Plasma Institute*. Professor. Plasma science and technology; pollutant mitigation; super-adiabatic combustion; nanotechnology and manufacturing.

Haviva M. Goldman, PhD *(City University of New York) Neurobiology and Anatomy*. Associate Professor. Understanding how the size and shape of whole bones, as well as the distribution quantity and quality of the mineralized tissue that forms the bone, reflect both evolutionary constraints of skeletal growth and development, and responsiveness to mechanical loading during life.

Lin Han, PhD *(Massachusetts Institute of Technology)*. Assistant Professor. Nanoscale structure-property relationships of biological materials, genetic and molecular origins soft joint tissue diseases, biomaterials under extreme conditions, coupling between stimulus-responsiveness and geometry.

E. Caglan Kumbur, PhD *(Pennsylvania State University)*. Associate Professor. Next generation energy technologies; fuel cell design and development.

Kenneth K.S. Lau, PhD *(Massachusetts Institute of Technology)*. Associate Professor. Surface science; nanotechnology; polymer thin films and coatings; chemical vapor deposition.

Bahram Nabet, PhD *(University of Washington)*. Professor. Optoelectronics; fabrication and modeling; fiber optic devices; nanoelectronics; nanowires.

Giuseppe R. Palmese, PhD *(University of Delaware) Department Head, Chemical and Biological Engineering*. Professor. Reacting polymer systems; nanostructured polymers; radiation processing of materials; composites and interfaces.

Wan Young Shih, PhD *(Ohio State University) School of Biomedical Engineering, Science and Health Systems*. Associate Professor.

Piezoelectric microcantilever biosensors development, piezoelectric finger development, quantum dots development, tissue elasticity imaging, piezoelectric microcantilever force probes.

Karl Sohlberg, PhD *(University of Delaware)*. Associate Professor. Computational and theoretical materials-related chemistry: (1) complex catalytic materials; (2) mechanical and electrical molecular devices.

Margaret Wheatley, PhD *(University of Toronto) School of Biomedical Engineering, Science and Health Systems, John M. Reid Professor*. Ultrasound contrast agent development (tumor targeting and triggered drug delivery), controlled release technology (bioactive compounds), microencapsulated allografts (*ex vivo* gene therapy) for spinal cord repair.

## Emeritus Faculty

Roger D. Corneliussen, PhD *(University of Chicago)*. Professor Emeritus. Fracture, blends and alloys, as well as compounding.

Roger D. Doherty, PhD *(Oxford University)*. Professor Emeritus. Metallurgical processing; thermo-mechanical treatment.

Ihab L. Kamel, PhD *(University of Maryland)*. Professor Emeritus. Nanotechnology, polymers, composites, biomedical applications, and materials-induced changes through plasma and high energy radiation.

Jack Keverian, PhD *(Massachusetts Institute of Technology)*. Professor Emeritus. Rapid parts manufacturing, computer integrated manufacturing systems, strip production systems, technical and/or economic modeling, melting and casting systems, recycling systems.

Alan Lawley, PhD *(University of Birmingham, England)*. Professor Emeritus. Mechanical and physical metallurgy, powder metallurgy, materials engineering design, engineering education.

## Courses

**MATE 500 Structure and Properties of Metals 3.0 Credits**
Covers crystallography, crystal defects, dislocation mechanisms, phase transformations, recovery and recrystallization, diffusional processes, and strengthening mechanisms.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 501 Structure and Properties of Polymers 3.0 Credits**
Covers step and free radical polymers, copolymerization, molecular weight characteristics, polymer morphology, thermodynamics, viscoelasticity, yielding and crazing, and Boltzmann and T-T superpositions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 502 Structure and Properties of Ceramic and Electronic Materials 3.0 Credits**
Covers bonding; crystal structure; defects; diffusion; electrical conductivity; and mechanical, electrical, dielectric, magnetic, and thermal properties.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 503 Introduction to Materials Engineering 3.0 Credits**
This course provides an introductory overview of materials science and engineering at the graduate level. The fundamental linkages between processing, structure and properties will be addressed with emphasis on micro- and nano-structural impacts on properties.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 505 Phase Equilibria 3.0 Credits**
Covers thermodynamic concepts of phase equilibria, including unary, binary, and ternary systems; pressure effects; and relationships between phase diagrams and structure.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 506 Diffusion 3.0 Credits**
Covers atomic migration in solids, self-diffusion, concentration gradients, mathematical analysis of diffusion, and applications of numerical methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 507 Kinetics 3.0 Credits**
Covers nucleation phenomena in homogeneous and heterogeneous metallic and ceramic systems, strain energy analysis, composition fluctuation analysis, growth and solution kinetics of second phases, coarsening processes, martensitic transformations, and crystallization of glass.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 510 Thermodynamics of Solids 3.0 Credits**
Covers classical thermodynamics, introduction to statistical mechanics, solution theory, thermodynamics of interfaces and crystal defects, and phase diagrams and reaction equilibrium.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 512 Introduction to Solid State Materials 3.0 Credits**
This course is a graduate level introduction to solid-state materials. The effects of crystal structure and bonding on properties will be discussed. Quantum theory of solids will be used to elucidate the electronic transport, magnetic, dielectric and optical properties of solid state materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 514 Structure, Symmetry, and Properties of Materials 3.0 Credits**
Structure–property relationships form a cornerstone for performance-engineering in nearly all materials. Condensed matter systems, including inorganic or organic materials, are defined by their internal structure— the distribution of atoms, defects, and large scale domains with preferred microstructures. This class aims to familiarize materials science students with the real space and k-space structural description of both ideal (defect free) and realistic (imperfect) crystalline materials and the properties derived from the underlying point and transitional symmetry.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 503 [Min Grade: C]

**MATE 515 Experimental Technique in Materials 3.0 Credits**
Covers electron microscopy techniques, scanning transmission and Auger analysis, x-ray diffraction, x-ray wavelength dispersive and energy dispersive analysis, thermal analysis, statistics and error analysis, and design of experiments.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 525 Introduction to Composite Materials 3.0 Credits**
Covers classification and definition of composite materials; properties of fibers, matrices, and their interfaces; structural geometry of reinforcing materials; formation and testing of composites; and properties and analysis of composite materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 530 Solidification Processing I 3.0 Credits**
Covers principles of solidification processing, heat flow during solidification, thermodynamics and kinetics of nucleation and growth, solute redistribution, interfacial stability and morphology, transport phenomena: continuum treatments and structural effects, and rapid solidification.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 531 Solidification Processing II 3.0 Credits**
The technology of solidification processing is covered in this course; clean metal processing; crystal growth; squeeze casting; thixo-and compo-casting; diffusion solidification and rheocasting; continuous casting processes, VM, VAR, ESR, and VADER processing; structural control via MDH; rapid solidification processes (RSP); microgravity casting.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 535 Numerical Engineering Methods 3.0 Credits**
Covers numerical solution of non-linear equations, linear systems, and integration of ordinary differential equations. Introduces finite differences and finite elements. Provides a user's perspective of finite elements, element selection, convergence, and error estimation. Applications to heat transfer, diffusion, stress analysis, and coupled problems. Maple and ABAQUS (a commercial non-linear finite element program) are used in this course. A term project using ABAQUS is required. Emphasis is placed on materials engineering examples.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 536 Materials Seminar Series 1.0 Credit**
MSE hosts visitors from materials and materials-related academic departments, national laboratories and industry to visit and interact with students and to present a seminar. Students will interact with visitors. Lectures on other selected topics: safety and health, ethics in science & engineering research, and writing and presentation skills.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated 12 times for 12 credits

**MATE 540 Polymer Morphology 3.0 Credits**
Covers crystallography, crystallization, single crystals, bulk crystallization, orientation, amorphous polymers, and experimental techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 541 Introduction to Transmission Electron Microscopy and Related Techniques 3.0 Credits**
This course covers fundamentals of electron optics, electron-specimen interaction, and transmission electron microscopy (TEM). Elastic (high resolution and in situ TEM) and inelastic scattering techniques (energy dispersive spectroscopy, electron energy loss speciroscopy) are reviewed. An introduction to scanning electron microscopy ( SEM), focused ion beam (FIB), and sample preparation is provided.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 542 Nuclear Fuel Cycle & Materials 3.0 Credits**
This course encompasses the nuclear fuel cycle, including extraction, enrichment, transmutation in a nuclear reactor, reprocessing, waste processing, repository performance, materials for nuclear reactors, mechanical and thermal performance will be discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 543 Thermal Spray Technology 3.0 Credits**
Thermal spray technology and coatings provides "solutions" to a large number of surface engineering problems - wear, corrosion, thermal degradation. This course will [i] be of interest and use to students majoring in materials, mechanical, chemical, electrical & environmental engineering; [ii] provide a thorough grounding and understanding of thermal spray processes, their principles and applications; [iii] integrate this knowledge with practical engineering applications and current industrial surfacing practice.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 544 Nanostructured Polymeric Materials 3.0 Credits**
This course is designed to address the role of polymer science in Nanotechnology. Topics that will be covered include block copolymer templated self assembly, polymer thin and thick films, LBL, self assembly, soft lithography and polymer nanocomposites.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 501 [Min Grade: C]

**MATE 545 Fracture of Polymeric Materials 3.0 Credits**
Theoretical strength; defects; brittle fracture;fracture surfaces; fracture mechanics; creep failure; fatigue failure; environmental stress cracking; composite failure; crazing; impact and high-speed failure.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 560 Powder Metallurgy I 3.0 Credits**
Covers commercial and near-commercial methods of powder making, material and process variables, atomization mechanisms, powder properties and characterization, powder compaction, and properties in the green state.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 561 Powder Metallurgy II 3.0 Credits**
Covers powder consolidation: pressing and sintering; preform forging, rolling, extrusion, and hot isostatic pressing; innovative powder processing techniques, including spray forming; and structure-property relationships in press and sinter and fully dense materials.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 563 Ceramics 3.0 Credits**
This course deals with the structure and bonding of ceramics. The fundamental role of point defects on electric and diffusional properties is discussed. Sintering, both solid and liquid phase, is explored. What affects strength, creep, subcritical crack growth and fatigue of ceramics is elucidated. Glasses and their properties are examined.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 565 Crystal Mechanics I 3.0 Credits**
Covers crystal plasticity, texture development, continuum aspects of dislocations, interaction and intersection of dislocations, dislocation multiplication, dislocations in crystalline solids, and dislocation boundaries and configurations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 566 Crystal Mechanics II 3.0 Credits**
Covers Peierls-Nabarro stress, thermally activated flow, work hardening, creep, superplasticity, ductile and brittle fracture, and fatigue.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 570 Materials Processing I 3.0 Credits**
Covers metal deformation processes: slab and deformation work analyses; slip line theory; and upper bound analysis applied to upsetting, drawing, extrusion, rolling, and deep drawing.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MATE 571 Materials Processing II 3.0 Credits**
Manufacture of objects from powder--atomization, compaction, sintering, and liquid phase consolidation techniques; deformation processing of powder preforms; manufacture of shapes by high-strength cold deformation-preferred orientation, substructure, strengthening mechanisms.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MATE 572 Materials for High Temperature and Energy 3.0 Credits**
This graduate level introduction to high temperature materials and materials used for energy applications, deals with metals and ceramics that are used in systems that produce or store energy, such as power generation facilities, solid oxide fuel cells, batteries, photovollaics, thermoelectric generators and supercapacitors.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 573 Electronic, Magnetic and Optical Characterization of Energy Materials 3.0 Credits**
This course will examine the selection criteria for component materials in each of these applications and cover how critical properties – electronic conductivity, mobility, ionic conductivity, magnetization, optical absorption, Seebeck coefficient – are measured.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 576 Recycling of Materials 3.0 Credits**
This course will examine the selection criteria for recycling component materials. Recycling involves both reusing materials for energy applications and reprocessing materials into new products.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 580 Special Topics in Materials Engineering 0.5-9.0 Credits**
Covers selected advanced-level topics. May be repeated for credit if topics vary.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MATE 582 Materials for Energy Storage 3.0 Credits**
The course will address principles of operation of electrochemical energy storage devices and describe materials used in those devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 583 Environmental Effects on Materials 3.0 Credits**
Environmental degradation is explored with focus on electrochemical corrosion reactions in metals and alloys due to atmospheric, aqueous, chemical or elevated temperature exposure. In addition, high temperature degradation of ceramics and degradation of polymers due to exposure to heat, light and chemicals will be addressed. The role of these environmental effects during service and the impact on performance and reliability will be explored.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 585 Nanostructured Carbon Materials 3.0 Credits**
Covers advanced carbon materials ranging from diamond to fullerenes and nanotubes. Structure, properties and applications will be discussed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 602 Soft Materials 3.0 Credits**
This course is designed to introduce the field of Soft Materials to senior undergraduate and graduate students. Topics that will be covered include Polymers, Gels, Colloids, Amphiphiles and Liquid Crystals.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 605 Computer Simulation of Materials and Processes I 4.0 Credits**
Simulation of equilibrium and transport properties of materials by Monte Carlo and molecular dynamics methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 610 Mechanical Behavior of Solids 3.0 Credits**
Covers stress and strain, three-dimensional nomenclature, hydrostatic and deviatoric stresses, isotropic and anisotropic elasticity and plasticity, viscoelasticity, crack growth, and fracture.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 651 Advanced Polymer Processing 3.0 Credits**
Covers continuum mechanics; heat transfer; application to extrusion, calendering, coating, injection molding, film blowing, rotational molding, and fiber spinning; powder processing; design; and equipment selection.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 661 Biomedical Materials I 3.0 Credits**
This course covers biocompatibility; implantable devices; survey of materials properties; corrosion;; cardiovascular applications; orthopedic applications; kidney dialysis; artificial heart and lung devices.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 662 Biomedical Materials II 3.0 Credits**
This course covers phase equilibria; strengthening of materials; dental cast alloys; denture base materials; adhesives and sealants; porcelain and glasses; dental materials laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MATE 699 Independent Study and Research 0.5-9.0 Credits**
Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MATE 702 Natural Polymers 3.0 Credits**
This course provides an introduction to natural and biomimetic polymers with an interdisciplinary view of biology, chemistry and macromolecular science. An understanding of natural building blocks and methods by which nature carries out polymer synthesis and modification reactions is coupled with insights into DNA; structural proteins; polysaccharides; and a wide variety of renewable resources.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MATE 501 [Min Grade: C]

**MATE 897 Research 1.0-12.0 Credit**
Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is MATE or major is MSE.

**MATE 898 [WI] Master's Thesis 1.0-12.0 Credit**
Hours and credits to be arranged. This is a writing intensive course.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is MATE or major is MSE.

**MATE 998 Ph.D. Dissertation 1.0-12.0 Credit**
Hours and credits to be arranged.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Restrictions:** Can enroll if major is MATE or major is MSE.

# Mechanical Engineering and Mechanics

*Master of Science in Mechanical Engineering and Mechanics (MSME): 45.0 quarter credits*
*Doctor of Philosophy: 90.0 quarter credits*

## About the Program

The Mechanical Engineering and Mechanics (MEM) Department offers MS and PhD degrees. The courses often associate with one or more areas of specialization: design and manufacturing, mechanics, systems and control, and thermal and fluid sciences. The mechanical engineering field is rapidly changing due to ongoing advances in modern science and technology. Effective mechanical engineers must possess expertise in mechanical engineering core subjects, interdisciplinary skills, teamwork skills, as well as entrepreneurial and managerial abilities. The degree programs are designed so students can learn the state-of-the-art knowledge now, and have the foundation to acquire new knowledge as they develop in future.

The MS degree program is offered on both a full-time and a part-time basis. The General (Aptitude) Test of the Graduate Record Examination (GRE) is required for applicants pursuing full-time study. Graduate courses are often scheduled in the late afternoon and evening, so full-time students and part-time students can take the same courses. The department has recently adopted the Graduate Co-op program at the master's level as an option.

The PhD degree program is offered for full-time students only and is a research intensive program. The research areas include, but are not limited to, bio-engineering, energy systems, high performance materials, nanotechnology, plasma science and engineering, and robotics.

## Admission Requirements

Applicants must meet the graduate requirements for admission to Drexel University. Students holding a bachelor's degree in a science or engineering discipline other than mechanical engineering are advised to take several undergraduate courses as preparation for graduate studies. Though these courses are not counted toward the required credits for the degree, they also must be listed in the student's plan of study. Outstanding students with a GPA of at least 3.5 in their master's program will be considered for admission to the program leading to the doctor of philosophy degree in mechanical engineering.

## Master of Science in Mechanical Engineering and Mechanics

### Requirements

The MS program has a two-fold mission: to prepare some students for continuation of their graduate studies and research toward a PhD degree, and to prepare other students for a career in industry upon graduation with the MS degree. The MS program has a non-thesis option and a thesis option. Students who plan to continue to the PhD degree are advised to select the thesis-option.

The MS program is structured so that students have the opportunity to specialize in areas of interest while also obtain the broadest engineering education possible. Of the required 45.0 credits (15 courses) MS students are required to complete two core-course sequences (two terms each) from two different core areas. Students can take eight technical elective courses of which up to four courses can be from outside the Mechanical Engineering and Mechanics Department if they are approved in the students' plan of study. MS students have opportunity to apply to the optional graduate Co-op program. Students in the MS program should consult with the department graduate adviser at the beginning of their program and must file a plan of study prior to the third quarter of study. Further details can be obtained from the department's Graduate Programs Manual (http://www.drexel.edu/mem/programs/graduate/GradPgmManual) .

**Typical MS Program**

| | |
|---|---|
| Two Core-Course Sequences (required) | 12.0 |
| Three Mathematics Courses (required) [*] | 9.0 |
| Eight Technical Electives (including 9 credits for thesis option) | 24.0 |
| **Total Credits** | **45.0** |

[*]    Mathematics courses: MEM 591, MEM 592, MEM 593.

## Core Areas

All students take core courses in the department's areas of specialization as part of a comprehensive and flexible program. Further details can be obtained from the department's Graduate Programs Manual (http://www.mem.drexel.edu/current/graduate/manual.php).

The core courses in each area are listed below:

| **Mechanics Area** | | |
|---|---|---|
| **Theory of Elasticity** | | |
| MEM 660 | Theory of Elasticity I | 3.0 |
| MEM 661 | Theory of Elasticity II | 3.0 |
| **Solid Mechanics** | | |
| MEM 663 | Continuum Mechanics | 3.0 |
| MEM 664 | Introduction to Plasticity | 3.0 |
| **Advanced Dynamics** | | |
| MEM 666 | Advanced Dynamics I | 3.0 |
| MEM 667 | Advanced Dynamics II | 3.0 |
| **Systems and Control Area** | | |
| **Robust Control Systems** | | |
| MEM 633 | Robust Control Systems I | 3.0 |
| MEM 634 | Robust Control Systems II | 3.0 |
| **Non-Linear Control Theory** | | |
| MEM 636 | Theory of Nonlinear Control I | 3.0 |
| MEM 637 | Theory of Nonlinear Control II | 3.0 |
| **Real-Time Microcomputer Control** | | |
| MEM 639 | Real Time Microcomputer Control I | 3.0 |
| MEM 640 | Real Time Microcomputer Control II | 3.0 |
| **Thermal and Fluid Sciences Area** | | |
| **Advanced Thermodynamics** [*] | | |
| MEM 601 | Statistical Thermodynamics I | 3.0 |

| MEM 602 | Statistical Thermodynamics II | 3.0 |
|---------|-------------------------------|-----|
| **Heat transfer** | | |
| MEM 611 | Conduction Heat Transfer | 3.0 |
| MEM 612 | Convection Heat Transfer | 3.0 |
| or MEM 613 | Radiation Heat Transfer | |
| **Fluid Mechanics** * | | |
| MEM 621 | Foundations of Fluid Mechanics | 3.0 |
| MEM 622 | Boundry Layers-Laminar & Turbulent | 3.0 |

* Consult the Thermal and Fluid Sciences area advisor for other options.

# PhD in Mechanical Engineering

Outstanding students with a GPA of at least 3.5 in their master's program will be considered for admission to the program leading to the Doctor of Philosophy degree in mechanical engineering.

### PhD Course Requirements

At least 90.0 credits are required for the PhD degree. The master's degree is not a prerequisite for the PhD, but does count as 45.0 credits toward the 90.0 credit requirement.

For students entering the PhD program with a prior MS degree:

- 45.0 credits of graduate courses out of which 18.0 credits are graduate courses exclusive of independent study and dissertation. If the MS degree was not from Drexel's Mechanical Engineering and Mechanics (MEM) Department, 12.0 of these 18.0 credits must be MEM graduate courses (600-level or above). The remaining 27.0 credits consist of a combination of dissertation, independent study, and additional advanced coursework consistent with the approved plan of study.

For students entering the PhD program with a BS degree but without a prior master's degree:

- 90.0 credits of graduate courses. 45.0 of these 90.0 credits must satisfy the MS in Mechanical Engineering degree requirements. The remaining 45.0 credits must satisfy the requirements above.

### PhD Candidacy Examination

A graduate student in the PhD program needs be nominated by his/her supervising adviser to take the candidacy examination. A student who enters the PhD program with a prior MS degree must take the Candidacy Examination within the first year after entry to the PhD program. A student who enters the PhD program without a prior MS degree must take the Candidacy Examination within 2 years after entry to the PhD program.

The Candidacy Examination consists of two components: A course-component examination and a research-component examination. The student must demonstrate excellence in both components. The research-component examination consists of a written report and an oral presentation. The Candidacy Committee selects three or more research papers in the student's declared research area for student to conduct a critical review. In three weeks the student submits a written report. One week after the written report is submitted the student makes an oral presentation. The presentation is followed by questions by the Committee. The goals of the questions: To evaluate the student's knowledge in the scientific fields related to the research area, including related background and fundamental material, and the student's ability to integrate information

germane to success in research. Additional details are given in the Mechanical Engineering and Mechanics Graduate Program Manual.

### Thesis Proposal

At least one year prior to graduation, the PhD candidate must give a thesis proposal to the dissertation advisory committee. The student must submit a written proposal and make a presentation. The written proposal normally includes: abstract, introduction, detailed literature review, preliminary results, proposed research tasks and timetable. The committee will approve/reject the thesis topic, the scope of work and the general method of attack.

### Thesis Defense

A final examination consisting of a presentation and defense of the research dissertation is required, before the PhD degree is granted.

Further details can be obtained from the department's Graduate Programs Manual (http://www.drexel.edu/mem/programs/graduate/GradPgmManual) .

## Facilities

A. J. Drexel Plasma Institute (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=11)
The A. J. Drexel Plasma Institute (DPI) was formed in 2002 to stimulate and coordinate research projects related to plasma and other modern high energy engineering techniques. Today the DPI is an active multidisciplinary organization involving 23 faculty members from 6 engineering departments working in close collaboration with School of Biomedical Engineering, College of Arts and Sciences and College of Nursing and Health Professions.

Advanced Design and Manufacturing Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=6)
This laboratory provides research opportunities in design methodology, computer-aided design, analysis and manufacturing, and materials processing and manufacturing. Facilities include various computers and software, I-DEAS, Pro/E,ANSYS, MasterCAM, Mechanical DeskTop, SurfCAM, Euclid, Strim, ABQUS, and more.The machines include two Sanders Model Maker rapid prototyping machines, a BridgePort CNC Machining Center, a BOY 220 injection molding machine, an Electra high-temperature furnace for metal sintering, infiltration, and other heat treatment.

Biofluid Mechanics Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=5)
The biofluid mechanics laboratory conducts computational and experimental research on the dynamics of flow in the cardiovascular and respiratory system, and the effects of flow on biological processes, particularly hemostasis and thrombosis. Lab resources include high-performance engineering workstations, commercial computational fluid dynamics (CFD) software, and basic experimental facilities including Laser Doppler Velocimetry (LDV), pressure and flow transducers, pumps, and microscopes.

Biological Systems Analysis Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=5)
The research in the Laboratory for Biological Systems Analysis involves the integration of biology with systems level engineering analysis and design, with an emphasis on: (1) the development of robotic systems that borrow from nature's designs and use novel technologies to achieve superior performance and function; and (2) the use of system identification techniques to evaluate the functional performance of animal physiological systems under natural, behavioral conditions. Facilities

include rapid prototyping machines, compliant material manufacturing, mold making facilities, and a traditional machine shop and electronics workshop.

Biomechanics Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=2)
Emphasis in this laboratory is placed on understanding the mechanical properties of human joints, characterization of the mechanical properties of biological materials, studies of human movements, and design and development of artificial limbs. Facilities include a 3-D kinematic measuring system, Instron testing machine, and microcomputers for data acquisition and processing. Additional biomechanical laboratory facilities are available at Moss Rehab Hospital.

Combustion, Fuel Chemistry, and Emissions Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
Emphasis in this laboratory is placed on developing an understanding of both the chemical and physical factors that control and, hence, can be used to tailor combustion processes for engineering applications. Facilities include two single cylinder research engines, a pressurized flow reactor (PFR) facility, flat flame and slot burner systems, and complete analytical and monitoring instrumentation. The engine systems are used to study the effects of operating variables, fuel type, ambient conditions, and control devices on engine performance and emissions. The PFR facility is used for detailed kinetic studies of hydrocarbon pyrolysis and oxidation processes.

Combustion Diagnostics Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
High speed cameras, spectrometers, and laser systems are used to conduct research in (1) low temperature hydrocarbon oxidation, (2) cool flames, and (3) plasma-assisted ignition and combustion. Research in optical diagnostic development is conducted in this lab with a specific focus on tools to measure small peroxy radicals.

Complex Fluids and Multiphase Transport Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
The research focus of this lab lies at the interface of thermal-fluid sciences, nano materials, and colloid and surface sciences. We apply these fundamental sciences to advance energy conversion and storage systems, to provide effective thermal management solutions, and to enable scalable additive nanomanufacturing. Facilities include materials printing systems, fluorescence microscope and imaging systems, complex fluid characterization, microfluidics and heat transfer testers, coating and solar cell testing devices, electrochemical characterization, and high performance computing facilities.

Composite Mechanics Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
Emphasis in this laboratory is placed on the characterization of performance of composite materials. Current interest includes damage mechanisms, failure processes, and time-dependent behavior in resin-, metal-, and ceramic-matrix composites. Major equipment includes servo-hydraulic and electromechanical Instron testing machines, strain/displacement monitoring systems, environmental chambers, microcomputers for data acquisition and processing, composites fabrication facility, interferometric displacement gauge, X-radiography, and acoustic emission systems.

Dynamic Multifunctional Materials Laboratory (DMML) (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
The focus of DMML is mechanics of materials; namely fracture and failure mechanisms under extreme conditions and their correlation to meso- and

microstructural characteristics. Utilizing highly integrated experimental facilities such as a Kolsky (split-Hopkinson pressure bar), single-stage, and two stage light-gas gun, complex material behavior is deconstructed into dominant time and length scales associated with the energetics of damage evolution. In-situ laser and optical diagnostics such as caustics, interferometry techniques, schlieren visualization and virtual grid method, are used to investigate coupled field properties of multifunctional materials with the goal of not only analyzing and understanding behavior, but ultimately tailoring material properties for specific applications.

Electrochemical Energy Systems Laboratory (ECSL) (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
The ECSL is specializes in the design, diagnostics and characterization of next generation electrochemical energy conversion and storage systems. Current areas of research include flow-assisted supercapacitors, next generation flow battery technology and fuel cells for transportation, stationary and portable applications. ECSL utilizes a comprehensive approach, including: advanced diagnostics, system design, materials characterization, and computational modeling of electrochemical energy systems. The core mission of ECSL is to develop novel diagnostic and computational tools to understand critical issues in flow-assisted electrochemical systems and enable better system design. Due to the complex nature of these systems, our research is highly interdisciplinary and spans the interface of transport phenomena, materials characterization, electrochemistry and system engineering.

Microcomputer Controls Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=7)
This laboratory provides an environment conducive to appreciating aspects of systems and control through hands-on experiments. They range from data acquisition and processing to modeling of dynamical systems and implementing a variety of controllers to control systems, such as DC motors and the inverted pendulum. Facilities also include microcontrollers such as Basic Stamp and the Motorola 68HCI 1. Active research is being conducted on control reconfiguration in the event of actuator failures in aircrafts.

Non-Newtonion Fluid and Heat Transfer Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=7)
Emphasis in this laboratory is placed on the study of hydrodynamic and thermal performance of various non-Newtonian viscoelastic fluids in complex flow geometries. Facilities and equipment include a 20-foot-long recirculating flow loop with a 500-gallon reservoir tank and a thermal conductivity measurement cell. A complete data acquisition system provides fully automated experimental operation and data reduction. A state-of-the-art finite element code FIDAP running on a CDC 180 computer provides three-dimensional flow and heat transfer simulations of flows in complex geometrics, with a complete post-processing graphic capability backed by template.

Precision Instrumentation and Metrology Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=7)
This laboratory is focused on activities related to precision measurement, computer-aided inspection, and precision instrument design. Facilities include 3D Coordinate Measuring Machine (Brown & Sharpe) with Micro Measurement and Reverse engineering software, Surface Profilometer, and Laser Displacement Measuring System.

Rheology Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=7)
Emphasis in this laboratory is placed on developing tools for rheological property measurement of various non-Newtonian fluids, including friction-reducing viscoelastic fluids, molten polymers, coal-water slurries,

ceramic slurries, and bonding cements for biomedical applications. A capillary tube viscometer, falling ball and needle viscometers, and Brookfield rotating viscometer are available. In particular, the capillary tube viscometer is designed to allow fully automated operation, thus avoiding time-consuming data collection procedures. A high-temperature and high-pressure capillary tube viscometer is under development, so that viscosities of advanced polymer materials can be measured at relatively high temperatures and shear rates.

Space Systems Laboratory (SSL) (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
The objective of SSL is ". . . to inspire future generations to advance aerospace engineering.' It provides research opportunities in orbital mechanics, rendezvous and docking maneuvers, mission planning, and space environment. The lab provides facilities for activities in High Altitude Balloons, construction of air-vehicles and nano-satellites, 0-g flights, and STK simulation package for satellite flights and trajectories.

Theoretical and Applied Mechanics Group (TAMG) (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
Research in the TAMG focuses on using experimental, analytical and computational tools to understand deformation and failure of materials, components and structures in a broad range of time and length scales. To accomplish this goal, TAMG develops procedures that include mechanical behavior characterization coupled with non-destructive testing and modern computational tools. This information is used both for understanding the role of important material scales in the observed bulk behavior and for the formulation of constitutive laws that can model the response including damage initiation and progression according to prescribed loading conditions. Equipment and facilities used by TAMG include a range of mechanical testing equipment for testing in tension, compression, fatigue and fracture as well as: a) two multichannel Acoustic Emission systems, b) a 5 Megapixel Digital Image Correlation system, c) a FLIR infrared thermography camera, and d) a 64-core High Performance Computational Cluster. TAMG has further developed procedures to use several pieces of equipment and facilities at Drexel University including the Machine Shop, Centralized Research Facilities and the University Research Computing Faci

Thermal Systems Laboratory (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
The thermal systems laboratory is outfitted with an array of instrumentation and equipment for conducting single- and multiphase heat transfer experiments in controlled environments. Facilities include computer-controlled data acquisition (LabVIEW ) systems, a Newport holographic interferometric system with associated lasers and optics, image enlargers, power amplifiers, precision voltmeters, slip-ring assemblies, and workstation for large-scale computing and simulation. A draft-free room is available with independent temperature control for carrying out natural convection experiments. An experimental test-rig is available for studying heat transfer from rotating surfaces. A bubble column has been recently built to study multiphase flow and heat transfer problems. Facilities are also available for measuring thermal conductivities of thin films using a thermal comparator.

Vascular Kinetics Laboratory (VKL) (http://www.mem.drexel.edu/current/labs/?m=research&a=lab_desc&labID=1)
The VKL uses engineering methods to understand how biomechanics and biochemistry interact in cardiovascular disease. In particular, we study fluid flow and blood vessel stiffness impact cellular response to glucose, growth factors, and inflammation to lead to atherosclerosis and metabolic syndrome. We then apply these discoveries to novel biomaterials and therapies, with a particular focus on treating cardiovascular disease in

under-served populations. This research is at the interface of engineering and medicine, with close collaborations with biologists and physicians and a strong emphasis on clinical applications.

## Mechanical Engineering and Mechanics Faculty

Jonathan Awerbuch, DSc *(Technion, Israel Institute of Technology)*. Professor. Mechanics of composites; fracture and fatigue; impact and wave propagation; structural dynamics.

Nicholas P. Cernansky, PhD *(University of California-Berkeley) Hess Chair Professor of Combustion.* Professor. Combustion chemistry and kinetics; combustion generated pollution; utilization of alternative and synthetic fuels.

Bor-Chin Chang, PhD *(Rice University)*. Professor. Computer-aided design of multivariable control systems; robust and optimal control systems.

Young I. Cho, PhD *(University of Illinois-Chicago)*. Professor. Heat transfer; fluid mechanics; non-Newtonian flows; biofluid mechanics; rheology.

Alisa Clyne, PhD *(Harvard-Massachusetts Institute of Technology)*. Associate Professor. Cardiovascular biomechanics.

Bakhtier Farouk, PhD *(University of Delaware) Billings Professor of Mechanical Engineering.* Professor. Heat transfer; combustion; numerical methods; turbulence modeling; materials processing.

Alexander Fridman, DSc, PhD *(Moscow Institute of Physics and Technology) Mechanical Engineering and Mechanics, John A. Nyheim Endowed University Chair Professor, Director of the Drexel Plasma Institute.* Professor. Plasma science and technology; pollutant mitigation; super-adiabatic combustion; nanotechnology and manufacturing.

Ani Hsieh, PhD *(University of Pennsylvania)*. Assistant Professor. Multi-robot systems, decentralized and distributed control, bio-inspired control, swarm robotics.

Andrei Jablokow, PhD *(University of Wisconsin; Madison)*. Associate Teaching Professor. Computational kinematics; geometric modeling.

Antonios Kontsos, PhD *(Rice University)*. Associate Professor. Applied mechanics; probabilistic engineering mechanics; modeling of smart multifunctional materials.

E. Caglan Kumbur, PhD *(Pennsylvania State University)*. Associate Professor. Next generation energy technologies; fuel cell design and development.

Harry G. Kwatny, PhD *(University of Pennsylvania) S. Herbert Raynes Professor of Mechanical Engineering.* Professor. Dynamic systems analysis; stochastic optimal control; control of electric power plants and systems.

John Lacontora, PhD *(New Jersey Institute of Technology)*. Associate Research Professor. Service engineering; industrial engineering.

Leslie Lamberson, PhD *(California Institute of Technology)*. Assistant Professor. Dynamic behavior of materials, dynamic fracture, damage micromechanics, active materials.

Alan Lau, PhD *(Massachusetts Institute of Technology) Associate Department Head for Graduate Affairs, Department of Mechanical Engineering and Mechanics.* Professor. Deformation and fracture of nano-devices and macroscopic structures; damage-tolerant structures and microstructures.

Matthew McCarthy, PhD *(Columbia University).* Assistant Professor. Micro- and nanoscale thermofluidic systems, bio-inspired cooling, smart materials and structures for self-regulated two-phase cooling, novel architectures for integrated energy conversion and storage.

David L. Miller, PhD *(Louisiana State University) Department Head.* Professor. Gas-phase reaction kinetics; thermodynamics; biofuels.

Hongseok (Moses) Noh, PhD *(Georgia Institute of Technology).* Associate Professor. MEMS; BioMEMS; lab-on-a-chip; microfabrication; microfluidics.

Paul Y. Oh, PhD *(Columbia University).* Adjunct Professor. Smart sensors servomechanisms; machine vision and embedded microcomputers for robotics and mechatronics.

Sorin Siegler, PhD *(Drexel University).* Professor. Orthopedic biomechanics; robotics; dynamics and control of human motion; applied mechanics.

Wei Sun, PhD *(Drexel University) Albert Soffa Chair Professor of Mechanical Engineering.* Professor. Computer-aided tissue engineering; solid freeform fabrication; CAD/CAM; design and modeling of nanodevices.

Ying Sun, PhD *(University of Iowa).* Associate Professor. Transport processes in multi-component systems with fluid flow; heat and mass transfer; phase change; pattern formation.

Tein-Min Tan, PhD *(Purdue University).* Associate Professor. Mechanics of composites; computational mechanics and finite-elements methods; structural dynamics.

James Tangorra, PhD *(Massachusetts Institute of Technology) Associate Department Head for Finance and Administration, Department of Mechanical Engineering and Mechanics.* Associate Professor. Analysis of human and (other) animal physiological systems; head-neck dynamics and control; balance, vision, and the vestibular system; animal swimming and flight; robotics; system identification; bio-inspired design.

Christopher Weinberger, PhD *(Stanford University).* Assistant Professor. Multiscale materials modeling of mechanical properties including DFT, atomistics, mesoscale and microscale FEM modeling.

Ajmal Yousuff, PhD *(Purdue University).* Associate Professor. Optimal control; flexible structures; model and control simplifications.

Jack G. Zhou, PhD *(New Jersey Institute of Technology).* Professor. CAD/CAM; computer integrated manufacturing systems; rapid prototyping; system dynamics and automatic control.

## Interdepartmental Faculty

Richard Chiou, PhD *(Georgia Institute of Technology).* Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Michael Glaser, MFA *(Ohio State University) Program Director for Product Design.* Assistant Professor. Quantifying the designer's intuition; the

interplay between digital and physical forms; human desire to shape our surroundings.

Yury Gogotsi, PhD *(Kiev Polytechnic Institute) Director, A. J. Drexel Nanotechnology Institute.* Distinguished University & Trustee Chair Professor. Nanomaterials; carbon nanotubes; nanodiamond; graphene; MXene; materials for energy storage, supercapacitors, and batteries.

Y. Grace Hsuan, PhD *(Imperial College).* Professor. Polymeric and cementitioius materials; geosynthetic reliability and durability.

Michele Marcolongo, PhD, PE *(University of Pennsylvania) Department Head.* Professor. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Roger Marino, PhD *(Drexel University).* Associate Teaching Professor. Fluid Mechanics, Water Resources, Engineering Education, Land Development

Mira S. Olson, PhD *(University of Virginia).* Associate Professor. Groundwater; environmental fluid mechanics; hydrology.

William C. Regli, PhD *(University of Maryland-College Park).* Professor. Artificial intelligence; computer graphics; engineering design and Internet computing.

Jonathan E. Spanier, PhD *(Columbia University) Associate Dean, Strategic Planning, College of Engineering.* Professor. Electronic, ferroic and plasmonic nanostructures and thin-film materials and interfaces; scanning probe microscopy; laser spectroscopy, including Raman scattering.

## Emeritus Faculty

Leon Y. Bahar, PhD *(Lehigh University).* Professor Emeritus. Analytical methods in engineering, coupled thermoelasticity, interaction between analytical dynamics and control systems.

Pei C. Chou, ScD *(Aeronautical Engineering from New York University) Billings Professor Emeritus of Mechanical Engineering.* Professor Emeritus. Material response due to impulsive loading, wave propagation in isotropic and composite materials, manufacturing technology.

Gordon D. Moskowitz, PhD *(Princeton University).* Professor Emeritus. Biomechanics, dynamics, design, applied mathematics.

Donald H. Thomas, PhD *(Case Institute of Technology).* Professor Emeritus. Biocontrol theory, biomechanics, fluidics and fluid control, vehicle dynamics, engineering design.

Albert S. Wang, PhD *(University of Delaware) Albert and Harriet Soffa Professor.* Professor Emeritus. Treatment of damage evolution processes in multi-phased high-temperature materials, including ceramics and ceramic-matrix composites.

# Courses

**MEM 503 Gas Turbines & Jet Propulsion 3.0 Credits**
Covers fundamentals of thermodynamics and aerothermodynamics, and application to propulsion engines; thermodynamic cycles and performance analysis of gas turbines and air-breathing propulsion systems, turbojet, turboprop, ducted fan, ramjet, and ducted rocket; theory and design of ramjets, liquid and solid rockets, air-augmented rockets, and hybrid rockets; aerodynamics of flames, including the thermodynamics and kinetics of combustion reactions; supersonic combustion technology and zero-g propulsion problems; and propulsion systems comparison and evaluation for space missions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 504 HVAC Equipment 3.0 Credits**
Covers performance of air handlers, pumps, direct expansion systems, chillers, cooling towers, and similar equipment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 505 HVAC Controls 3.0 Credits**
Covers control theory and application to heating, ventilating, air conditioning, including pneumatic, fluidic, and electronic controls.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 517 Fundamentals of Nanomanufacturing 3.0 Credits**
This course introduces conventional methods that emerged from microelectronics and nonconventional or alternative approaches as applied to fabricate nanometer-scale biological and solid-state devices; Preliminary concepts for nanofabrication; Conventional lithographic methods; Nonconventional methods such as nanoimprint lithography and chemical and biological approaches; Cell culturing for application in biology; The safe development and use of advanced nanotechnological manufacturing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** (MEM 417 [Min Grade: C] and ENGR 201 [Min Grade: C] and ENGR 202 [Min Grade: C]) or PHYS 201 [Min Grade: C]

**MEM 518 Introduction to Nanoscale Metrology 3.0 Credits**
Highlights the most innovative and powerful developments in nano/ microscale diagnostics; Reviews conventional and non-conventional micro- and nanofabrication, preliminary concepts for nanoscale metrology; Covers optical diagnostics for microfluidics and nanofluidics, scanning electron microscopy, transmission electron microscopy, atomic force microscopy, ionic current blockage measurement, mass spectroscopy and UV-Vis spectroscopy, and laser induced fluorescence.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 530 Aircraft Flight Dynamics & Control I 3.0 Credits**
Covers development of dynamic models, linearization, aerodynamic coefficients, control derivatives, longitudinal and lateral modes, and open-loop analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 540 Control Applications of DSP Microprocessors 3.0 Credits**
Most of the control systems today are digital and implemented using microprocessors. In this course, the students will learn how to employ the state-of-the-art DSP microprocessors to perform analog-to-digital conversion, digital-to-analog conversion, digital signal processing, decision making, and feedback control action to achieve precise regulation/ tracking, disturbance reduction, and robust stability/ performance for physical systems. In addition to lectures by the instructor, the course will feature eight hands-on lab projects centered on the design and microprocessor implementation of digital controllers for MIMO (multi-input-multi-output) electro-mechanical systems. Cross-listed with undergraduate course MEM 459.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 545 Solar Energy Fundamentals 3.0 Credits**
This course focuses on basic theories of solar radiation, solar thermal energy, and photovoltaics. Students will learn basic radiation heat transfer, solar radiation, solar thermal collection and storage, passive and active solar heating/cooling, physics of photovoltaic cells, and characteristics and types of solar cells.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 345 [Min Grade: D] or PHYS 201 [Min Grade: D]

**MEM 569 Introduction to Composite Materials I 3.0 Credits**
Introduces anisotropic elasticity, lamina stiffness and compliance, plane-stress and plane-strain, stress-strain relations of a lamina, testing methods, engineering elastic constants, failure criteria, and micromechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 570 Introduction to Composite Materials II 3.0 Credits**
Covers laminated plate theory, stiffness and compliance of laminated plates, effect of laminate configuration on elastic performance, and review of research topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 569 [Min Grade: C]

**MEM 571 Introduction to Robot Technology 3.0 Credits**
Covers robot configuration; components, actuators, and sensors; vision; and control, performance, and programming. Includes lectures and laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 572 Mechanics of Robot Manipulators 3.0 Credits**
Covers homogeneous transformation, direct and inverse kinematic manipulators, velocities and acceleration, static forces, and manipulators' dynamics, via Lagrange and Newton-Euler formulations. Includes lectures and laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 666 [Min Grade: C]

**MEM 573 Industrial Application of Robots 3.0 Credits**
Covers path planning and workspace determination, robot accuracy and repeatability measurements, robot call design, application engineering and manufacturing, material transfer, processing operations, and assembly and inspection. Includes lectures and laboratory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 574 Introduction to CAM 3.0 Credits**
Examines the basic elements used to integrate design and manufacturing processes, including robotics, computerized-numerical controlled machines, and CAD/CAM systems. Covers manufacturability considerations when integrating unit process elements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 591 Applied Engr Analy Methods I 3.0 Credits**
Covers effective methods to analyze engineering problems. This module focuses on analytical and computational methods for problems tractable with vectors, tensors and linear algebra. Uses symbolic/numerical computational software. Examples drawn from thermal fluid sciences, mechanics and structures, systems and control, and emerging technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 592 Applied Engr Analy Methods II 3.0 Credits**
Covers effective methods to analyze engineering problems. This module focuses on computational and analytical methods for complex variables and ordinary differential equations. Uses symbolic/numerical computational software. Examples drawn from thermal fluid sciences, mechanics and structures, systems and control, and emerging technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 591 [Min Grade: C]

**MEM 593 Applied Engr Analy Methods III 3.0 Credits**
Covers effective methods to computationally and analytically solve engineering problems. This module focuses on solution methods for partial differential equations, Fourier analysis, finite element analysis and probabilistic analysis. Uses symbolic/numerical computational software. Examples drawn from mechanical and civil engineering.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 592 [Min Grade: C]

**MEM 601 Statistical Thermodynamics I 3.0 Credits**
Covers probability theory; statistical interpretation of the laws of thermodynamics; systems of independent particles; systems of dependent particles; kinetic theory of dilute gases; quantum mechanics; energy storage and degrees of freedom; and thermochemical properties of monatomic, diatomic, and polyatomic gases.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 602 Statistical Thermodynamics II 3.0 Credits**
Covers analysis of monatomic solids, theory of liquids, chemical equilibrium, kinetic and thermochemical description of rate processes, transport phenomena, and spectroscopy.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 601 [Min Grade: C]

**MEM 603 Advanced Thermodynamics 3.0 Credits**
Covers reformulation of empirical thermodynamics in terms of basic postulates; presentation of the geometrical, mathematical interpretation of thermodynamics; Legendre transforms; requirements for chemical and phase equilibrium; first-and second-order phase transitions; Onsager reciprocal relations; and irreversible thermodynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 611 Conduction Heat Transfer 3.0 Credits**
Covers conduction of heat through solid, liquid, and gaseous media; advanced analytical methods of analysis, including integral transform and Green's functions, the use of sources and sinks, and numerical and experimental analogy methods; and variational techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 612 Convection Heat Transfer 3.0 Credits**
Covers convective heat transfer without change of phase or constitution, fundamental equations, exact solutions, application of the principle of similarity and the boundary-layer concept to convective heat transfer, similarity between heat and momentum transfer, and heat transfer in high-velocity flows.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 613 Radiation Heat Transfer 3.0 Credits**
Covers radiation heat transfer between surfaces and within materials that absorb and emit. Formulates and applies methods of analysis to problems involving radiation alone and radiation combined with conduction and convection.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 617 Introduction to Microfabrication 3.0 Credits**
This course focuses on the fundamentals of microfabrication technologies. The materials, principles, and applications of silicon-based microfabrication technologies such as photolithography, wet/dry etching, deposition techniques, surface micromachining, and polymer micromachining will be covered. This course also includes two lab sessions through which students will have a hands-on experience in microfabrication.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 619 Microfluidics and Lab-on-a-Chip 3.0 Credits**
The course explores applications of microfluidic phenomena and lab-on-a-chip technology. The topics include fluid behavior in microchannels, electrokinetic manipulation, micro-scale separation/surface sciences, transducer effects, and microactuators. Students will also have a hands-on experience through laboratory sessions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 417 [Min Grade: C] or MEM 617 [Min Grade: C]

**MEM 621 Foundations of Fluid Mechanics 3.0 Credits**
Covers kinematics and dynamics of fluid motion; Lagrangian and Eulerian description of motion; transport theorem; continuity and momentum equations (Navier-Stokes equations); vorticity vector and equation; three-dimensional, axisymmetric, and two-dimensional complex potential flows; constitutive equations of a viscous fluid; dynamic similarity; Stokes flow; and similarity analysis.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 622 Boundry Layers-Laminar & Turbulent 3.0 Credits**
Covers laminar boundary layers; approximate integral method; three-dimensional laminar boundary layer and boundary-layer control; transient boundary-layer flows; the integral momentum equation; origins of turbulence; transition to turbulent flow; Reynolds-averaged equations; Reynolds stress; measurement of turbulent quantities; study of turbulent wall bounded flows, including pipe flow, flow over a flat plate, and flow over a rotating disk; and boundary layer in a pressure gradient.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 621 [Min Grade: C]

**MEM 630 Linear Multivariable Systems I 3.0 Credits**
State space representation, continuous time and discrete time systems, similarity transformation, invariant subspaces, state response, stability, controllability, observability, Kalman decomposition, spectral and singular value decompositions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 631 Linear Multivariable Systems II 3.0 Credits**
Pole assignment, output feedback, linear quadratic regulator, observer design, stochastic processes, state response to white noise, Kalman filter, linear quadratic Gaussian controller, evaluation of closed loop system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 632 Linear Multivariable Systems III 3.0 Credits**
Model reduction: approximation of transfer functions, modal truncations, oblique projections, component cost analysis, internal balancing; controller reduction: observer-based controller parametrization, Riccati balancing, q-COVER theory, optimal projections.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 633 Robust Control Systems I 3.0 Credits**
Covers linear spaces and linear operators; Banach and Hilbert spaces; time-domain spaces; frequency-domain spaces; singular value decomposition; EISPACK, LINPACK, and MATLAB, including internal stability; coprime factorization over the ring of polynomial matrices; matrix fraction description; properties of polynomial matrices; irreducible mfds; Smith-McMillan form; poles and zeros; canonical realizations; and computation of minimal realizations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 634 Robust Control Systems II 3.0 Credits**
Covers the structure of stabilizing controllers; coprime factorization over the ring of proper stable rational matrices; algebraic Riccati equation; state space computation of coprime factorization; yvb controller parametrization; linear fractional transformation; state space structure of proper stabilizing controllers; formulation of control problem, H, and H optimization problem; model matching problem; tracking problem; robust stabilization problem; inner-outer factorization; and Sarason's H interpolation theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 633 [Min Grade: C]

**MEM 635 Robust Control Systems III 3.0 Credits**
Covers Hankel-norm approximations, balanced realizations, two-block H optimization, generalized multivariable stability margins, structured and non-structured stability margins, structured singular values, robust stabilization and performance, and recent developments in robust control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 634 [Min Grade: C]

**MEM 636 Theory of Nonlinear Control I 3.0 Credits**
Provides a comprehensive introduction to the geometric theory of non-linear dynamical systems and feedback control. Includes stability, controllability, and observability of non-linear systems; exact linearization, decoupling, and stabilization by smooth feedback; and zero dynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 637 Theory of Nonlinear Control II 3.0 Credits**
Covers systems with parameters, including bifurcation and stability; static bifurcation; local regulation of parameter-dependent non-linear dynamics; tracking; limit cycles in feedback systems; perturbation methods; frequency domain analysis; and applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 636 [Min Grade: C]

**MEM 638 Theory of Nonlinear Control III 3.0 Credits**
Covers high gain and discontinuous feedback systems, including sliding modes, applications, and advanced topics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 637 [Min Grade: C]

**MEM 639 Real Time Microcomputer Control I 3.0 Credits**
Covers discrete-time systems and the Z-transform, sampling and data reconstruction, the pulse transfer function, discrete state equations, time-domain analysis, digital simulation, stability, frequency-domain analysis, Labview programming, and data acquisition and processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 640 Real Time Microcomputer Control II 3.0 Credits**
Covers design of discrete-time controllers, sampled data transformation of analog filter, digital filters, microcomputer implementation of digital filters, Labview programming techniques, using the daq library, writing a data acquisition program, and Labview implementation of pid controllers.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 639 [Min Grade: C]

**MEM 646 Fundamentals of Plasmas I 3.0 Credits**
Introduces the fundamentals of plasma science and modern industrial plasma applications in electronics, fuel conversion, environmental control, chemistry, biology, and medicine. Topics include quasi-equilibrium and non-equilibrium thermodynamics, statistics, fluid dynamics and kinetics of plasma and other modern high temperature and high energy systems and processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 647 Fundamentals of Plasmas II 3.0 Credits**
Continues the development of the engineering fundamentals of plasma discharges applied in modern industrial plasma applications in electronics, fuel conversion, environmental control, chemistry, biology, and medicine. Topics include quasi-equilibrium and non-equilibrium thermodynamics, statistics, fluid dynamics of major thermal and non-thermal plasma discharges, operating at low, moderate and atmospheric pressures.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 646 [Min Grade: C]

**MEM 648 Applications of Thermal Plasmas 3.0 Credits**
Introduces applications of modern thermal plasma processes focused on synthesis of new materials, material treatment, fuel conversion, environmental control, chemistry, biology, and medicine. Topics include: thermodynamics and fluid dynamics of high temperature plasma processes, engineering organization of specific modern thermal plasma technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 649 Application of Non-Thermal Plasmas 3.0 Credits**
Application of modern non-thermal plasma processes focused on synthesis of new materials, material treatment, fuel conversion, environmental control, chemistry, biology, and medicine. Topics include: non-equilibrium thermodynamics and fluid dynamics of cold temperature plasma processes, engineering organization of specific modern non-thermal plasma technologies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 660 Theory of Elasticity I 3.0 Credits**
Summarizes mechanics of materials courses. Covers vector and tensor analysis, indicial notation, theory of stress, equilibrium equations, displacements and small strains, compatibility, and strain energy; formulation of the governing equations and the appropriate boundary conditions in linear elasticity, and uniqueness of the solutions; elementary three-dimensional examples and two-dimensional theory; stress functions; solutions in Cartesian and polar coordinates; and Fourier series.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 661 Theory of Elasticity II 3.0 Credits**
Covers two-dimensional problems by the method of Muskhelishvili, torsion problem, stress function and solutions by means of complex variables and conformal mapping, three-dimensional solutions for straight beams, energy theorems, virtual work and their applications, and Rayleigh-Ritz method.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 660 [Min Grade: C]

**MEM 662 Theory of Elasticity III 3.0 Credits**
Covers use of Fourier series and Green's functions for plane problems; three-dimensional problems in terms of displacement potentials; use of the Galerkin vector and the Boussinesq-Papkovitch-Neuber functions; fundamental solutions to the Kelvin, Boussinesq, Cerruti, and Mindlin problems; and elastic contact. Introduces non-linear elasticity.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 661 [Min Grade: C]

**MEM 663 Continuum Mechanics 3.0 Credits**
Covers kinematics, Eulerian, and Lagrangian formulations of deformation; theory of stress; balance principles; continuum thermodynamics; and constitutive relations in fluids and solids.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 664 Introduction to Plasticity 3.0 Credits**
Reviews stress and strain deviators, invariants and distortional energy, principal and octahedral stresses and strains, Tresca and von Mises yield criteria, yield surface and Haigh-Westergaard stress space, Lode's stress parameter, subsequent yield surface, Prandtl-Reuss relations, work hardening and strain hardening, stress-strain relations from Tresca criteria, incremental and deformation theories, the slip-line field, slip-line equations for stress, velocity equations and geometry of slip-line field, limit analysis, simple truss, bending of beams, lower and upper bound theorems, and plasticity equations in finite-element methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 660 [Min Grade: C]

**MEM 665 Time-Dependent Solid Mechanics 3.0 Credits**
Part a: Covers elastodynamics, including plane, cylindrical, and spherical waves; characteristics; the acoustic tensor; polarizations and wave speeds; transmission and reflection at plane interfaces; critical angles and surface waves; and waveguides and dispersion relationships. Part b: Covers linear viscoelasticity, including relaxation modulus and creep compliance, hereditary integrals, Laplace transform, correspondence principle, creep buckling and vibrations, viscoplasticity, creep, strain-rate effects, shear bands, and shock waves.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 660 [Min Grade: C]

**MEM 666 Advanced Dynamics I 3.0 Credits**
Covers analytical statics (principle of virtual work), Lagrange's equations, conservation laws, stability analysis by perturbation about steady state, Jacobi first integral, ignoration of coordinates, classification of constraints, solution of constrained dynamical problems by constraint embedding (elimination) or constraint adjoining (Lagrange multipliers), generalized impulse and momentum, and formulation and solution of non-holonomic systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 667 Advanced Dynamics II 3.0 Credits**
Covers vector dynamics in three dimensions, including a detailed study of rotational kinematics, motion of the mass center and about the mass center for a system of particles and a rigid body, moments of inertia, three-dimensional dynamical problems, and comparison between Lagrangian techniques and the vector methods of Euler and Newton. Includes vibrations, Euler's angles, motion of a gyroscope, and motion of an axially symmetric body under no force other than its weight.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 666 [Min Grade: C]

**MEM 668 Advanced Dynamics III 3.0 Credits**
Covers central forces, effect of the earth's rotation, Foucault's pendulum, variational methods, Hamilton's principle, state space techniques for the integration of equations of motion, and numerical integration of equations of motion on microcomputers through the CSMP program. Depending on student interest, includes either Hamiltonian dynamics (canonical equations, contact transformations, Hamilton-Jacobi theory) or rigid body kinematics of complex dynamical systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 667 [Min Grade: C]

**MEM 670 Theory of Plates and Shells 3.0 Credits**
Covers elements of the classical plate theory, including analysis of circular and rectangular plates, combined lateral and direct loads, higher-order plate theories, the effects of transverse shear deformations, and rotatory inertia; matrix formulation in the derivation of general equations for shells; and membrane and bending theories for shells of revolution.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 671 Mechanical Vibrations I 3.0 Credits**
Free and forced responses of single degree of freedom linear systems; two degree of freedom systems; multiple degree of freedom systems; the eigenvalue problem; modal analysis; continuous systems; exact solutions; elements of analytical dynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 672 Mechanical Vibrations II 3.0 Credits**
Continuous systems; approximate solutions; the finite element method; nonlinear systems; geometric theory, perturbation methods; random vibrations; computational techniques.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 673 Ultrasonics I 3.0 Credits**
Basic elements of ultrasonic nondestructive evaluation, wave analysis, transducers, transform techniques, A,B,C,M,F and Doppler imaging, medical imaging, multiple element arrays, real-time imaging, calibration.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 674 Ultrasonics II 3.0 Credits**
Basic elements of guided wave analysis, oblique incidence reflection factor, critical angle reflectivity, surface waves, lamb waves, plate waves, dispersion, phase and group velocity, experimental techniques for guided waves.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 675 Medical Robotics I 3.0 Credits**
Use of robots in surgery, safety considerations, understanding robot kinematics, analysis of surgeon performance using a robotic devices, inverse kinematics, velocity analysis, acceleration analysis, various types of surgeries case study.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 676 Medical Robotics II 3.0 Credits**
Force and movement for robot arms, robot dynamics, computer vision, vision based control, combining haptics, vision and robot dynamics in a cohesive framework for the development of a medical robotic system.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 675 [Min Grade: C]

**MEM 677 Haptics for Medical Robotics 3.0 Credits**
Introduction to haptics, physiology of touch, actuators, sensors, non-portable force feedback, portable voice feedback, tactile feedback interfaces, haptic sensing and control.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 678 Nondestructive Evaluation Methods 3.0 Credits**
This course covers the tools necessary for the inspection and evaluation of materials and infrastructures. Most relevant methods used for Non-Destructive Evaluation (NDE) of structural components will be discussed. Physical principles of continuum mechanics, electrical engineering, acoustics and elastic wave propagation underlying the NDE methods will be covered. Sensor data acquisition and digital signal processing will be addressed.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 681 Finite Element Methods I 3.0 Credits**
Covers formulation of finite element methods for linear analysis of static and dynamic problems in solids, structures, fluid mechanics, heat transfer, and field problems; displacement-based, hybrid, and stress-based methods; variational and weighted residual approaches; effective computational procedures for solution of finite element equations in static and dynamics analyses; and pre-processing and post-processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 682 Finite Element Methods II 3.0 Credits**
Covers formulation of advanced finite element methods for non-linear analysis of static and dynamic problems in solids, structures, fluid mechanics, heat transfer, and field problems; material non-linearity; large displacement; large rotation; large strain; effective solution procedures for non-linear finite element equations in static and dynamic analyses; and effective finite element methods for eigenvalue problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 681 [Min Grade: C]

**MEM 684 Mechanics of Biological Tissues 3.0 Credits**
Covers composition and structure of tendons, ligaments, skin, and bone; bone mechanics and its application in orthopedics; viscoelasticity of soft biological tissues; models of soft biological tissues; mechanics of skeletal muscle; and muscle models and their applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 685 Mechanics of Human Joints 3.0 Credits**
Covers the structure of human joints, including experimental and analytical techniques in the study of human joint kinematics; applications to the design of artificial joints and to clinical diagnosis and treatments; stiffness characteristics of joints and their applications to joint injuries; and prosthetic design and graft replacements.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 686 Mechanics of Human Motion 3.0 Credits**
Examines experimental and analytical techniques in human motion analysis and human locomotion; interdeterminacy of muscle force distribution in human motion; modeling and simulation of bipedal locomotion; energetics, stability, control, and coordination of human motion; and pathological gait.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 687 Manufacturing Processes I 3.0 Credits**
Introduces basic manufacturing process technology and the mechanical properties of metals and plastics. Covers dimensional and geometry tolerancing; surface finishing; material removal processes and machine tools; processing of polymers and reinforced plastics, including general properties of plastic materials and forming, shaping, and processing of plastics; and CNC machining and programming. Combines lectures and laboratory work.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 688 Manufacturing Processes II 3.0 Credits**
Covers processing of polymers and reinforced plastics, including general properties of plastic materials and forming, shaping, and processing of plastics; CNC machining and programming; casting processes; sheet-metal forming processes; bulk deformation processes; and computer integrated manufacturing systems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 687 [Min Grade: C]

**MEM 689 Computer-Aided Manufacturing 3.0 Credits**
Covers development of software and hardware for computer-aided manufacturing systems, basic elements used to integrate the manufacturing processes, and manufacturability studies.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 699 Independent Study and Research 0.5-9.0 Credits**
Offers independent study and research in mechanical engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 701 Physical Gas Dynamics I 3.0 Credits**
Reviews equilibrium kinetic theory of dilute gases. Covers non-equilibrium flows of reacting mixtures of gases, flows of dissociating gases in thermodynamics equilibrium, flow with vibrational or chemical non-equilibrium, non-equilibrium kinetic theory, flow with translational non-equilibrium, and equilibrium/non-equilibrium radiation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 602 [Min Grade: C]

**MEM 705 Combustion Theory I 3.0 Credits**
Covers thermochemistry, including the relationship between heats of formation and bond energies, heat capacities and heats of reaction, chemical equilibrium and the equilibrium constant, calculation of adiabatic flame temperature and composition of burned gas, free energy and phase equilibrium, classical chemical kinetics, and chain reaction theory.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 706 Combustion Theory II 3.0 Credits**
Covers laminar flame propagation in premixed gases, detonation and deflagration, heterogeneous chemical reactions, burning of liquid and solid fuels, and diffusion flames.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 705 [Min Grade: C]

**MEM 707 Combustion Theory III 3.0 Credits**
Covers advanced topics in combustion, including combustion-generated air pollution, incineration of hazardous wastes, supersonic combustion, propellants and explosives, and fires.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 706 [Min Grade: C]

**MEM 711 Computational Fluid Mechanics and Heat Transfer I 3.0 Credits**
Covers classification of fluid flow and heat transfer phenomena, including time-dependent multidimensional heat conduction and finite-difference and finite-element formulations; convection and diffusion; upwind, exponential, and hybrid schemes; and boundary-layer-type fluid flow and heat transfer problems.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 712 Computational Fluid Mechanics and Heat Transfer II 3.0 Credits**
Covers basic computational methods for incompressible Navier-Stokes equations, including vorticity-based methods and primitive variable formulation; computational methods for compressible flows; inviscid and viscous compressible flows; finite-element methods applied to incompressible flows; and turbulent flow models and calculations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 711 [Min Grade: C]

**MEM 714 Two-Phase Flow & Heat Transfer 3.0 Credits**
Covers selected topics in two-phase flow, with emphasis on two-phase heat transfer problems, basic conservation equations for two-phase flows, nucleation, bubble dynamics, pool boiling, forced convective boiling, condensation heat transfer, two-phase flow equipment design, tube vibration and flow instability in two-phase flows, and fouling in heat transfer equipment.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 717 Heat Transfer in Manufacturing 3.0 Credits**
Covers heat conduction fundamentals, including phase change problems (casting, welding, and rapid solidification processes) and cooling controls of rolling, forging, and extrusion processes.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 611 [Min Grade: C]

**MEM 721 Non-Newtonian Fluid Mechanics and Heat Transfer 3.0 Credits**
Covers the stress-strain rate relationship, simple flow, general constitutive and conservation equations, generalized Newtonian models, molecular theories, rheological property measurements, plane Couette flow, hydrodynamic theory of lubrication, helical flow, boundary layer flows, pipe flows, natural convection, thin film analysis, drag reduction phenomenon, and biorheology.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 622 [Min Grade: C]

**MEM 722 Hydrodynamic Stability 3.0 Credits**
Introduces stability, including discrete and continuous systems. Covers linear theory; instability of shear flows, spiral flows between concentric cylinders and spheres, thermoconductive systems, and viscous flows; global stability and non-linear theories; and time periodic and non-periodic flows, attractors, and bifurcation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 622 [Min Grade: C]

**MEM 723 Vortex Interactions and Complex Turbulent Flow 3.0 Credits**
Nonlinear vertex motion and interaction; motion of point vortices; generation and interaction of vortex rings and counter-rotating vortex pairs; vortex impulse, energy, pairing, bifurcation, and bursting; study of free and separating turbulent flows: mixing layers, wakes, jets, and buoyant plumes; recirculation behind bluff bodies and backsteps; longitudinal and lateral vortex waves and shear layers; sweeps and bursts in turbulent boundary layers; characteristics of turbulence: entrainment and molecular mixing, effects of buoyancy, rotation, acceleration, and heat release; the 3-D turbulent energy cascade and the 2-D inverse cascade.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 725 Compressible Fluid Dynamics 3.0 Credits**
Reviews one-dimensional flows. Covers steady flow of a compressible fluid; two-and three-dimensional subsonic, transonic, supersonic, and hypersonic flow; normal and oblique shock waves; wave reflections; oblique shock wave interactions and generation vorticity; compressible boundary layers; and shock boundary-layer interactions.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 621 [Min Grade: C]

**MEM 727 Fluid Dynamics in Manufacturing Processes 3.0 Credits**
Covers transport of slurries, molten metals, and polymers; hydrodynamics in forming processes; resin flow model in polymer composites; shaped charge jet technology; separation and filtration; coating; lubrication; and melt-spinning process.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 730 Control of Flexible Space Structures I 3.0 Credits**
Covers modeling of FSS including PDE description and finite element modeling, model errors, model reduction, component cost analysis, modal cost analysis, stability of mechanical systems, gyroscopic and non-gyroscopic systems, and rate and position feedback.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 731 Control of Flexible Space Structures II 3.0 Credits**
Covers probability theory, stochastic processes, Kalman filter, LQG compensators, controller reduction, CCA theory, balancing reductions, and applications.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 730 [Min Grade: C]

**MEM 733 Applied Optimal Control I 3.0 Credits**
Covers necessary conditions from calculus of variations, equality and inequality constraints, fixed and free final time problems, linear-quadratic control, bang-bang control, and application to problems in flight mechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 734 Applied Optimal Control II 3.0 Credits**
Covers neighboring extremals and the second variation, perturbation feedback control, sufficient conditions, numerical solution methods, and application to problems in flight mechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 733 [Min Grade: C]

**MEM 735 Advanced Topics in Optimal Control 3.0 Credits**
Covers singular arc control, model following control, variable structure control, singular perturbation methods, differential games, and applications.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit
**Prerequisites:** MEM 734 [Min Grade: C]

**MEM 760 Mechanical Composite Materials I 3.0 Credits**
Covers anisotropic elastic moduli, stress-strain relations of a lamina, failure criteria of a lamina, introduction to micromechanics, laminated plate theory, residual stresses, and strength of laminates.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 660 [Min Grade: C]

**MEM 761 Mechanical Composite Materials II 3.0 Credits**
Covers anisotropic plates and shells, boundary value problem in anisotropic heterogeneous elasticity, vibrations and buckling of laminated plates, and testing methods.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 760 [Min Grade: C]

**MEM 762 Mechanical Composite Materials III 3.0 Credits**
Covers classical failure criteria for orthotropic materials, fracture in laminates, three-dimensional stress analysis, simulation of delamination and transverse cracks, fatigue damage, and cumulative damage models.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit
**Prerequisites:** MEM 761 [Min Grade: C]

**MEM 770 Theory of Elastic Stability 3.0 Credits**
General stability criteria; beam column; the elastica; energy methods; torsional stability; combined torsion and flexure; lateral buckling of beams in pure bending; buckling of rings; curved bars and arches.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 777 Fracture Mechanics I 3.0 Credits**
Covers fundamental mechanics of fracture, including linear elastic crack mechanics, energetics, small-scale yielding, fully plastic crack mechanics, creep crack mechanics, fracture criteria, mixed mode fracture, stable quasi-static crack growth (fatigue crack growth and environmentally induced crack growth), toughness and toughening, and computational fracture mechanics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 782 Impact and Wave Propagation I 3.0 Credits**
Governing equations for elastic waves; longitudinal waves in a bar; transverse in a flexible string; flexural waves in a Bernoulli-Euler beam; flexural waves in a Timoshenko beam; Rayleigh surface waves; Pochhammer-Chree waves in circular cylinders; reflection of plane waves at a plane boundary.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 783 Impact and Wave Propagation II 3.0 Credits**
Spherical and cylindrical waves in unbounded medium; method of Laplace transform; method of characteristics; flexural waves in a Timoshenko plate; viscoelastic and viscoplastic waves; dispersion and phase velocity; natural frequency in free vibration.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 784 Impact & Wave Propagation III 3.0 Credits**
Governing equations for unsteady, nonisentropic fluid flows; shock waves; method of characteristics for nonlinear system; numerical integration along characteristics; impact and vibration of shell topics in wave propagation.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 800 Special Topics Mechanical Engineering 0.5-9.0 Credits**
Covers topics of current interest to faculty and students; specific topics for each term will be announced prior to registration. May be repeated for credit if topics vary.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 891 Topics in Advanced Engineering I 2.0 Credits**
Linear systems; control theory; vibrations and eigenvalue problems; systems dynamics; Fourier transformation; flight dynamics.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 892 Topics in Advanced Engineering II 2.0 Credits**
Separation of variables; thermodynamics; heat transfer; fluid mechanics; boundary layer theory; elasticity; finite element methods. Solid mechanics; aeroelasticity.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 893 Topics in Advanced Engineering III 2.0 Credits**
Basic probability and statistics; communication theory; sampled data system; digital and optical processing.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 894 Engineering Mathematics 3.0 Credits**
Application of matrices, linear algebra, and complex analysis to engineering problems. Ordinary and partial differential equations.
**College/Department:** College of Engineering
**Repeat Status:** Not repeatable for credit

**MEM 897 Research 1.0-12.0 Credit**
Supervised research in Mechanical Engineering.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 898 Master's Thesis 1.0-20.0 Credit**
Master's thesis.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit

**MEM 998 Ph.D. Dissertation 1.0-12.0 Credit**
Ph.D. dissertation.
**College/Department:** College of Engineering
**Repeat Status:** Can be repeated multiple times for credit