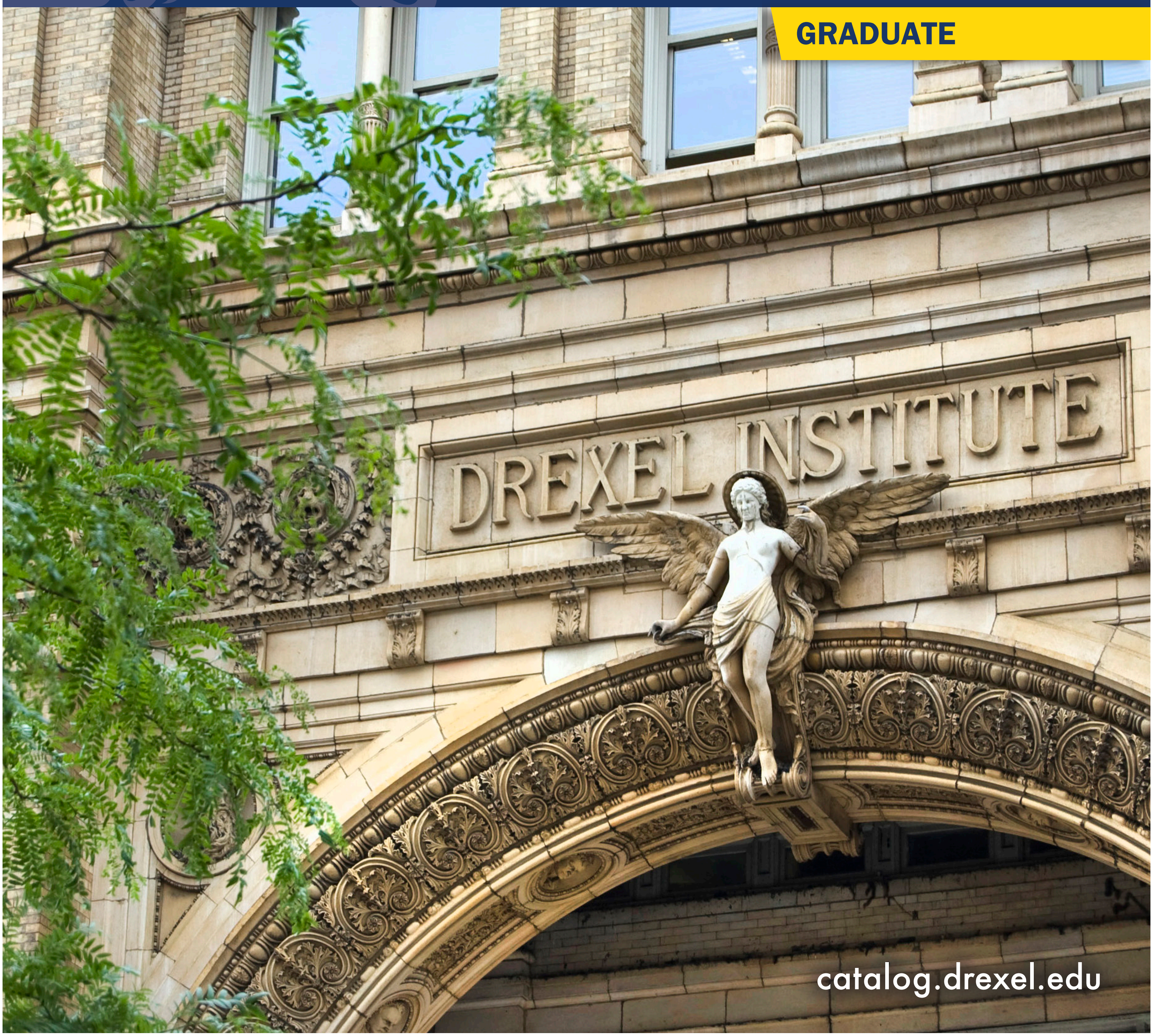
DREXEL UNIVERSITY
College of
Engineering

CATALOG
2024-2025

GRADUATE



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The College of Engineering

About the College

The rapid advances and evolving challenges in our world necessitate engineers who can think broadly, adjust quickly and act decisively. That's why our focus at Drexel University is empowering students to engineer change – in their lives and through their careers – by emphasizing a balance of theory and practical experience.

Since the beginning more than 130 years ago, engineering has been the cornerstone of Drexel University. Today, the college is home to some of the top-ranked engineering programs. Within the College of Engineering departments, faculty and staff work to conduct theoretical and applied research while the relevant, challenging and high quality academics are taught by accomplished faculty and leaders in their fields from all over the world. College curricula are grounded in foundational principles and practices while providing opportunities to explore emerging topics in the disciplines.

As a comprehensive, global institution, our programs equip students with the tools to advance in the profession and follow a trajectory towards making an impact. As an engineering student at the college you will learn to find sustainable and achievable outcomes to address society's biggest challenges while making them relevant to your career goals. Master's and certificate programs offer education that propels careers forward as an expert in the field and doctoral programs have students learning at a R1 designated institution alongside world-renowned faculty.

Majors

Minors

Certificates

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/co-op/graduate/) (GCP), provides students with the opportunity to gain work experience directly related to their career goals. Graduate co-op is typically a three to six-month engagement with an employer. Students generally get paid for their work ranging from 20-40 hours per week. You will seek your position opportunities with the resources and connections available through our Steinbright Career Development Center (https://drexel.edu/scdc/co-op/graduate/). 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.

More about Graduate Co-op from the College of Engineering (https://drexel.edu/engineering/academics/experiential-learning-co-op/graduate-co-ops/).

Architectural Engineering MSAE

Major: Architectural Engineering
Degree Awarded: Master of Science in Architectural Engineering (MSAE)
Calendar Type: Quarter
Minimum Required Credits: 45.0 (MSAE)
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0401
Standard Occupational Classification (SOC) code: 11-9041

About the Program

Architectural Engineering is inherently an interdisciplinary enterprise that is centered on the design, construction, and operation of the built environment. Architectural Engineering MS 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):

- Building energy efficiency and alternative energy
- 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.

Additional Information

For more information, visit the MS in Architectural Engineering (https://drexel.edu/engineering/academics/graduate-programs/masters/architectural-engineering/) or Department of Civil, Architectural and Environmental Engineering (https://drexel.edu/engineering/academics/departments/civil-architectural-environmental-engineering/) webpage.

Admission Requirements

Applicants to the MS 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:
  - *Introduction to Fluid Flow* – CIVE 320
  - *Introduction to Thermodynamics* – ENGR 210
  - *Heat Transfer* – MEM 345 – for Building Energy students
  - *General Chemistry II* – 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 (optional)
- 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.

For more information, visit College of Engineering Graduate Admissions (https://drexel.edu/engineering/admissions/graduate/).

Degree Requirements

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 544	Building Envelope Systems	3.0
AE 550	Indoor Air Quality	3.0

AE 551	Building Energy Systems I *	3.0
or AE 552	Building Energy Systems II	
MEM 591	Applied Engr Analy Methods I	3.0
MEM 592	Applied Engr Analy Methods II	3.0
Graduate Technical Electives		
Must complete at least 9.0 credits the list below:		9.0
AE 552	Building Energy Systems II *	
AE 555	Data Acquisition and Analytics in Built Environment	
AE 561	Airflow Simulation in Built Environment	
CHE 513	Chemical Engineering Thermodynamics I	
CHE 525	Transport Phenomena I	
ENVE 560	Fundamentals of Air Pollution Control	
ENVE 571	Environmental Life Cycle Assessment	
ENVE 660	Chemical Kinetics in Environmental Engineering	
ENVE 727	Risk Assessment	
ENVE 750	Data-based Engineering Modeling	
ENVS 501	Chemistry of the Environment	
MEM 611	Conduction Heat Transfer	
MEM 612	Convection Heat Transfer	
MEM 621	Foundations of Fluid Mechanics	
Additional Electives **		18.0
Total Credits		**45.0**

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If AE 552 is taken as a core required course, it cannot be taken as a technical elective. Conversely, if AE 552 is taken as a technical elective, it cannot be counted as a core required course.

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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 in any of the following subjects: AE, CHE, CHEC, CHEM, CIVE, ENVE, ENSS, ENVP, ENVS, MATH, MEM (500-699).

Sample Plan of Study

Sample Plan of Study

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
AE 544	3.0	AE 510	3.0	Graduate Technical Elective	3.0
AE 550	3.0	AE 551 or 552	3.0	Additional Electives	6.0
MEM 591	3.0	MEM 592	3.0		
	9		**9**		**9**

Second Year			
Fall	**Credits**	**Winter**	**Credits**
Graduate Technical Elective	3.0	Graduate Technical Elective	3.0
Additional Electives	6.0	Additional Electives	6.0
	9		**9**

Total Credits 45

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

Program Level Outcomes

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- Communicate effectively with a range of audiences

- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- Acquire and apply new knowledge as needed, using appropriate learning strategies

Civil, Architectural and Environmental Engineering Faculty

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

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

Shannon Capps, PhD *(Georgia Institute of Technology)*. Associate Professor. Atmospheric chemistry; data assimilation; advanced sensitivity analysis; inverse modeling.

Zhiwei Chen, PhD *(University of South Florida)*. Assistant Professor. Mobility system modeling, simulation, optimization, control, and social impact analysis, with applications to modular, connected, and automated vehicle systems, mobility as a service, public transit systems.

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

Arvin Ebrahimkhanlou, PhD *(University of Texas at Austin)*. Assistant Professor. Non-destructive evaluation, structural health monitoring, artificial intelligence, robotics.

Yaghoob (Amir) Farnam, PhD *(Purdue University)*. Associate Professor. Advanced and sustainable infrastructure materials; multifunctional, self-responsive and bioinspired construction materials; advanced multiscale manufacturing; characterization, and evaluation of construction materials; durability of cement-based materials.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute and State University)*. Professor. Geotechnical and geoenvironmental engineering; soil improvement; soil improvement; recycled materials in geotechnics.

Patrick Gurian, PhD *(Carnegie-Mellon University)*. 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-Champaign) Program Head for Environmental Engineering; L. D. Betz Professor of Environmental Engineering*. Water treatment and wastewater resuse; risk analysis; microbial risk assessment; environmental modeling and statistics; microbiology; environmental health.

Simi Hoque, PhD *(University of California - Berkeley) Program Head for Architectural Engineering*. Professor. Computational methods to reduce building energy and environmental impacts, urban metabolism, thermal comfort, climate resilience.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Durability of polymeric construction materials; advanced construction materials; and performance of geosynthetics.

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

L. James Lo, PhD *(University of Texas at Austin)*. Associate Professor. Architectural fluid mechanics; building automation and autonomy; implementation of natural and hybrid ventilation in buildings; airflow distribution in buildings; large-scale air movement in an urban built environment; building and urban informatics; data-enhanced sensing and control for optimal building operation and management; novel data gathering methods for building/urban problem solving; interdisciplinary research on occupant behaviors in the built environment.

Franco Montalto, PhD *(Cornell University)*. Professor. Water in the built environment; planning, design, and restoration of natural and nature-based systems, including green stormwater infrastructure; urban ecohydrology; hydrologic and hydraulic modeling; urban flooding; urban sustainability; and climate change and climate resilience.

Mira S. Olson, PhD *(University of Virginia)*. Associate Professor. Peace engineering; source water quality protection and management; contaminant and bacterial fate and transport; community engagement.

Miguel A. Pando, PhD *(Virginia Polytechnic Institute and State University)*. Associate Professor. Slope stability and landslides; natural hazards; geotechnical earthquake engineering and liquefaction; laboratory and field measurement of soil and rock properties; soil erosion and scour; soil-structure-interaction; earth-based construction materials.

Matthew Reichenbach, PhD *(University of Austin at Texas)*. Assistant Teaching Professor. Design and behavior of steel structures, bridge engineering, structural stability

Fernanda Cruz Rios, PhD *(Arizona State University)*. Assistant Professor. Circular economy, life cycle assessment, convergence research, sustainable buildings and cities.

Michael Ryan, PhD *(Drexel University) Associate Department Head of Graduate Studies*. Associate Teaching Professor. Microbial Source Tracking (MST); Quantitative Microbial Risk Assessment (QMRA); dynamic engineering systems modeling; molecular microbial biology; phylogenetics; metagenomics; bioinformatics; environmental statistics; engineering economics; microbiology; potable and wastewater quality; environmental management systems.

Christopher Sales, PhD *(University of California, Berkeley)*. Associate Professor. Environmental microbiology and biotechnology; biodegradation of environmental contaminants; microbial processes for energy and resource recovery from waste; application of molecular biology, analytical chemistry and bioinformatic techniques to study environmental biological systems.

Robert Swan, PhD *(Drexel University) Associate Department Head for Undergraduates*. Teaching Professor. Geotechnical and geosynthetic engineering; soil/geosynthetic interaction and performance; laboratory and field geotechnical/geosynthetic testing.

Sharon Walker, PhD *(Yale University) Dean, College of Engineering*. Distinguished Professor. Water quality systems engineering; fate and transport of nanomaterials; pathogen adhesion phenomena.

Michael Waring, PhD *(University of Texas at Austin) Department Head, Civil, Architectural, and Environmental Engineering*. Professor. Indoor air quality, indoor aerosols, indoor air modeling, indoor chemistry, healthy buildings, and building sustainability intelligent ventilation, air cleaning, indoor disease transmission.

Jin Wen, PhD *(University of Iowa) Associate Dean for Research and Innovation, College of Engineering*. Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Building-grid integration; Occupant Centric Control; and Indoor Air Quality.

Emeritus Faculty

A. Emin Aktan, PhD *(University of Illinois, Urbana-Champaign)*. Professor Emeritus. Health monitoring and management of large infrastructures with emphasis on health monitoring.

Eugenia Ellis, PhD, AIA *(Virginia Polytechnic Institute and State University)*. Professor Emerita. Natural and electrical light sources and effects on biological rhythms and health outcomes; ecological strategies for smart, sustainable buildings of the nexus of health, energy, and technology.

Ahmad Hamid, PhD *(McMaster University)*. Professor Emeritus. Engineered masonry; seismic behavior, design and retrofit of masonry structures; development of new materials and building systems.

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

Joseph P. Martin, PhD *(Colorado State University)*. Professor Emeritus. Geotechnical and geoenvironmental engineering; hydrology; transportation; waste management.

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

Aspasia Zerva, PhD *(University of Illinois, Urbana-Champaign)*. Professor. Earthquake engineering; mechanics; seismology; structural reliability; system identification; advanced computational methods in structural analysis.

Architectural Engineering PhD

Major: Architectural Engineering
Degree Awarded: Doctor of Philosophy (PhD)
Calendar Type: Quarter
Minimum Required Credits: 90.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0401
Standard Occupational Classification (SOC) code: 11-9041

About the Program

Architectural Engineering is inherently an interdisciplinary enterprise that is centered on the design, construction, and operation of the built environment. Architectural Engineering 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):

- Building energy efficiency and alternative energy
- 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.

Additional Information

For more information, visit the Doctorate in Architectural Engineering (https://drexel.edu/engineering/academics/graduate-programs/doctoral/architectural-engineering/) and the Department of Civil, Architectural and Environmental Engineering (https://drexel.edu/engineering/academics/departments/civil-architectural-environmental-engineering/) webpage.

Admission Requirements

Applicants to the 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:
  - *Introduction to Fluid Flow* – CIVE 320
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The application package will include:

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- GRE scores (optional)
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Competitive applicants will possess an undergraduate GPA of 3.30 or higher and GRE scores above the 60th percentile.

For more information, visit College of Engineering Graduate Admissions (https://drexel.edu/engineering/admissions/graduate/).

Degree Requirements

The following general requirements must be satisfied to complete the PhD in Architectural Engineering:

- Establishment of plan of study with PhD advisor
- Completion of 90.0 quarter credits (or 45 credit hours post-MS), including taking certain qualifying courses
- Passing of PhD candidacy exam
- Approval of PhD dissertation proposal
- Defense of PhD dissertation

Students entering the PhD program with an approved Master of Science (MS) degree must take 45.0 credit hours of coursework and research to be approved by their PhD advisor. Students entering the PhD program without an approved MS degree can either complete the 45-credit hour Master of Science in Architectural Engineering (MSAE) degree followed by an additional 45 credit hours post MSAE, or they can choose not to obtain the MSAE and complete only the required "core" courses for the PhD degree within the completion of a total 90 required credit hours. Students with previous graduate coursework, may transfer no ore than 15 quarter credits (equivalent to 12 semester credits) from approved institutions if deemed equivalent to courses offered within the department.

All PhD students are required to meet all milestones of the program. The total credit amount, candidacy exam, and dissertation are University Requirements. Additional requirements are determined by the department offering the degree.

Qualifying Courses

To satisfy the qualifying requirements, students must earn a grade of B+ or better in the six required “core” courses taken at Drexel and must earn an overall GPA of 3.5 or better in these courses.

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 by the PhD advisor following the student's first year in the PhD program.

For more information visit the Architectural Engineering's PhD Program Requirements page (https://drexel.edu/engineering/academics/graduate-programs/doctoral/architectural-engineering/).

Candidacy Exam

After approximately one year of study beyond the MS degree or completion of the required “core” courses, if their GPA is # 3.5, PhD students can and must take a candidacy examination, consisting of written and oral parts. Successful completion of the candidacy exam enables a student to progress from the designation of PhD student to PhD candidate. The candidacy exam represents the first exam in a series of three that comprise the PhD curriculum.

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 foundational results in that domain. 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 by asking a student to summarize literature and/or undertake a small research project. The student will prepare a written summary of review and/or project results, present the outcome orally, and answer questions about the report or presentation. The candidacy examination committee will evaluate the written report, the oral presentation, and the student’s answers. The candidacy committee membership must follow the requirements of the Graduate College and must be approved by the Graduate College.

Students with a GPA < 3.5 do not meet eligibility requirements to sit for the candidacy exam. In this case, a student may petition the Graduate Advisor to take a Preliminary Written Exam (PWE). A committee will be formed consisting of three members selected from the pool of faculty in the field of research interest of the student and the pool of faculty who taught the courses taken by the student during the preceding terms. An exam will be developed consisting of a series of questions/problems prepared by the three written exam committee members. The written exam, while fixed in duration, may be composed of several different problem-solving assignments. Additionally, the exam may be closed book or open book or a combination thereof. The student will consult with the advisor to become acquainted with the specific rules of the exam. The exam will be graded by the PWE Committee to determine if the student may sit for the candidacy exam.

Dissertation Proposal

After successfully completing the candidacy examination, the PhD candidate must prepare a dissertation proposal that outlines, in detail, the specific problems that will be solved during the research that is conducted to complete the PhD dissertation. The quality of the dissertation proposal should be at the level of a peer-reviewed proposal to a federal funding agency, or a publishable scientific paper. The candidate is responsible for sending the dissertation proposal to the PhD committee no less than two weeks before the scheduled oral presentation. The PhD committee membership need not be the same as the candidacy exam committee, but follows the same requirements and must be approved by the Graduate College. The

oral presentation involves a presentation by the candidate followed by a period during which the committee will ask questions. The committee will then determine if the dissertation proposal has been accepted. The dissertation proposal can be repeated at most once if the proposal was not accepted.

A dissertation proposal must be approved within two years of becoming a PhD candidate. After approval of the dissertation proposal, the committee may meet to review the progress of the research.

Dissertation Defense

After successfully completing the dissertation proposal, 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 no less than two weeks prior to the scheduled oral defense. The oral presentation by the candidate is 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. The committee will then determine if the candidate has passed or failed the examination. If not passed, the candidate will be granted one more chance to pass the final defense.

The PhD degree is awarded for original research on a significant Architectural Engineering problem. Graduate students will work closely with individual faculty members to purse the PhD degree. 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.

Program Requirements

Post Bachelor of Science Degree		
Required Core Courses		**18.0**
AE 510	Intelligent Buildings	
AE 544	Building Envelope Systems	
AE 550	Indoor Air Quality	
AE 551	Building Energy Systems I	
or AE 552	Building Energy Systems II	
MEM 591	Applied Engr Analy Methods I	
MEM 592	Applied Engr Analy Methods II	
Technical Elective Requirements		**0.0-30.0**
To be determined by the PhD faculty advisor and approved by the graduate advisor		

500+ level courses in AE, CIVE, ENVE, or other courses approved by the graduate advisor		
Research Requirements		**71.0-140.0**
Please note that the number of research credits may be reduced based on the number of Technical Electives that are required.		
CIVE 997	Research	
Dissertation Requirements		**1.0-12.0**
CIVE 998	Ph.D. Dissertation	
Total Credits		**90.0-200.0**

Post Master of Science Degree

Technical Elective Requirements		**0.0-30.0**
To be determined by the PhD faculty advisor and approved by the graduate advisor		
500+ level courses in AE, CIVE, ENVE, or other courses approved by the graduate advisor		
Research Requirements		**44.0-100.0**
Please note that the number of research credits may be reduced based on the number of Technical Electives that are required		
CIVE 997	Research	
Dissertation Requirements		**1.0-12.0**
CIVE 998	Ph.D. Dissertation	
Total Credits		**45.0-142.0**

Sample Plan of Study

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 advisor and uploaded to the E-Forms system no later than the end of the first term. The Eforms (https://gradcollege.irt.drexel.edu/) system will be used to track program progression and milestones. Sample Plans of Study are presented below:

Post Bachelor of Science Degree

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
AE 544	3.0	AE 510	3.0	CIVE 997	9.0	Vacation	0.0
AE 550	3.0	AE 551 or 552	3.0				
MEM 591	3.0	MEM 592	3.0				
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		**9**		**9**		**0**
Third Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		**9**		**9**		**0**
Fourth Year							
Fall	**Credits**						
CIVE 997	6.0						
CIVE 998	3.0						
	9						

Total Credits 90

Post Master of Science Degree

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
Technical Electives	6.0	Technical Electives	6.0	Technical Electives	6.0	Vacation	0.0
CIVE 997	3.0	CIVE 997	3.0	CIVE 997	3.0		
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**				
CIVE 997	9.0	CIVE 997	6.0				
		CIVE 998	3.0				
	9		**9**				

Total Credits 45

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- Communicate effectively with a range of audiences
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
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Yaghoob (Amir) Farnam, PhD *(Purdue University)*. Associate Professor. Advanced and sustainable infrastructure materials; multifunctional, self-responsive and bioinspired construction materials; advanced multiscale manufacturing; characterization, and evaluation of construction materials; durability of cement-based materials.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute and State University)*. Professor. Geotechnical and geoenvironmental engineering; soil improvement; soil improvement; recycled materials in geotechnics.

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

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Simi Hoque, PhD *(University of California - Berkeley) Program Head for Architectural Engineering*. Professor. Computational methods to reduce building energy and environmental impacts, urban metabolism, thermal comfort, climate resilience.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Durability of polymeric construction materials; advanced construction materials; and performance of geosynthetics.

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

L. James Lo, PhD *(University of Texas at Austin)*. Associate Professor. Architectural fluid mechanics; building automation and autonomy; implementation of natural and hybrid ventilation in buildings; airflow distribution in buildings; large-scale air movement in an urban built environment; building and urban informatics; data-enhanced sensing and control for optimal building operation and management; novel data gathering methods for building/urban problem solving; interdisciplinary research on occupant behaviors in the built environment.

Franco Montalto, PhD *(Cornell University)*. Professor. Water in the built environment; planning, design, and restoration of natural and nature-based systems, including green stormwater infrastructure; urban ecohydrology; hydrologic and hydraulic modeling; urban flooding; urban sustainability; and climate change and climate resilience.

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Matthew Reichenbach, PhD *(University of Austin at Texas)*. Assistant Teaching Professor. Design and behavior of steel structures, bridge engineering, structural stability

Fernanda Cruz Rios, PhD *(Arizona State University)*. Assistant Professor. Circular economy, life cycle assessment, convergence research, sustainable buildings and cities.

Michael Ryan, PhD *(Drexel University) Associate Department Head of Graduate Studies*. Associate Teaching Professor. Microbial Source Tracking (MST); Quantitative Microbial Risk Assessment (QMRA); dynamic engineering systems modeling; molecular microbial biology; phylogenetics; metagenomics; bioinformatics; environmental statistics; engineering economics; microbiology; potable and wastewater quality; environmental management systems.

Christopher Sales, PhD *(University of California, Berkeley)*. Associate Professor. Environmental microbiology and biotechnology; biodegradation of environmental contaminants; microbial processes for energy and resource recovery from waste; application of molecular biology, analytical chemistry and bioinformatic techniques to study environmental biological systems.

Robert Swan, PhD *(Drexel University) Associate Department Head for Undergraduates*. Teaching Professor. Geotechnical and geosynthetic engineering; soil/geosynthetic interaction and performance; laboratory and field geotechnical/geosynthetic testing.

Sharon Walker, PhD *(Yale University) Dean, College of Engineering*. Distinguished Professor. Water quality systems engineering; fate and transport of nanomaterials; pathogen adhesion phenomena.

Michael Waring, PhD *(University of Texas at Austin) Department Head, Civil, Architectural, and Environmental Engineering*. Professor. Indoor air quality, indoor aerosols, indoor air modeling, indoor chemistry, healthy buildings, and building sustainability intelligent ventilation, air cleaning, indoor disease transmission.

Jin Wen, PhD *(University of Iowa) Associate Dean for Research and Innovation, College of Engineering*. Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Building-grid integration; Occupant Centric Control; and Indoor Air Quality.

Emeritus Faculty

A. Emin Aktan, PhD *(University of Illinois, Urbana-Champaign)*. Professor Emeritus. Health monitoring and management of large infrastructures with emphasis on health monitoring.

Eugenia Ellis, PhD, AIA *(Virginia Polytechnic Institute and State University)*. Professor Emerita. Natural and electrical light sources and effects on biological rhythms and health outcomes; ecological strategies for smart, sustainable buildings of the nexus of health, energy, and technology.

Ahmad Hamid, PhD *(McMaster University)*. Professor Emeritus. Engineered masonry; seismic behavior, design and retrofit of masonry structures; development of new materials and building systems.

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

Joseph P. Martin, PhD *(Colorado State University)*. Professor Emeritus. Geotechnical and geoenvironmental engineering; hydrology; transportation; waste management.

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

Aspasia Zerva, PhD *(University of Illinois, Urbana-Champaign)*. Professor. Earthquake engineering; mechanics; seismology; structural reliability; system identification; advanced computational methods in structural analysis.

Chemical Engineering MS

Major: Chemical Engineering
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter

Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus, master's-level students
Classification of Instructional Programs (CIP) code: 14.0701
Standard Occupational Classification (SOC) code: 17-2041

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 polymer science and engineering, energy and the environment, multiscale modeling and process systems engineering, and biological 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.

A graduate co-op is available for the Master of Science program. For more information, visit the Drexel Engineering graduate co-op (https://drexel.edu/engineering/academics/experiential-learning-co-op/graduate-co-ops/) and Steinbright Career Development Center's website (http://www.drexel.edu/scdc/co-op/graduate/).

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 the MS in Chemical Engineering (https://drexel.edu/engineering/academics/graduate-programs/masters/chemical-engineering/) and Drexel University's Department of Chemical and Biological Engineering (https://drexel.edu/engineering/academics/departments/chemical-biological-engineering/) webpages.

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.

Additional Information

For more information on how to apply, visit Drexel's Admissions page for Chemical Engineering (http://www.drexel.edu/grad/programs/coe/chemical-engineering/).

Degree Requirements

In general, each program leading to the Master of Science in Chemical Engineering must meet the following requirements: total, 45.0 credits; core chemical engineering, 15.0 credits; technical electives, at least 15.0 credits; free electives, at most 6.0 credits; thesis or additional technical electives, 9.0 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). At the discretion of the research advisor, up to 12.0 credits of independent study (CHE I799) can be used to fulfill the free and technical elective requirements.

Coursework-only (non-thesis) option: Students not pursuing master's with thesis must complete 24.0 credits of technical electives, 6.0 credits of free electives, and 15.0 credits of core chemical engineering. Students may take up to 21.0 credits of independent study (CHE I799) to fulfill the free and technical elective requirements although 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 15.0 credit series of technical electives. Technical 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. Free (non-concentration) electives need only be graduate level.

Co-op: Students have the option to pursue a co-op as part of their master's program. In conjunction with the Steinbright Career Development Center (http://drexel.edu/scdc/co-op/graduate/), students will be provided an overview of professionalism, resume writing, and the job search process. Co-op will be for a six-month position running in the summer/fall terms. Students will not earn academic credit for the co-op but will earn 9.0 non-academic co-op units per term.

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.

Program Requirements

Required Core		
CHE 502	Mathematical Methods in Chemical Engineering	3.0
CHE 513	Chemical Engineering Thermodynamics I	3.0
CHE 525	Transport Phenomena I	3.0
CHE 543	Kinetics & Catalysis I	3.0
CHE 554	Process Systems Engineering	3.0
Technical Electives *		**15.0**
Thesis or No-Thesis Option		**9.0**
For Thesis Option:		
CHE 898	Master's Thesis	
For No-Thesis Option:		
Technical Electives		
Free Electives		**6.0**
Optional Co-op Experience **		0-1
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

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Choose from:

- Any graduate course in the College of Engineering >=500 level
- Any graduate course in STEM disciplines >=500 level
- Graduate courses in these disciplines, subject to advisor approval: AE, BIO, BMES, CAE, CHE (including CHE I799) CHEM, CIVE, CMGT, CS, DSCI, ECE, ECEC, ECET, ECEE, ECES, EET, EGMT, ENTP, ENVP, ENVS, FDSC, GEO, MATE, MEM, PROJ, REAL, SYSE, PENG, MATH, PHYS, SE

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Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

Sample Plan of Study

No co-op, no thesis option

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CHE 502	3.0	CHE 525	3.0	CHE 543	3.0	Technical Elective	3.0
CHE 513	3.0	Technical Electives	6.0	CHE 554	3.0	Free Electives	6.0
Technical Elective	3.0			Technical Elective	3.0		
	9		**9**		**9**		**9**

Second Year	
Fall	**Credits**
Technical Electives	9.0
	9

Total Credits 45

Thesis, no co-op option

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CHE 502	3.0	CHE 525	3.0	CHE 543	3.0	CHE 898	6.0
CHE 513	3.0	Technical Electives	6.0	CHE 554	3.0	Free Elective	3.0
Technical Elective	3.0			Free Elective	3.0		
	9		**9**		**9**		**9**

Second Year	
Fall	**Credits**
CHE 898	3.0
Technical Electives	6.0
	9

Total Credits 45

With co-op, no thesis option:

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CHE 502	3.0	CHE 525	3.0	CHE 543	3.0	Free Electives	6.0
CHE 513	3.0	Technical Electives	6.0	CHE 554	3.0	Technical Elective	3.0
COOP 500	1.0			Technical Elective	3.0		
Technical Elective	3.0						
	10		**9**		**9**		**9**

Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COOP EXPERIENCE		COOP EXPERIENCE		Technical Electives	9.0
	0		**0**		**9**

Total Credits 46

With co-op and thesis option:

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CHE 502	3.0	CHE 525	3.0	CHE 543	3.0	CHE 898	3.0
CHE 513	3.0	Technical Electives	6.0	CHE 554	3.0	Free Electives	6.0
COOP 500	1.0			CHE 898	3.0		
Technical Elective	3.0						
	10		**9**		**9**		**9**

Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COOP EXPERIENCE		COOP EXPERIENCE		CHE 898	3.0
				Technical Electives	6.0
	0		**0**		**9**

Total Credits 46

Facilities

Abrams Laboratory (Abrams)

Software:

- The Abrams group Github repository (https://github.com/cameronabrams (https://github.com/cameronabrams/))

Computational resources:

- Proteus, Drexel's high-performance cluster
- NSF XSEDE (www.xsede.org (http://www.xsede.org))
- DoD HPCMP (www.hpc.mil (https://www.hpc.mil))

Alvarez Research Group (Alvarez)

- Rheo Filament- VADER1000 - Filament Extensional Rheometer with forced convection oven
- TA DHR3 – Controlled Stress Rheometer with Electronic Heated Platesx
- TA ARES G2 – Controlled Strain Rheometer with Forced Convection Oven
- Controlled Film Coater
- Gel Spinning Apparatus for continuous filament and fiber formation
- Microtensiometer for measurement of dynamic transport of surfactant to fluid-fluid interfaces, including dilatational rheology of equilibrated surfaces.
- Supercritical Microtensiometer for measurement of surfactant transport to fluid-fluid interfaces at elevated pressures
- Nikon TE microscope with 3MP camera and various objectives.
- Fluigent - 4 port continuous pressure fluid pump

Nanomaterials for Energy Applications and Technology Laboratory (Baxter)

- 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)

- 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

Nanocrystal Solar Laboratory (Fafarman)

- Two chamber fabrication glove box with separate air-purification for wet-chemical synthesis and dry-process fabrication steps, featuring HEPA filtered laminar flow air handling for class-1 cleanroom conditions in an inert atmosphere. In the wet-chemical fabrication chamber there are a spincoater, centrifuge, hot-plates and solid and liquid reagents. On the dry chamber side, there is an integrated thermal evaporator for depositing metal, and a UV-ozone cleaner.
- Custom built Schlenk vacuum/gas manifold, all necessary glassware, J-Kem precision temperature controllers and heating mantles
- Perkin Elmer Lambda 35 UV-vis spectrometer
- ThermoFisher Nicolet iS50R Fourier-transform vis-NIR-MIR absorption spectrometer covering spectral ranges 13000 – 600 and 25000 – 8000 1/cm
- Keithley dual-channel precision source-meter
- Crystalaser Q-switch laser, 300 mW at 532 nm
- Home-built 4-point probe station for thin film electrical conductivity
- 80 MHz digital oscilloscope
- Stanford Research Systems lock-in amplifier

Nanofibers for Energy Storage and Conversion Laboratory (Kalra)

- Four Electrospinning Stations (with core-shell spinning capability)
- Mbraun Dual User Glove Box
- Carver Heat Press
- Four Gamry Potentiostats (Ref 3000 and Interface 1000)

- 32-channel Maccor Battery Cycler, three 8-channel NEWARE Battery Cyclers
- Rotating Disc Electrode Test Station (Pine Instruments)
- Tube Furnaces/Convection Ovens/Vacuum Ovens/Ultrasonicator/Hot Plates/Precision Balances
- Environmental Chamber (Tenney) with high temperature/humidity control ranging from 25-200C and 5-95%RH and integrated with vapor permeation and EIS
- Thermo Fisher Nicolet IS50 FTIR Spectrometer equipped with in-operando battery/supercapacitor cells

Thin Films and Devices Laboratory (Lau)

- Chemical Vapor Deposition Thin Film Reactor System I
- Chemical Vapor Deposition Thin Film Reactor System II
- Chemical Vapor Deposition Rotating Bed Reactor System
- Denton Desktop High Vacuum Sputtering System
- Harrick RF Plasma Reactor
- Gamry Reference 600 Electrochemical Testing Station
- Gamry Interface 1000 Electrochemical Impedance Spectrometer
- Agilent Electrochemical Impedance Analyzer 4294A
- Solar Illuminator
- Nicolet 6700 FTIR Spectrometer
- Shimadzu UV-1800 UV-VIS Spectrophotometer
- Laurell Technologies Spin Coater
- Ramé-Hart 290 Goniometer
- Meiji MT5310L Microscope
- Vacuum Ovens/Hot Plates

Polymers and Composites Laboratory (Palmese)

- 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)

- Shimadzu GPC
- Mini-Reactors
- Agilent GC/MS
- Fluidized Sand Bath
- IKA-RCT Stirred Hotplate Reactors
- Olympus Microscope
- Shimadzu UV-Vis Spectrophotometer (UV-1700)

Electrochemical Interfaces and Catalysis Laboratory (Snyder)

- Millipore DI water system
- 302N Autolab Potentiostats (x2)
- Mettler Toledo Micro-Balance
- Ultracentrifuge
- 4 port Schlenk line
- 4 kW Ambrell Radio Frequency Induction Furnace

Tang Laboratory (Tang)

- Six-channel Bio-Logic SP-300 potentiostat with electrochemical impedance spectroscopy
- LC Technology dual-user glovebox with argon atmosphere. Includes oxygen and water analyzers, electronic feedthroughs, and integrated vacuum oven
- Coin cell crimper /decrimper for battery fabrication (TOB Battery)
- Automatic electrode film coater (TOB Battery)
- Tube furnace
- Vacuum oven
- Karl-Fischer titration apparatus (Mettler Toledo)
- Two rotating disk electrode test station (Pine Instruments) with rotating ring-disk accessories
- 32-channel battery cycler (Arbin)

Wrenn Laboratory (Wrenn)

- 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

Program Level Outcomes

- Demonstrate advanced level proficiency in fundamental chemical engineering principles of thermodynamics, transport phenomena, and reaction kinetics.
- Demonstrate advanced level proficiency in engineering mathematics.
- Demonstrate advanced level proficiency in one or more relevant areas of specialization for chemical engineers such as biological engineering, computational engineering, energy, environment and sustainability, polymers, and engineering management.
- Demonstrate the ability to solve unique scientific/engineering problems through independent research that applies experimentation, theory, modeling, and/or simulation (for MS thesis option).

Chemical 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.

Nicolas Alvarez, PhD *(Carnegie Mellon University)*. Assistant Professor. Phototonic crystal defect chromatography; extensional rheology of polymer/polymer composites; surfactant/polymer transport to fluid and solid interfaces; aqueous lubrication; interfacial instabilities.

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

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

Aviel Chaimovich, PhD *(University of Southern California, Santa Barbara)*. Assistant Teaching Professor. Molecular simulations.

Megan A. Creighton, PhD *(Brown University)*. Assistant Professor. Sustainable manufacturing practices. Valorization of waste, feasibility assessments of commercialization pipelines, circular economy strategies, and responsible innovation.

Peter Deak, PhD *(University of Notre Dame)*. Assistant Professor. Design of innate immune modulating nanoparticles for vaccines, autoimmune diseases and transplantation. Chemical modulation of immunity.

Aaron Fafarman, PhD *(Stanford University)*. Associate Professor. Photovoltaic energy conversion; solution-based synthesis of semiconductor thin films; colloidal nanocrystals; electromodulation and photomodulation spectroscopy.

Joshua Lequieu, PhD *(University of Chicago)*. Assistant Professor. Polymer physics; statistical mechanics; field-theoretic simulation; molecular simulation.

Matthew A. McDonald, PhD *(Georgia Institute of Technology)*. Assistant Professor. Automation and machine learning to accelerate development of challenging chemical processes; pharmaceutical discovery and process engineering; crystallization as a separation technology.

Joshua Snyder, PhD *(Johns Hopkins University)*. Associate Professor. Electrocatalysis (energy conversion/storage); hetergeneous catalysis corrosion (dealloying nanoporous metals); interfacial electrochemical phenomena in nanostructured materials; colloidal synthesis.

Masoud Soroush, PhD *(University of Michigan)*. Professor. Process systems engineering; polymer engineering.

John H. Speidel, BSHE, MCHE *(University of Delaware; Illinois Institute of Technology)*. Teaching Professor. Chemical process safety; process design engineering.

Maureen Tang, PhD *(University of California, Berkeley)*. Associate Professor. Batteries and fuel cells; nonaqueous electrochemistry; charge transport at interfaces.

Michael Walters, PhD *(Drexel University)*. Associate Teaching Professor. Undergraduate laboratory.

Emeritus Faculty

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

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

Chemical Engineering PhD

Major: Chemical Engineering
Degree Awarded: Doctor of Philosophy (PhD)
Calendar Type: Quarter
Minimum Required Credits:90.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0701
Standard Occupational Classification (SOC) code: 17-2041

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 polymer science and engineering, energy and the environment, multiscale modeling and process systems engineering, and biological 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 (https://drexel.edu/engineering/academics/departments/chemical-biological-engineering/) webpage.

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.

Additional Information

For more information on how to apply, visit Drexel's Admissions page for Chemical Engineering (http://www.drexel.edu/grad/programs/coe/chemical-engineering/).

Degree Requirements

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 the graduate program advisor.

The following general requirements must be satisfied in order to complete the PhD in Chemical Engineering:

- 90.0 credit hours total
- 15.0 core credits
- 12.0 credit hours of specialized plan of study
- 63.0 credit hours of research (including a 3.0 credit research practice course)
- Qualifying exam (2nd term)
- Establishing a plan of study (2nd term)
- Candidacy exam (5th term)
- Dissertation/thesis
- Defense of dissertation/thesis
- GPA requirements: 3.0 overall; 3.0 graduate chemical engineering (CHE) courses; 3.0 core graduate chemical engineering (CHE) courses

Qualifying Exam

The qualifying exam is administered once a year in January at the start of the second term. The objective of the exam is to evaluate proficiency in core undergraduate chemical engineering material. The format is made up of four problems, each covering a core chemical engineering subject at the undergraduate level, including thermodynamics, fluid mechanics, heat/mass transfer, and kinetics and reactor design. Students must demonstrate mastery in all four subjects to pass the qualifying exam. A student can appeal to take a second-chance exam at the end of the second term if the qualifying exam was not satisfactory in the first instance; however, the appeal is not guaranteed and will depend on student's overall performance in coursework, research, and teaching assistant duties.

Program Requirements

Core Requirements		
CHE 502	Mathematical Methods in Chemical Engineering	3.0
CHE 513	Chemical Engineering Thermodynamics I	3.0
CHE 525	Transport Phenomena I	3.0
CHE 543	Kinetics & Catalysis I	3.0
CHE 590	Research Methods and Practices	3.0
Specialized Plan of Study Courses		**12.0**
12.0 credit hours of courses approved by research advisor. All students are expected to develop competence in their area(s) of specialization.		
Research		**63.0**
63.0 credit hours of research, 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 their advisor's input). The proposal must be submitted to each member of the student's thesis committee and to the graduate program advisor on the first day of the student's fifth term.
- Proposal Defense (oral): The student provides a formal defense of their proposal to their thesis committee before the end of the student's fifth term.

Preliminary Exam

A preliminary exam is targeted at least six months prior to the thesis defense with this scheduling subject to the research advisor's discretion. This preliminary exam is to ensure that the student has made adequate progress in their project. The components of the preliminary exam include:

- Exam Documents (written): The student is required to write an abstract of the preliminary defense talk, a one-page document describing the plan for completing the thesis, a tentative list of the thesis chapter titles, and a current list of publications/presentations. These must be submitted to each member of the student's thesis committee and to the graduate program advisor in advance of the oral exam date.
- Preliminary Defense (oral): The student provides a formal defense of the work to date and the anticipated work to be completed for the thesis to their thesis committee.
- Publications: At a minimum, at least one manuscript (original article) must have been submitted to a refereed journal prior to the oral exam date.

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. The requirements of the thesis/dissertation and defense are:

- Thesis (written): The student is required to write a thesis detailing the entire PhD project, including background, methods, results, discussion, conclusions, and bibliography.
- Defense (oral): The student provides a formal defense of their PhD thesis in an oral examination to their thesis committee.
- Publications: At a minimum, at least one original article must be published in a refereed journal (department's minimum requirement). At the discretion of the research advisor, further publication requirements may be imposed above this minimum.

Additional Information

For more information, visit the Chemical and Biological Engineering Department (https://drexel.edu/engineering/academics/departments/chemical-biological-engineering/) webpage.

Facilities

Abrams Laboratory (Abrams)

Software:

- The Abrams group Github repository (https://github.com/cameronabrams (https://github.com/cameronabrams/))

Computational resources:

- Proteus, Drexel's high-performance cluster
- NSF XSEDE (www.xsede.org (http://www.xsede.org))
- DoD HPCMP (www.hpc.mil (https://www.hpc.mil))

Alvarez Research Group (Alvarez)

- Rheo Filament- VADER1000 - Filament Extensional Rheometer with forced convection oven
- TA DHR3 – Controlled Stress Rheometer with Electronic Heated Platesx
- TA ARES G2 – Controlled Strain Rheometer with Forced Convection Oven
- Controlled Film Coater
- Gel Spinning Apparatus for continuous filament and fiber formation
- Microtensiometer for measurement of dynamic transport of surfactant to fluid-fluid interfaces, including dilatational rheology of equilibrated surfaces.
- Supercritical Microtensiometer for measurement of surfactant transport to fluid-fluid interfaces at elevated pressures

- Nikon TE microscope with 3MP camera and various objectives.
- Fluigent - 4 port continuous pressure fluid pump

Nanomaterials for Energy Applications and Technology Laboratory (Baxter)

- 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)

- 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

Nanocrystal Solar Laboratory (Fafarman)

- Two chamber fabrication glove box with separate air-purification for wet-chemical synthesis and dry-process fabrication steps, featuring HEPA filtered laminar flow air handling for class-1 cleanroom conditions in an inert atmosphere. In the wet-chemical fabrication chamber there are a spincoater, centrifuge, hot-plates and solid and liquid reagents. On the dry chamber side, there is an integrated thermal evaporator for depositing metal, and a UV-ozone cleaner.
- Custom built Schlenk vacuum/gas manifold, all necessary glassware, J-Kem precision temperature controllers and heating mantles
- Perkin Elmer Lambda 35 UV-vis spectrometer
- ThermoFisher Nicolet iS50R Fourier-transform vis-NIR-MIR absorption spectrometer covering spectral ranges 13000 – 600 and 25000 – 8000 1/cm
- Keithley dual-channel precision source-meter
- Crystalaser Q-switch laser, 300 mW at 532 nm
- Home-built 4-point probe station for thin film electrical conductivity
- 80 MHz digital oscilloscope
- Stanford Research Systems lock-in amplifier

Nanofibers for Energy Storage and Conversion Laboratory (Kalra)

- Four Electrospinning Stations (with core-shell spinning capability)
- Mbraun Dual User Glove Box
- Carver Heat Press
- Four Gamry Potentiostats (Ref 3000 and Interface 1000)
- 32-channel Maccor Battery Cycler, three 8-channel NEWARE Battery Cyclers
- Rotating Disc Electrode Test Station (Pine Instruments)
- Tube Furnaces/Convection Ovens/Vacuum Ovens/Ultrasonicator/Hot Plates/Precision Balances
- Environmental Chamber (Tenney) with high temperature/humidity control ranging from 25-200C and 5-95%RH and integrated with vapor permeation and EIS
- Thermo Fisher Nicolet IS50 FTIR Spectrometer equipped with in-operando battery/supercapacitor cells

Thin Films and Devices Laboratory (Lau)

- Chemical Vapor Deposition Thin Film Reactor System I
- Chemical Vapor Deposition Thin Film Reactor System II
- Chemical Vapor Deposition Rotating Bed Reactor System
- Denton Desktop High Vacuum Sputtering System
- Harrick RF Plasma Reactor
- Gamry Reference 600 Electrochemical Testing Station

- Gamry Interface 1000 Electrochemical Impedance Spectrometer
- Agilent Electrochemical Impedance Analyzer 4294A
- Solar Illuminator
- Nicolet 6700 FTIR Spectrometer
- Shimadzu UV-1800 UV-VIS Spectrophotometer
- Laurell Technologies Spin Coater
- Ramé-Hart 290 Goniometer
- Meiji MT5310L Microscope
- Vacuum Ovens/Hot Plates

Polymers and Composites Laboratory (Palmese)

- 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)

- Shimadzu GPC
- Mini-Reactors
- Agilent GC/MS
- Fluidized Sand Bath
- IKA-RCT Stirred Hotplate Reactors
- Olympus Microscope
- Shimadzu UV-Vis Spectrophotometer (UV-1700)

Electrochemical Interfaces and Catalysis Laboratory (Snyder)

- Millipore DI water system
- 302N Autolab Potentiostats (x2)
- Mettler Toledo Micro-Balance
- Ultracentrifuge
- 4 port Schlenk line
- 4 kW Ambrell Radio Frequency Induction Furnace

Tang Laboratory (Tang)

- Six-channel Bio-Logic SP-300 potentiostat with electrochemical impedance spectroscopy
- LC Technology dual-user glovebox with argon atmosphere. Includes oxygen and water analyzers, electronic feedthroughs, and integrated vacuum oven
- Coin cell crimper /decrimper for battery fabrication (TOB Battery)
- Automatic electrode film coater (TOB Battery)
- Tube furnace

- Vacuum oven
- Karl-Fischer titration apparatus (Mettler Toledo)
- Two rotating disk electrode test station (Pine Instruments) with rotating ring-disk accessories
- 32-channel battery cycler (Arbin)

Wrenn Laboratory (Wrenn)

- 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

Chemical 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.

Nicolas Alvarez, PhD *(Carnegie Mellon University)*. Assistant Professor. Phototonic crystal defect chromatography; extensional rheology of polymer/ polymer composites; surfactant/polymer transport to fluid and solid interfaces; aqueous lubrication; interfacial instabilities.

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

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

Aviel Chaimovich, PhD *(University of Southern California, Santa Barbara)*. Assistant Teaching Professor. Molecular simulations.

Megan A. Creighton, PhD *(Brown University)*. Assistant Professor. Sustainable manufacturing practices. Valorization of waste, feasibility assessments of commercialization pipelines, circular economy strategies, and responsible innovation.

Peter Deak, PhD *(University of Notre Dame)*. Assistant Professor. Design of innate immune modulating nanoparticles for vaccines, autoimmune diseases and transplantation. Chemical modulation of immunity.

Aaron Fafarman, PhD *(Stanford University)*. Associate Professor. Photovoltaic energy conversion; solution-based synthesis of semiconductor thin films; colloidal nanocrystals; electromodulation and photomodulation spectroscopy.

Joshua Lequieu, PhD *(University of Chicago)*. Assistant Professor. Polymer physics; statistical mechanics; field-theoretic simulation; molecular simulation.

Matthew A. McDonald, PhD *(Georgia Institute of Technology)*. Assistant Professor. Automation and machine learning to accelerate development of challenging chemical processes; pharmaceutical discovery and process engineering; crystallization as a separation technology.

Joshua Snyder, PhD *(Johns Hopkins University)*. Associate Professor. Electrocatalysis (energy conversion/storage); hetergeneous catalysis corrosion (dealloying nanoporous metals); interfacial electrochemical phenomena in nanostructured materials; colloidal synthesis.

Masoud Soroush, PhD *(University of Michigan)*. Professor. Process systems engineering; polymer engineering.

John H. Speidel, BSHE, MCHE *(University of Delaware; Illinois Institute of Technology)*. Teaching Professor. Chemical process safety; process design engineering.

Maureen Tang, PhD *(University of California, Berkeley)*. Associate Professor. Batteries and fuel cells; nonaqueous electrochemistry; charge transport at interfaces.

Michael Walters, PhD *(Drexel University)*. Associate Teaching Professor. Undergraduate laboratory.

Emeritus Faculty

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

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

Civil Engineering MSCE

Major: Civil Engineering
Degree Awarded: Master of Science in Civil Engineering (MSCE)
Calendar Type: Quarter
Total Credit Hours: 45.0
Co-op Option: MSCE: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.0801
Standard Occupational Classification (SOC) code: 17-2015

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.

General Information

The civil engineering programs comprise the following areas of specialization: geotechnical engineering, structural engineering and water resource engineering.

Additional Information

For more information, visit the MS in Civil Engineering program (https://drexel.edu/engineering/academics/graduate-programs/masters/civil-engineering/) and Department of Civil, Architectural and Environmental Engineering (https://drexel.edu/engineering/academics/departments/civil-architectural-environmental-engineering/) webpages.

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 optional. 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.

Both full- and part-time students are welcome in the MSCE program. 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 15.0 credits are Required Theme Courses within the major field of interest, 15.0 credits are Core Technical Electives within the major field of interest, and the remaining 15.0 credits are taken as Additional Technical Electives in the related areas or in combination with research and thesis credits or from approved certificate programs (up to a maximum of 15.0 credits). The choice of Core Technical Electives and Additional Technical Elective courses is made in consultation with the student's graduate advisor.

Areas of concentration include:

- Geotechnical Engineering
- Structural Engineering
- Water Resources Engineering

Co-op

Students have the option to pursue a co-op as part of their master's program. In conjunction with the Steinbright Career Development Center, students will be provided an overview of professionalism, resume writing, and the job search process. Co-op will be for a six-month position running in the summer/fall terms. Students will not earn academic credit for the co-op but will earn 9.0 non-academic co-op units per term.

Geotechnical Engineering Requirements

Required Theme Courses *		**15.0**
CIVE 531	Advanced Foundation Engineering	
CIVE 632	Advanced Soil Mechanics	
CIVE 633	Lateral Earth Pressures and Retaining Structures	
CIVE 635	Slope Stability and Landslides	
CIVE 637	Seepage and Consolidation	
Core Technical Electives		**15.0-30.0**
Select from any of the following:		
CIVE 516	Geotechnical Site Investigation	
CIVE 518	Natural Hazards and Infrastructure	
CIVE 605	Advanced Mechanics of Materials	
CIVE 636	Engineering Ground Improvement	
CIVE 639	Applied Finite Element Analysis in Geotechnical Engineering	
CIVE 650	Geosynthetics in Civil Infrastructure	
or CIVE 651	Geosynthetics in Waste Containment	
CIVE 730	Experimental Soil Mechanics I	
or CIVE 731	Experimental Soil Mechanics II	
or CIVE 732	Experimental Soil Mechanics III	
CIVE 737	Seismic Geotechnics	
CIVE 839	Constitutive Models in Geomechanics	
MATH 520	Numerical Analysis I	
or MATH 521	Numerical Analysis II	
MEM 591	Applied Engr Analy Methods I	
or MEM 592	Applied Engr Analy Methods II	
MEM 681	Finite Element Methods I	
or MEM 682	Finite Element Methods II	
MEM 777	Fracture Mechanics I	
Additional Technical Elective Courses **		**0.0-15.0**
These courses must be approved by the student's advisor and the graduate advisor.		
Select from any of the following or courses from the Core Technical Electives which have not aready been taken for credit.		
CIVE 562	Introduction to Groundwater Hydrology	
CIVE 640	Environmental Geotechnics	
ENVE 555	Geographic Information Systems	
ENVE 727	Risk Assessment	
ENVE 750	Data-based Engineering Modeling	
MEM 660	Theory of Elasticity I	
MEM 663	Continuum Mechanics	
MEM 664	Introduction to Plasticity	
Thesis, Research Project, or additional Graduate Technical Electives ***		**0.0-9.0**
Optional Coop Experience †		**0 - 1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-61.0**

*

Must achieve grade of B or better.

**

It should be noted that up to 15 credits from an approved certificate program can be applied to meet the requirements for the “Additional Technical Electives”.

***
For students writing a master’s thesis, nine credits should consist of a minimum of 8 research credits (CIVE 997) and a minimum of 1 thesis credit (CIVE 898). Full time master’s students are encouraged to do a thesis. Students opting not to do a thesis could do a research project which would consist of a minimum of 5 research credits (CIVE 997) and a minimum of 1 thesis credit (CIVE 898) or would require the completion of an additional 9.0 graduate technical elective credits from the list above, therefore, the total graduate technical elective credits required will be 15.0.

†
Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500. The total credits required for this degree with the co-op experience is 46.
Students not participating in the co-op experience will need 45.0 credits to graduate

Structural Engineering Requirements

Required Theme Courses *		**15.0**
CIVE 605	Advanced Mechanics of Materials *	
CIVE 701	Advanced Structural Analysis I	
CIVE 702	Advanced Structural Analysis II	
CIVE 703	Advanced Structural Analysis III	
CIVE 708	Fundamentals of Structural Dynamics	
Core Technical Elective Courses		**15.0-30.0**
Select from any of the following:		
CIVE 510	Prestressed Concrete	
CIVE 511	Advanced Steel Design	
CIVE 512	Wood and Timber Design	
CIVE 513	Introduction to Artificial Intelligence for Smart Structures and Systems	
CIVE 531	Advanced Foundation Engineering	
CIVE 540	Forensic Structural Engineering	
CIVE 615	Infrastructure Condition Evaluation	
CIVE 639	Applied Finite Element Analysis in Geotechnical Engineering	
CIVE 704	Behavior and Stability of Structural Members I	
CIVE 705	Behavior and Stability of Structural Members II	
CIVE 711	Engineered Masonry I	
CIVE 714	Behavior of Concrete Structures I	
CIVE 839	Constitutive Models in Geomechanics	
MATH 520	Numerical Analysis I	
or MATH 521	Numerical Analysis II	
MEM 591	Applied Engr Analy Methods I	
or MEM 592	Applied Engr Analy Methods II	
MEM 660	Theory of Elasticity I	
MEM 663	Continuum Mechanics	
MEM 664	Introduction to Plasticity	
MEM 681	Finite Element Methods I	
or MEM 682	Finite Element Methods II	
MEM 777	Fracture Mechanics I	
Additional Technical Elective Courses **		**0.0-15.0**
These courses must be approved by the student's advisor and the gradute advisor.		
Select from any of the following or courses from the Core Technical Electives which have not aready been taken for credit.		
AE 510	Intelligent Buildings	
AE 561	Airflow Simulation in Built Environment	
CIVE 520	Advanced Concrete Technology	
ENVE 555	Geographic Information Systems	
ENVE 571	Environmental Life Cycle Assessment	
ENVE 727	Risk Assessment	
ENVE 750	Data-based Engineering Modeling	
Thesis, Research Project, or additional Graduate Technical Electives ***		**0.0-9.0**
Optional Coop Experience †		**0 - 1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-61.0**

*
Must achieve grade of B or better.

**

It should be noted that up to 15 credits from an approved certificate program can be applied to meet the requirements for the “Additional Technical Electives”.

***

For students writing an master’s thesis, nine credits should consist of a minimum of 8 research credits (CIVE 997) and a minimum of 1 thesis credit (CIVE 898). Full time master’s students are encouraged to do a thesis. Students opting not to do a thesis could do a research project which would consist of a minimum of 5 research credits (CIVE 997) and a minimum of 1 thesis credit (CIVE 898) or would require the completion of an additional 9.0 graduate technical elective credits from the list above, therefore, the total graduate technical elective credits required will be 21.0.

†

Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500. The total credits required for this degree with the co-op experience is 46.
Students not participating in the co-op experience will need 45.0 credits to graduate

Water Resources Engineering Requirements

Required Theme Courses [*]		**15.0**
CIVE 564	Sustainable Water Resource Engineering	
CIVE 565	Urban Ecohydraulics	
CIVE 664	Open Channel Hydraulics	
ENVE 681	Analytical and Numerical Techniques in Hydrology	
or CIVE 567	Watershed Analysis	
ENVS 501	Chemistry of the Environment	
Core Technical Courses		**15.0-30.0**
Select from any of the following:		
CIVE 562	Introduction to Groundwater Hydrology	
CIVE 567	Watershed Analysis	
ENVE 660	Chemical Kinetics in Environmental Engineering	
ENVE 661	Env Engr Op-Chem & Phys	
ENVE 665	Hazardous Waste & Groundwater Treatment	
ENVE 727	Risk Assessment	
ENVE 750	Data-based Engineering Modeling	
Additional Technical Elective Courses [**]		**0.0-15.0**
These courses must be approved by the student's advisor and the graduate advisor.		
Select from any of the following or courses from the Core Technical Electives which have not aready been taken for credit.		
CIVE 615	Infrastructure Condition Evaluation	
ENVE 555	Geographic Information Systems	
ENVE 571	Environmental Life Cycle Assessment	
Thesis, Research Project, or additional Graduate Technical Electives [***]		**0.0-9.0**
Optional Coop Experience [†]		**0 - 1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-61.0**

*

Must achieve grade of B or better.

**

It should be noted that up to 15 credits from an approved certificate program can be applied to meet the requirements for the “Additional Technical Electives”.

***

For students writing an master’s thesis, nine credits should consist of a minimum of 8 research credits (CIVE 997) and a minimum of 1 thesis credit (CIVE 898). Full time master’s students are encouraged to do a thesis. Students opting not to do a thesis could do a research project which would consist of a minimum of 5 research credits (CIVE 997) and a minimum of 1 thesis credit (CIVE 898) or would require the completion of an additional 9.0 graduate technical elective credits from the list above, therefore, the total graduate technical elective credits required will be 21.0.

†

Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500. The total credits required for this degree with the co-op experience is 46.
Students not participating in the co-op experience will need 45.0 credits to graduate

Sample Plan of Study (MS)

MSCE No CO-OP, with Thesis Option

First Year							
Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
Required Theme Course	6.0	Required Theme Course	3.0	Required Theme Course	3.0	VACATION	
Core Technical Elective	3.0	Core Technical Elective	3.0	Core Technical Elective	3.0		
		Additional Technical Elective	3.0	Additional Technical Elective	3.0		
	9		9		9		0
Second Year							
Fall	Credits	Winter	Credits				
Required Theme Course	3.0	Core Technical Elective	3.0				
Core Technical Electives	3.0	Additional Technical Elective or Research Credit	3.0				
Additional Technical Elective or Research Credit	3.0	Additional Technical Elective or Thesis Credit	3.0				
	9		9				

Total Credits 45

MSCE CO-OP Option, No Thesis

First Year							
Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
COOP 500	1.0	Required Theme Course	3.0	Required Theme Course	3.0	VACATION	
Required Theme Course	6.0	Core Technical Elective	6.0	Core Technical Elective	3.0		
Core Technical Elective	3.0	Additional Technical Elective	3.0	Additional Technical Elective	6.0		
	10		12		12		0
Second Year							
Fall	Credits	Winter	Credits	Spring	Credits		
COOP EXPERIENCE		COOP EXPERIENCE		Core Technical Elective	3.0		
				Additional Technical Elective	6.0		
				Required Theme Course	3.0		
	0		0		12		

Total Credits 46

Facilities

The Civil, Architectural, and Environmental Engineering Department laboratories provide students with fully equipped space for education and research opportunities.

Structural and Geotechnical Research Laboratory Facilities and Equipment

The geotechnical and structural engineering research labs at Drexel University provide a forum to perform large-scale experimentation across a broad range of areas including infrastructure preservation and renewal, structural health monitoring, geosynthetics, nondestructive evaluation, earthquake engineering, and novel ground modification approaches among others.

The laboratory is equipped with different data acquisition systems (MTS, Campbell Scientific, and National Instruments) capable of recording strain, displacement, tilt, load and acceleration time histories. An array of sensors including LVDTs, wire potentiometers, linear and rotational accelerometers, and load cells are also available. Structural testing capabilities include two 220kips capacity loading frames (MTS 311 and Tinius Olsen), in addition to several medium capacity testing frames (Instron 1331 and 567 and MTS 370 testing frames), two 5-kips MTS actuators for dynamic testing and one degree of freedom 22kips ANCO shake table. The laboratory also features a phenomenological physical model which resembles the dynamic features of common highway bridges and is used for field testing preparation and for testing different measurement devices.

The **Woodring Laboratory** hosts a wide variety of geotechnical, geosynthetics, and materials engineering testing equipment. The geotechnical engineering testing equipment includes Geotac unconfined compression and a triaxial compression testing device, ring shear apparatus, constant rate of strain consolidometer, an automated incremental consolidometer, an automated Geotac direct shear device and a large-scale consolidometer (12” by 12” sample size). Other equipment includes a Fisher pH and conductivity meter as well as a Brookfield rotating viscometer. Electronic and digital equipment include FLIR SC 325 infrared camera for thermal measurements, NI Function generators, acoustic emission sensors and ultrasonic transducers, signal conditioners, and impulse hammers for nondestructive testing.

The geosynthetics testing equipment in the Woodring lab includes pressure cells for incubation and a new differential scanning calorimetry device including the standard-OIT. Materials testing equipment that is available through the materials and chemical engineering departments includes a scanning electron microscope, liquid chromatography, and Fourier transform infrared spectroscopy.

The Building Science and Engineering Group (BSEG) research space is also located in the Woodring Laboratory. This is a collaborative research unit working at Drexel University with the objective of achieving more comprehensive and innovative approaches to sustainable building design and operation through the promotion of greater collaboration between diverse sets of research expertise. Much of the BSEG work is simulation or model based. Researchers in this lab also share some instrumentation with the DARRL lab (see below).

Environmental Engineering Laboratory Facilities and Equipment

The environmental engineering laboratories at Drexel University allow faculty and student researchers access to state-of-the-art equipment needed to execute a variety of experiments. These facilities are located in the Alumni Engineering Laboratory Building and includes approximately 2000 SF shared laboratory space, and a 400 SF clean room for cell culture and PCR.

The major equipment used in this laboratory space consists of: Roche Applied Science LightCyclerÔ 480 Real-time PCR System, Leica fluorescence microscope with phase contrast and video camera, Spectrophotometer, Zeiss stereo microscope with heavy duty boom stand, fluorescence capability, and a SPOT cooled color camera, BIORAD iCycler thermocycler for PCR, gel readers, transilluminator and electrophoresis setups, temperature controlled circulator with immersion stirrers suitable for inactivation studies at volumes up to 2 L per reactor, BSL level 2 fume hood, laminar hood, soil sampling equipment, Percival Scientific environmental chamber (model 1-35LLVL), custom-built rainfall simulator.

The **Drexel Air Resources Research Laboratory (DARRL)** is located in the Alumni Engineering Laboratory Building and contains state-of-the-art aerosol measurement instrumentation including a Soot Particle Aerosol Mass Spectrometer (Aerodyne Research Inc.), mini-Aerosol Mass Spectrometer, (Aerodyne Research Inc.), Scanning Electrical Mobility Sizer (Brechtel Manufacturing), Scanning Mobility Particle Sizer (TSI Inc.), Fast Mobility Particle Sizer (TSI Inc.), Centrifugal Particle Mass Analyzer (Cambustion Ltd.), GC-FID, ozone monitors, and other instrumentation. These instruments are used for the detailed characterization of the properties of particles less than 1 micrometer in diameter including: chemical composition, size, density, and shape or morphology.

In addition to the analytical instrumentation in DARRL, the laboratory houses several reaction chambers. These chambers are used for controlled experiments meant to simulate chemical reactions that occur in the indoor and outdoor environments. The reaction chambers vary in size from 15 L to 1 m3, and allow for a range of experimental conditions to be conducted in the laboratory.

Computer Equipment and Software

The Civil, Architectural, and Environmental Engineering (CAEE) Department at Drexel University has hardware and software capabilities for students to conduct research. The CAEE department operates a computer lab that is divided into two sections; one open access room, and a section dedicated to teaching. The current computer lab has 25 desktop computers that are recently updated to handle resource intensive GIS (Geographic Information Systems) and image processing software. There are a sufficient number of B&W and color laser printers that can be utilized for basic printing purposes.

Drexel University has site-licenses for a number of software, such as ESRITM ArcGIS 10, Visual Studio, SAP 2000, STAAD, Abaqus and MathworksTM Matlab. The Information Resources & Technology (IRT) department at Drexel University provides support (e.g., installation, maintenance and troubleshooting) to the above-mentioned software. It is currently supporting the lab by hosting a software image configuration that provides a series of commonly used software packages, such as MS Office and ADOBE Acrobat among others. As a part of ESRI campus license (the primary maker of GIS applications, i.e. ArcGIS) the department has access to a suite of seated licenses for GIS software with necessary extensions (e.g., LIDAR Analyst) required for conducting research.

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- Communicate effectively with a range of audiences
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

- Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- Acquire and apply new knowledge as needed, using appropriate learning strategies

Civil, Architectural and Environmental Engineering Faculty

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

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

Shannon Capps, PhD *(Georgia Institute of Technology)*. Associate Professor. Atmospheric chemistry; data assimilation; advanced sensitivity analysis; inverse modeling.

Zhiwei Chen, PhD *(University of South Florida)*. Assistant Professor. Mobility system modeling, simulation, optimization, control, and social impact analysis, with applications to modular, connected, and automated vehicle systems, mobility as a service, public transit systems.

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

Arvin Ebrahimkhanlou, PhD *(University of Texas at Austin)*. Assistant Professor. Non-destructive evaluation, structural health monitoring, artificial intelligence, robotics.

Yaghoob (Amir) Farnam, PhD *(Purdue University)*. Associate Professor. Advanced and sustainable infrastructure materials; multifunctional, self-responsive and bioinspired construction materials; advanced multiscale manufacturing; characterization, and evaluation of construction materials; durability of cement-based materials.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute and State University)*. Professor. Geotechnical and geoenvironmental engineering; soil improvement; soil improvement; recycled materials in geotechnics.

Patrick Gurian, PhD *(Carnegie-Mellon University)*. 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-Champaign) Program Head for Environmental Engineering; L. D. Betz Professor of Environmental Engineering*. Water treatment and wastewater resuse; risk analysis; microbial risk assessment; environmental modeling and statistics; microbiology; environmental health.

Simi Hoque, PhD *(University of California - Berkeley) Program Head for Architectural Engineering*. Professor. Computational methods to reduce building energy and environmental impacts, urban metabolism, thermal comfort, climate resilience.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Durability of polymeric construction materials; advanced construction materials; and performance of geosynthetics.

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

L. James Lo, PhD *(University of Texas at Austin)*. Associate Professor. Architectural fluid mechanics; building automation and autonomy; implementation of natural and hybrid ventilation in buildings; airflow distribution in buildings; large-scale air movement in an urban built environment; building and urban informatics; data-enhanced sensing and control for optimal building operation and management; novel data gathering methods for building/urban problem solving; interdisciplinary research on occupant behaviors in the built environment.

Franco Montalto, PhD *(Cornell University)*. Professor. Water in the built environment; planning, design, and restoration of natural and nature-based systems, including green stormwater infrastructure; urban ecohydrology; hydrologic and hydraulic modeling; urban flooding; urban sustainability; and climate change and climate resilience.

Mira S. Olson, PhD *(University of Virginia)*. Associate Professor. Peace engineering; source water quality protection and management; contaminant and bacterial fate and transport; community engagement.

Miguel A. Pando, PhD *(Virginia Polytechnic Institute and State University)*. Associate Professor. Slope stability and landslides; natural hazards; geotechnical earthquake engineering and liquefaction; laboratory and field measurement of soil and rock properties; soil erosion and scour; soil-structure-interaction; earth-based construction materials.

Matthew Reichenbach, PhD *(University of Austin at Texas)*. Assistant Teaching Professor. Design and behavior of steel structures, bridge engineering, structural stability

Fernanda Cruz Rios, PhD *(Arizona State University)*. Assistant Professor. Circular economy, life cycle assessment, convergence research, sustainable buildings and cities.

Michael Ryan, PhD *(Drexel University) Associate Department Head of Graduate Studies*. Associate Teaching Professor. Microbial Source Tracking (MST); Quantitative Microbial Risk Assessment (QMRA); dynamic engineering systems modeling; molecular microbial biology; phylogenetics; metagenomics; bioinformatics; environmental statistics; engineering economics; microbiology; potable and wastewater quality; environmental management systems.

Christopher Sales, PhD *(University of California, Berkeley)*. Associate Professor. Environmental microbiology and biotechnology; biodegradation of environmental contaminants; microbial processes for energy and resource recovery from waste; application of molecular biology, analytical chemistry and bioinformatic techniques to study environmental biological systems.

Robert Swan, PhD *(Drexel University) Associate Department Head for Undergraduates*. Teaching Professor. Geotechnical and geosynthetic engineering; soil/geosynthetic interaction and performance; laboratory and field geotechnical/geosynthetic testing.

Sharon Walker, PhD *(Yale University) Dean, College of Engineering*. Distinguished Professor. Water quality systems engineering; fate and transport of nanomaterials; pathogen adhesion phenomena.

Michael Waring, PhD *(University of Texas at Austin) Department Head, Civil, Architectural, and Environmental Engineering*. Professor. Indoor air quality, indoor aerosols, indoor air modeling, indoor chemistry, healthy buildings, and building sustainability intelligent ventilation, air cleaning, indoor disease transmission.

Jin Wen, PhD *(University of Iowa) Associate Dean for Research and Innovation, College of Engineering*. Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Building-grid integration; Occupant Centric Control; and Indoor Air Quality.

Emeritus Faculty

A. Emin Aktan, PhD *(University of Illinois, Urbana-Champaign)*. Professor Emeritus. Health monitoring and management of large infrastructures with emphasis on health monitoring.

Eugenia Ellis, PhD, AIA *(Virginia Polytechnic Institute and State University)*. Professor Emerita. Natural and electrical light sources and effects on biological rhythms and health outcomes; ecological strategies for smart, sustainable buildings of the nexus of health, energy, and technology.

Ahmad Hamid, PhD *(McMaster University)*. Professor Emeritus. Engineered masonry; seismic behavior, design and retrofit of masonry structures; development of new materials and building systems.

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

Joseph P. Martin, PhD *(Colorado State University)*. Professor Emeritus. Geotechnical and geoenvironmental engineering; hydrology; transportation; waste management.

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

Aspasia Zerva, PhD *(University of Illinois, Urbana-Champaign)*. Professor. Earthquake engineering; mechanics; seismology; structural reliability; system identification; advanced computational methods in structural analysis.

Civil Engineering PhD

Major: Civil Engineering
Degree Awarded: Doctor of Philosophy (PhD)
Calendar Type: Quarter
Minimum Required Credits: 90.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0801
Standard Occupational Classification (SOC) code: 17-2015

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.

Civil Engineering is inherently an interdisciplinary enterprise that is centered on the design, construction, and operation of the build environment. Civil Engineering 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 or focus of expertise):

- Structural engineering
- Geotechnical/geosynthetics engineering
- Transportation engineering
- Water resources engineering
- Sustainable engineering

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.

Additional Information

For more information, visit the Doctorate in Civil Engineering program (https://drexel.edu/engineering/academics/graduate-programs/doctoral/civil-engineering/) and Department of Civil, Architectural and Environmental Engineering (https://drexel.edu/engineering/academics/departments/civil-architectural-environmental-engineering/) webpages.

Admission Requirements

Applicants to the PhD in Civil Engineering must have a minimum of a Bachelor of Science degree. 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 (optional)
- 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.

For additional information on how to apply, visit Drexel's Admissions page for Civil Engineering (http://www.drexel.edu/grad/programs/coe/civil-engineering/).

Degree Requirements

Requirements

The following general requirements must be satisfied to complete the PhD in Civil Engineering:

- Establishment of plan of study with PhD advisor
- Completion of 90.0 quarter credit hours (or 45 credit hours post-Masters), including taking certain qualifying courses
- Passing of PhD candidacy exam
- Approval of PhD dissertation proposal
- Defense of PhD dissertation

Students entering the PhD program with an approved Master of Science (MS) degree must take 45 credit hours of coursework and research to be approved by their PhD advisor. Students entering the PhD program without an approved MS degree can either complete the 45-credit hour Master of Science in Civil Engineering (MSCE) degree followed by an additional 45 credit hours post MSCI, or they can choose to not obtain the MSCE and complete only the required "core" courses for the PhD degree with the completion of a total of 90 required credit hours. Students with previous graduate coursework may transfer no more than 15 quarter credits (equivalent to 12 semester credit) from approved institutions if deemed equivalent to courses offered within the department.

All PhD students are required to meet all milestones of the program. The total credit amount, candidacy exam, and dissertation are university requirements. Additional requirements are determined by the department offering the degree.

Qualifying Courses

To satisfy the qualifying requirements, students must earn a grade of B+ or better in the five required "core" courses (depending on the program of study) taken at Drexel and must earn an overall GPA of 3.5 or better in these courses.

Undergraduate courses, independent studies, research credits, and courses from other departments cannot be counted toward the qualifying requirements. Students progress toward these requirements will be assessed by the PhD advisor following the student's first year in the PhD program. For more information, visit the Civil Engineering's PhD Program Requirements page.

Candidacy Exam

After approximately one year of study beyond the MS degree or completion of the required "core" courses, if their GPA is greater than or equal to 3.5, PhD students can and must take a candidacy examination consisting of written and oral parts. Successful completion of the candidacy exam enables a student to progress from the designation of PhD student to PhD candidate. The candidacy exam represents the first exam in a series of three that comprise the PhD curriculum.

The Civil Engineering candidacy examination serves to define the student's research domain and to evaluate the student's knowledge and understanding of various fundamental and foundational results in that domain. The student is expected to be able to read, understand, analyze, and explain advanced technical results in a specialized area of Civil Engineering at an adequate level of detail. The candidacy examination will evaluate those abilities by asking a student to summarize literature and/or undertake a small research project. The student will prepare a written summary of review and/or project results, present the outcome orally, and answer questions about the report or presentation. The candidacy examination committee will evaluate the written report, the oral presentation, and the student's answers. The candidacy committee membership must follow the requirements of the Graduate College and must be approved by the Graduate College.

Students with a GPA < 3.5 do not meet eligibility requirements to sit for the candidacy exam. In this case, a student may petition a Graduate Advisor to take a Preliminary Written Exam (PWE). A committee will be formed consisting of three members selected from the pool of faculty in the field of research interest of the student and the pool of faculty who taught the courses taken by the student during the preceding terms. An exam will be developed consisting of a series of questions/problems prepared by the three written exam committee members. The written exam, while fixed in duration, may be composed of several different problem-solving assignments. Additionally, the exam may be closed book or open book or a combination thereof. The student will consult with the advisor to become acquainted with the specific rules of the exam. The exam will be graded by the PWE Committee to determine if the student may sit for the candidacy exam.

Dissertation Proposal

After successfully completing the candidacy examination, the PhD candidate must prepare a dissertation proposal that outlines, in detail, the specific problems that will be solved during the research that is conducted to complete the PhD dissertation. The quality of the dissertation proposal should be at the level of a peer-reviewed proposal to a federal funding agency, or a publishable scientific paper. The candidate is responsible for sending the dissertation proposal to the PhD committee no less than two weeks before the scheduled oral presentation. The PhD committee membership need not be the same as the candidacy exam committee, but it follows the same requirements and must be approved by the Graduate College. The oral presentation involves a presentation by the candidate followed by a period during which the committee will ask questions. The committee will then determine if the dissertation proposal has been accepted. The dissertation proposal can be repeated at most once if the proposal was not accepted.

A dissertation proposal must be approved within two years of becoming a PhD candidate. After approval of the dissertation proposal, the committee may meet to review the progress of the research.

Dissertation Defense

After successfully completing the dissertation proposal, 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 no less than two weeks prior to the scheduled oral defense. The oral presentation by the candidate is 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. The committee will then determine if the candidate has passed or failed the examination. If not passed, the candidate will be granted one more chance to pass the final defense.

The PhD degree is awarded for original research on a significant Civil Engineering problem. Graduate students will work closely with individual faculty members to pursue the PhD degree. 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.

Program Requirements

Post Bachelor of Science Degree - Geotechnical Engineering

Required Core Courses		
CIVE 531	Advanced Foundation Engineering	3.0
CIVE 632	Advanced Soil Mechanics	3.0
CIVE 633	Lateral Earth Pressures and Retaining Structures	3.0
CIVE 635	Slope Stability and Landslides	3.0
CIVE 637	Seepage and Consolidation	3.0
Technical Elective Requirements		**0.0-33.0**
To be determined by the PhD faculty advisor and approved by the graduate advisor		
500+ level courses in AE, CIVE, ENVE, or other courses approved by the graduate advisor		
Research Requirements *		
CIVE 997	Research	71.0-140.0
Dissertation Requirements		

CIVE 998	Ph.D. Dissertation	1.0-12.0
Total Credits		**90.0-170.0**

*

Please note that the number of research credits may be reduced based on the number of Technical Electives that are required.

Post Bachelor of Science Degree - Structural Engineering

Required Core Courses		
CIVE 605	Advanced Mechanics of Materials	3.0
CIVE 701	Advanced Structural Analysis I	3.0
CIVE 702	Advanced Structural Analysis II	3.0
CIVE 703	Advanced Structural Analysis III	3.0
CIVE 708	Fundamentals of Structural Dynamics	3.0
Technical Elective Requirements		**0.0-33.0**
To be determined by the PhD faculty advisor and approved by the graduate advisor		
500+ level courses in AE, CIVE, ENVE, or other courses approved by the graduate advisor		
Research Requirements *		
CIVE 997	Research	71.0-140.0
Dissertation Requirements		
CIVE 998	Ph.D. Dissertation	1.0-12.0
Total Credits		**90.0-170.0**

*

Please note that the number of research credits may be reduced based on the number of Technical Electives that are required.

Post Bachelor of Science Degree - Water Resources Engineering

Required Core Courses		
CIVE 564	Sustainable Water Resource Engineering	3.0
CIVE 565	Urban Ecohydraulics	3.0
CIVE 664	Open Channel Hydraulics	3.0
ENVE 681	Analytical and Numerical Techniques in Hydrology	3.0
or CIVE 567	Watershed Analysis	
ENVS 501	Chemistry of the Environment	3.0
Technical Elective Requirements		**0.0-30.0**
To be determined by the PhD faculty advisor and approved by the graduate advisor		
500+ level courses in AE, CIVE, ENVE, or other courses approved by the graduate advisor		
Research Requirements *		
CIVE 997	Research	71.0-140.0
Dissertation Credit Requirements		
CIVE 998	Ph.D. Dissertation	1.0-12.0
Total Credits		**90.0-170.0**

*

Please note that the number of research credits may be reduced based on the number of Technical Electives that are required.

Post Master of Science Degree

Technical Elective Requirements		**0.0-30.0**
To be determined by the PhD faculty advisor and approved by the graduate advisor		
500+ level courses in AE, CIVE, ENVE, or other courses approved by the graduate advisor		
Research Requirements *		
CIVE 997	Research	44.0-100.0
Dissertation Requirements		
CIVE 998	Ph.D. Dissertation	1.0-12.0
Total Credits		**45.0-142.0**

*

Please note that the number of research credits may be reduced based on the number of Technical Electives that are required.

Sample Plan of Study

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 advisor and uploaded to the E-Forms system no later than the end of the first term. The E-Forms system will be used to track program progression and milestones. Sample Plans of Study are presented below:

Post Bachelor of Science Degree - Geotechnical/Geosynthetics Engineering

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 531	3.0	CIVE 633	3.0	CIVE 635	3.0	Vacation	0.0
CIVE 632	3.0	Technical Electives	6.0	CIVE 637	3.0		
Technical Electives	3.0			Technical Electives	3.0		
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		**9**		**9**		**0**
Third Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		**9**		**9**		**0**
Fourth Year							
Fall	**Credits**						
CIVE 997	6.0						
CIVE 998	3.0						
	9						

Total Credits 90

Post Bachelor of Science Degree - Structural Engineering

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 605	3.0	CIVE 702	3.0	CIVE 703	3.0	Vacation	0.0
CIVE 701	3.0	CIVE 708	3.0	Technical Electives	6.0		
Technical Electives	3.0	Technical Electives	3.0				
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		**9**		**9**		**0**
Third Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		**9**		**9**		**0**
Fourth Year							
Fall	**Credits**						
CIVE 997	6.0						
CIVE 998	3.0						
	9						

Total Credits 90

Post Bachelor of Science Degree - Water Resources Engineering

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ENVE 681 or CIVE 567	3.0	CIVE 565	3.0	CIVE 564	3.0	Vacation	0.0
ENVS 501	3.0	Technical Electives	6.0	ENVE 665	3.0		
Technical Electives	3.0			Technical Electives	3.0		
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		**9**		**9**		**0**

Third Year							
Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		9		9		0

Fourth Year	
Fall	Credits
CIVE 997	6.0
CIVE 998	3.0
	9

Total Credits 90

Post Master of Science Degree

First Year							
Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
CIVE 997	3.0	CIVE 997	3.0	CIVE 997	3.0	Vacation	0.0
Technical Electives	6.0	Technical Electives	6.0	Technical Electives	6.0		
	9		9		9		0

Second Year			
Fall	Credits	Winter	Credits
CIVE 997	9.0	CIVE 997	6.0
		CIVE 998	3.0
	9		9

Total Credits 45

Facilities

The Civil, Architectural, and Environmental Engineering Department laboratories provide students with fully equipped space for education and research opportunities.

Structural and Geotechnical Research Laboratory Facilities and Equipment

The geotechnical and structural engineering research labs at Drexel University provide a forum to perform large-scale experimentation across a broad range of areas including infrastructure preservation and renewal, structural health monitoring, geosynthetics, nondestructive evaluation, earthquake engineering, and novel ground modification approaches among others.

The laboratory is equipped with different data acquisition systems (MTS, Campbell Scientific, and National Instruments) capable of recording strain, displacement, tilt, load and acceleration time histories. An array of sensors including LVDTs, wire potentiometers, linear and rotational accelerometers, and load cells are also available. Structural testing capabilities include two 220kips capacity loading frames (MTS 311 and Tinius Olsen), in addition to several medium capacity testing frames (Instron 1331 and 567 and MTS 370 testing frames), two 5-kips MTS actuators for dynamic testing and one degree of freedom 22kips ANCO shake table. The laboratory also features a phenomenological physical model which resembles the dynamic features of common highway bridges and is used for field testing preparation and for testing different measurement devices.

The **Woodring Laboratory** hosts a wide variety of geotechnical, geosynthetics, and materials engineering testing equipment. The geotechnical engineering testing equipment includes Geotac unconfined compression and a triaxial compression testing device, ring shear apparatus, constant rate of strain consolidometer, an automated incremental consolidometer, an automated Geotac direct shear device and a large-scale consolidometer (12” by 12” sample size). Other equipment includes a Fisher pH and conductivity meter as well as a Brookfield rotating viscometer. Electronic and digital equipment include FLIR SC 325 infrared camera for thermal measurements, NI Function generators, acoustic emission sensors and ultrasonic transducers, signal conditioners, and impulse hammers for nondestructive testing.

The geosynthetics testing equipment in the Woodring lab includes pressure cells for incubation and a new differential scanning calorimetry device including the standard-OIT. Materials testing equipment that is available through the materials and chemical engineering departments includes a scanning electron microscope, liquid chromatography, and Fourier transform infrared spectroscopy.

The Building Science and Engineering Group (BSEG) research space is also located in the Woodring Laboratory. This is a collaborative research unit working at Drexel University with the objective of achieving more comprehensive and innovative approaches to sustainable building design and operation through the promotion of greater collaboration between diverse sets of research expertise. Much of the BSEG work is simulation or model based. Researchers in this lab also share some instrumentation with the DARRL lab (see below).

Environmental Engineering Laboratory Facilities and Equipment

The environmental engineering laboratories at Drexel University allow faculty and student researchers access to state-of-the-art equipment needed to execute a variety of experiments. These facilities are located in the Alumni Engineering Laboratory Building and includes approximately 2000 SF shared laboratory space, and a 400 SF clean room for cell culture and PCR.

The major equipment used in this laboratory space consists of: Roche Applied Science LightCyclerÔ 480 Real-time PCR System, Leica fluorescence microscope with phase contrast and video camera, Spectrophotometer, Zeiss stereo microscope with heavy duty boom stand, fluorescence capability, and a SPOT cooled color camera, BIORAD iCycler thermocycler for PCR, gel readers, transilluminator and electrophoresis setups, temperature controlled circulator with immersion stirrers suitable for inactivation studies at volumes up to 2 L per reactor, BSL level 2 fume hood, laminar hood, soil sampling equipment, Percival Scientific environmental chamber (model 1-35LLVL), custom-built rainfall simulator.

The **Drexel Air Resources Research Laboratory (DARRL)** is located in the Alumni Engineering Laboratory Building and contains state-of-the-art aerosol measurement instrumentation including a Soot Particle Aerosol Mass Spectrometer (Aerodyne Research Inc.), mini-Aerosol Mass Spectrometer, (Aerodyne Research Inc.), Scanning Electrical Mobility Sizer (Brechtel Manufacturing), Scanning Mobility Particle Sizer (TSI Inc.), Fast Mobility Particle Sizer (TSI Inc.), Centrifugal Particle Mass Analyzer (Cambustion Ltd.), GC-FID, ozone monitors, and other instrumentation. These instruments are used for the detailed characterization of the properties of particles less than 1 micrometer in diameter including: chemical composition, size, density, and shape or morphology.

In addition to the analytical instrumentation in DARRL, the laboratory houses several reaction chambers. These chambers are used for controlled experiments meant to simulate chemical reactions that occur in the indoor and outdoor environments. The reaction chambers vary in size from 15 L to 1 m3, and allow for a range of experimental conditions to be conducted in the laboratory.

Computer Equipment and Software

The Civil, Architectural, and Environmental Engineering (CAEE) Department at Drexel University has hardware and software capabilities for students to conduct research. The CAEE department operates a computer lab that is divided into two sections; one open access room, and a section dedicated to teaching. The current computer lab has 25 desktop computers that are recently updated to handle resource intensive GIS (Geographic Information Systems) and image processing software. There are a sufficient number of B&W and color laser printers that can be utilized for basic printing purposes.

Drexel University has site-licenses for a number of software, such as ESRITM ArcGIS 10, Visual Studio, SAP 2000, STAAD, Abaqus and MathworksTM Matlab. The Information Resources & Technology (IRT) department at Drexel University provides support (e.g., installation, maintenance and troubleshooting) to the above-mentioned software. It is currently supporting the lab by hosting a software image configuration that provides a series of commonly used software packages, such as MS Office and ADOBE Acrobat among others. As a part of ESRI campus license (the primary maker of GIS applications, i.e. ArcGIS) the department has access to a suite of seated licenses for GIS software with necessary extensions (e.g., LIDAR Analyst) required for conducting research.

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- Communicate effectively with a range of audiences
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- Acquire and apply new knowledge as needed, using appropriate learning strategies

Civil, Architectural and Environmental Engineering Faculty

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

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

Shannon Capps, PhD *(Georgia Institute of Technology)*. Associate Professor. Atmospheric chemistry; data assimilation; advanced sensitivity analysis; inverse modeling.

Zhiwei Chen, PhD *(University of South Florida)*. Assistant Professor. Mobility system modeling, simulation, optimization, control, and social impact analysis, with applications to modular, connected, and automated vehicle systems, mobility as a service, public transit systems.

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

Arvin Ebrahimkhanlou, PhD *(University of Texas at Austin)*. Assistant Professor. Non-destructive evaluation, structural health monitoring, artificial intelligence, robotics.

Yaghoob (Amir) Farnam, PhD *(Purdue University)*. Associate Professor. Advanced and sustainable infrastructure materials; multifunctional, self-responsive and bioinspired construction materials; advanced multiscale manufacturing; characterization, and evaluation of construction materials; durability of cement-based materials.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute and State University)*. Professor. Geotechnical and geoenvironmental engineering; soil improvement; soil improvement; recycled materials in geotechnics.

Patrick Gurian, PhD *(Carnegie-Mellon University)*. 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-Champaign) Program Head for Environmental Engineering; L. D. Betz Professor of Environmental Engineering*. Water treatment and wastewater resuse; risk analysis; microbial risk assessment; environmental modeling and statistics; microbiology; environmental health.

Simi Hoque, PhD *(University of California - Berkeley) Program Head for Architectural Engineering*. Professor. Computational methods to reduce building energy and environmental impacts, urban metabolism, thermal comfort, climate resilience.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Durability of polymeric construction materials; advanced construction materials; and performance of geosynthetics.

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Sharon Walker, PhD *(Yale University) Dean, College of Engineering*. Distinguished Professor. Water quality systems engineering; fate and transport of nanomaterials; pathogen adhesion phenomena.

Michael Waring, PhD *(University of Texas at Austin) Department Head, Civil, Architectural, and Environmental Engineering*. Professor. Indoor air quality, indoor aerosols, indoor air modeling, indoor chemistry, healthy buildings, and building sustainability intelligent ventilation, air cleaning, indoor disease transmission.

Jin Wen, PhD *(University of Iowa) Associate Dean for Research and Innovation, College of Engineering*. Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Building-grid integration; Occupant Centric Control; and Indoor Air Quality.

Emeritus Faculty

A. Emin Aktan, PhD *(University of Illinois, Urbana-Champaign)*. Professor Emeritus. Health monitoring and management of large infrastructures with emphasis on health monitoring.

Eugenia Ellis, PhD, AIA *(Virginia Polytechnic Institute and State University)*. Professor Emerita. Natural and electrical light sources and effects on biological rhythms and health outcomes; ecological strategies for smart, sustainable buildings of the nexus of health, energy, and technology.

Ahmad Hamid, PhD *(McMaster University)*. Professor Emeritus. Engineered masonry; seismic behavior, design and retrofit of masonry structures; development of new materials and building systems.

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

Joseph P. Martin, PhD *(Colorado State University)*. Professor Emeritus. Geotechnical and geoenvironmental engineering; hydrology; transportation; waste management.

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

Aspasia Zerva, PhD *(University of Illinois, Urbana-Champaign)*. Professor. Earthquake engineering; mechanics; seismology; structural reliability; system identification; advanced computational methods in structural analysis.

Computer Engineering MS

Major: Computer Engineering
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.0901
Standard Occupational Classification (SOC) code: 15-1132; 15-1133; 15-1143; 17-2031

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).

Full-time students within the Master of Science in Computer Engineering are eligible to take part in the Graduate Coop Program (https://drexel.edu/engineering/academics/experiential-learning-co-op/graduate-co-ops/), which combines classroom coursework with a six-month, full-time work experience.

Additional Information

For more information, visit the MS in Computer Engineering program (https://drexel.edu/engineering/academics/graduate-programs/masters/computer-engineering/) and Department of Electrical and Computer Engineering (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) website.

Admission Requirements

Applicants should 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).

Degree Requirements

The Master of Science in Computer Engineering curriculum encompasses 45.0 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, the Department of Biology, and the Department of Computer Science. 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) 500+ level Courses		**21.0**
General Electrical and Computer Engineering (ECE) Courses *		**9.0**
Mathematical Foundations Requirement		
6.0 credits from one of the following courses must be included within (not in addition to) the 45.0 total required MS credits:		
CS 525	Theory of Computation	
CS 567	Applied Symbolic Computation	
CS 583	Introduction to Computer Vision	
CS 613	Machine Learning	
CS 621	Approximation Algorithms	
CS 623	Computational Geometry	
ECES 510	Analytical Methods in Systems	
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 631	Fundamentals of Deterministic Digital Signal Processing	
ECES 681	Fundamentals of Computer Vision	
ECES 811	Optimization Methods for Engineering Design	
ECET 602	Information Theory and Coding	
OPR 624	Advanced Mathematical Program	
OPR 992	Applied Math Programming	
MATH 500-900 level		
Elective Courses **		**15.0**
Optional Co-op Experience ***		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

*****
500+ level courses from subject codes ECEC, ECEE, ECEP, ECES, ECET, ECE.

******
500+ level courses in the following areas: ECEC, ECEE, ECEP, ECES, ECET, ECE, AE, CHE, CIVE, CMGT, EGMT, ENGR, ENVE, ET, MATE, MEM, PROJ, SYSE, BMES, MATH, PHYS, CHEM, BIO, OPR, CS.

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Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

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 working on curriculum related projects. Graduate Co-op enables graduate students to alternate class terms with a six-month period of hands-on experience, gaining access to employers in their chosen industries. Whether co-op takes students throughout the United States or abroad, they are expanding their professional networks, enhancing their resumes, and bring that experience back to the classroom and their peers.

For more information on curricular requirements, visit the Department of Electrical and Computer Engineering's (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/?_gl=1*1rgm25a*_ga*OTEwNTAxODM1LjE2NjQ0NjE3MzI.*_ga_6KJ1PNLE19*MTY4NTU1Mjk1NS42MzIuMS4xNjg1NTUzMTQ5LjQwLjAuMA..) website.

Sample Plan of Study

Full Time, No CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ECEC Courses	6.0	ECEC Courses	6.0	ECEC Course	3.0	Vacation	
Elective	3.0	Elective	3.0	Electives	6.0		
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**				
ECEC Course	3.0	ECEC Course	3.0				
General ECE Course	3.0	General ECE Courses	6.0				
Elective	3.0						
	9		**9**				
Total Credits 45							

Full Time With CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	ECEC Courses	6.0	ECEC Course	3.0	ECEC Course	3.0
ECEC Courses	6.0	Elective	3.0	Electives	6.0	General ECE Course	3.0
Elective	3.0					Elective	3.0
	10		**9**		**9**		**9**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**		
COOP EXPERIENCE		COOP EXPERIENCE		ECEC Course	3.0		
				General ECE Courses	6.0		
	0		**0**		**9**		
Total Credits 46							

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 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:

- Delay mitigating codes for network coded systems
- Distributed estimation in sensor networks via expectation propagation
- Turbo speaker identification

- Performance and convergence of expectation propagation
- 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 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 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:

- software defined radio network testbeds for rapidly prototyping new communications and network systems,
- electromagnetic anechoic chamber and reverberation chambers for testing new wireless technologies,
- experimental cell tower for field testing new wireless technologies.

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. The lab offers laboratory coursework in wireless network security, collaborative intelligent radio networks, and fundamental analog and digital communication systems.

Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (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.

Multimedia & Information Security Lab [MISL]

The Multimedia and Information Security Lab (MISL) develops algorithms to detect fake images and videos, along with algorithms to determine the true source an image or video. This research is particularly important because widely available editing software enables multimedia forgers to create perceptually realistic forgeries. Our goal at MISL, is to conduct research that provides information verification and security in scenarios when an information source cannot be trusted.

The research conducted at MISL is part of a new area, known as multimedia forensics, which lies at the intersection of many areas in machine learning and artificial intelligence, signal processing, image and video processing, game theory, etc. Our algorithms work by identifying or learning visually imperceptible traces left in images and videos by processing operations. We use these traces to detect editing or forgery as well as to link an image or video back to the camera that captured it. We also perform research on anti-forensic operations designed to fool forensic techniques. By studying anti-forensics, researchers can identify and address weaknesses in existing forensic techniques as well as develop techniques capable of identifying the use of anti-forensics.

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

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.

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- Apply knowledge of mathematics, science, and engineering
- Design and conduct experiments, as well as to analyze and interpret data
- 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
- Function on multidisciplinary teams
- Identify, formulate, and solve engineering problems
- Understand professional and ethical responsibility
- Communicate effectively
- Understand the impact of engineering solutions in a global, economic, environmental, and societal context
- Recognize the need for, and an ability to engage in life-long learning
- Attain knowledge of contemporary issues
- Use the techniques, skills, and modern engineering tools necessary for engineering practice

Computer Engineering Faculty

Tom Chmielewski, PhD *(Drexel University)*. 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, ScD *(Drexel University)*. Professor. Digital and microwave photonics; nonlinear microwave circuits; RFIC; medical imaging.

Anup Das, PhD *(Universit of Singapore)*. Assistant Professor. Design of algorithms for neuromorphic computing, particularly using spiking neural networks, dataflow-based design of neuromorphic computing system, design of scalable computing system; hardware-software co-design and management, and thermal and power management of many-core embedded systems

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

Adam K. Fontecchio, PhD *(Brown University) Director, Center for the Advancement of STEM Teaching and Learning Excellence (CASTLE)*. Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park) Associate Department Head for Graduate Affairs*. Professor. Biological and biomedical applications of nanoscale magnetic systems.

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

Peter R. Herczfeld, PhD *(University of Minnesota)*. Professor. Lightwave technology; microwaves; millimeter waves; fiberoptic and integrated optic devices.

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

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

Youngmoo Kim, PhD *(MIT) Director, Expressive and Creative Interactive Technologies (ExCITe) Center*. Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Fei Lu, PhD *(University of Michigan)*. Assistant Professor. Power electronics; wireless power transfer technology for the high-power electric vehicles and the low-power electronic devices.

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, PhD *(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.

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

Christopher Peters, PhD *(University of Michigan)*. 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 Prabhu, PhD *(Harvard University)*. Teaching Professor. Computer engineering education; computer architecture; embedded 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)*. Associate 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 Dean for Undergraduate Affairs*. 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)*. Associate 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)*. Associate Professor. Information Security; multimedia forensics and anti-forensics; information verification; adversarial dynamics; signal processing

Baris Taskin, PhD *(University of Pittsburgh)*. Professor. Very large-scal integration (VLSI) systems, computer architecture, circuits and systems, electronic design automation (EDA), energy efficient computing.

John Walsh, PhD *(Cornell University)*. Associate Professor. Bounding the region of entropic vectors and its implications for the limits of communication networks, big data distributed storage systems, and graphical model based machine learning; efficient computation and analysis of rate regions for network coding and distributed storage; code construction, polyhedral computation, hierarchy, and symmetry

Steven Weber, PhD *(University of Texas-Austin) Department Head*. Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice de Oliveira, PhD *(Georgia Institute of Technology)*. Associate Professor. Software-defined networking; social and economic networks; network security; design and analysis of protocols, algorithms and architectures in computer networks, particularly solutions for the Internet of Things

Emeritus Faculty

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

Eli Fromm, PhD *(Jefferson Medical College)*. Professor Emeritus. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania)*. Professor Emeritus. Computerized instruments and measurements; undergraduate engineering education.

Computer Engineering PhD

Major: Computer Engineering
Degree Awarded: Doctor of Philosophy (PhD)
Calendar Type: Quarter
Minimum Required Credits: 90.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0901
Standard Occupational Classification (SOC) code: 15-1132; 15-1133; 15-1143; 17-2031

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.

Additional Information

For more information, visit the Department of Electrical and Computer Engineering (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) website.

Admission Requirements

Applicants should 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 the full-time PhD program. 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).

Additional Information

For more information on how to apply, visit Drexel's Admissions page for Computer Engineering (http://www.drexel.edu/grad/programs/coe/computer-engineering/).

Degree Requirements

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 on the Graduate College's webpage (http://drexel.edu/graduatecollege/academics/thesis-and-dissertation/). The student must be a PhD candidate for at least one year before he/she can defend his/her doctoral thesis.

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 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:

- Delay mitigating codes for network coded systems
- Distributed estimation in sensor networks via expectation propagation
- Turbo speaker identification
- Performance and convergence of expectation propagation
- 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 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 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:

- software defined radio network testbeds for rapidly prototyping new communications and network systems,
- electromagnetic anechoic chamber and reverberation chambers for testing new wireless technologies,
- experimental cell tower for field testing new wireless technologies.

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. The lab offers laboratory coursework in wireless network security, collaborative intelligent radio networks, and fundamental analog and digital communication systems.

Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (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.

Multimedia & Information Security Lab [MISL]

The Multimedia and Information Security Lab (MISL) develops algorithms to detect fake images and videos, along with algorithms to determine the true source an image or video. This research is particularly important because widely available editing software enables multimedia forgers to create perceptually realistic forgeries. Our goal at MISL, is to conduct research that provides information verification and security in scenarios when an information source cannot be trusted.

The research conducted at MISL is part of a new area, known as multimedia forensics, which lies at the intersection of many areas in machine learning and artificial intelligence, signal processing, image and video processing, game theory, etc. Our algorithms work by identifying or learning visually imperceptible traces left in images and videos by processing operations. We use these traces to detect editing or forgery as well as to link an image or video back to the camera that captured it. We also perform research on anti-forensic operations designed to fool forensic techniques. By studying anti-forensics, researchers can identify and address weaknesses in existing forensic techniques as well as develop techniques capable of identifying the use of anti-forensics.

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

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.

Computer Engineering Faculty

Tom Chmielewski, PhD *(Drexel University)*. 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, ScD *(Drexel University)*. Professor. Digital and microwave photonics; nonlinear microwave circuits; RFIC; medical imaging.

Anup Das, PhD *(Universit of Singapore)*. Assistant Professor. Design of algorithms for neuromorphic computing, particularly using spiking neural networks, dataflow-based design of neuromorphic computing system, design of scalable computing system; hardware-software co-design and management, and thermal and power management of many-core embedded systems

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

Adam K. Fontecchio, PhD *(Brown University) Director, Center for the Advancement of STEM Teaching and Learning Excellence (CASTLE)*. Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park) Associate Department Head for Graduate Affairs*. Professor. Biological and biomedical applications of nanoscale magnetic systems.

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

Peter R. Herczfeld, PhD *(University of Minnesota)*. Professor. Lightwave technology; microwaves; millimeter waves; fiberoptic and integrated optic devices.

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

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

Youngmoo Kim, PhD *(MIT) Director, Expressive and Creative Interactive Technologies (ExCITe) Center*. Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Fei Lu, PhD *(University of Michigan)*. Assistant Professor. Power electronics; wireless power transfer technology for the high-power electric vehicles and the low-power electronic devices.

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, PhD *(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.

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

Christopher Peters, PhD *(University of Michigan)*. 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 Prabhu, PhD *(Harvard University)*. Teaching Professor. Computer engineering education; computer architecture; embedded 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)*. Associate 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 Dean for Undergraduate Affairs*. 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)*. Associate 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)*. Associate Professor. Information Security; multimedia forensics and anti-forensics; information verification; adversarial dynamics; signal processing

Baris Taskin, PhD *(University of Pittsburgh)*. Professor. Very large-scal integration (VLSI) systems, computer architecture, circuits and systems, electronic design automation (EDA), energy efficient computing.

John Walsh, PhD *(Cornell University)*. Associate Professor. Bounding the region of entropic vectors and its implications for the limits of communication networks, big data distributed storage systems, and graphical model based machine learning; efficient computation and analysis of rate regions for network coding and distributed storage; code construction, polyhedral computation, hierarchy, and symmetry

Steven Weber, PhD *(University of Texas-Austin) Department Head*. Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice de Oliveira, PhD *(Georgia Institute of Technology)*. Associate Professor. Software-defined networking; social and economic networks; network security; design and analysis of protocols, algorithms and architectures in computer networks, particularly solutions for the Internet of Things

Emeritus Faculty

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

Eli Fromm, PhD *(Jefferson Medical College)*. Professor Emeritus. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania)*. Professor Emeritus. Computerized instruments and measurements; undergraduate engineering education.

Construction Management MS

Major: Construction Management
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 52.2001
Standard Occupational Classification (SOC) code: 11-9021

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. Students are admitted to start in the Fall and the Spring terms.

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 nation's construction industry.

Focus Areas

Focused study through elective courses in the program allow for deeper knowledge in the following areas:

Construction Project Management
Successfully manage complex construction projects through skills and knowledge gained from courses covering the 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
Explore the creation, maintenance, and built 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
Become an expert in sustainable development through integrating the decision-making process across the project team, with an eye to the greatest long-term benefits. Learn about the construction process within the Leadership in Energy and Environmental Design (LEED) green building rating system, which represents a significant portion of the effort required to achieve these high performance building programs.

Additional Information

For more information, view the College of Engineering's website. (https://drexel.edu/engineering/academics/graduate-programs/)

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/grad/resources/international/) page.

Additional Information

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 six required courses (18.0 credits), a concentration (21.0 credits), 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
CMGT 528	Construction Contract Administration	3.0
Electives		**21.0**
Students may select 7 elective courses from the following areas:		
CMGT 525	Applied Construction Project Management	
CMGT 530	Equipment Applications and Economy	
CMGT 532	International Construction Practices	
CMGT 535	Community Impact Analysis	
CMGT 538	Strategic Management in Construction	
CMGT 540	Schedule Impact Analysis	
CMGT 545	Sustainable Principles & Practices	
CMGT 546	Sustainable Technologies	
CMGT 547	LEED Concepts	
CMGT 548	Quality Management and Construction Performance	
CMGT 550	Productivity Analysis and Improvement	
CMGT 558	Community Sustainability	
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	
Culminating Experience		**6.0**
CMGT 696	Capstone Project in Construction Management I	
CMGT 697	Capstone Project in Construction Management II	
Total Credits		**45.0**

Sample Plan of Study

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
CMGT 501	3.0	CMGT 528	3.0	CMGT 510	3.0	CMGT 515	3.0
CMGT 505	3.0	CMGT 538	3.0	CMGT 512	3.0	CMGT 540	3.0
	6		**6**		**6**		**6**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
CMGT 525	3.0	CMGT 548	3.0	CMGT 530	3.0	CMGT 697	3.0

CMGT 532	3.0 CMGT 550	3.0 CMGT 696	3.0	
	6	**6**	**6**	**3**

Total Credits 45

Note: Second Year Summer is less than the 4.5-credit minimum required (considered half-time status) of graduate programs to be considered financial aid eligible. As a result, aid will not be disbursed to students this term.

Program Level Outcomes

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

Construction Management Faculty

Johanna Casale, PhD *(Rutgers University)*. Assistant Teaching Professor. Engineering education, first year design, structural aspects of construction.

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

Christine M. Fiori, PhD *(Drexel University) Program Director*. Clinical Professor. Improving the delivery of safety education in construction curriculum; Ancient construction techniques; Design and construction in developing countries; Leadership in construction; Workforce development

Kathleen M. Short, PhD *(Virginia Tech)*. Associate Teaching Professor. Workforce development and women in construction; transformative safety leadership; construction education.

Xi Wang, PhD, PE *(University of Kentucky)*. Assistant Teaching Professor. Technology adoption in workforce development in the construction industry, sustainable developments in construction education, and learning motivation for student success in engineering education.

Cybersecurity MS

Major: Cybersecurity
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 11.1003
Standard Occupational Classification (SOC) code: 15-1122

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 & (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) Computer Engineering Department (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) 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 an option to participate in the Graduate Co-op Program. For more information visit COE Graduate Co-op (https://drexel.edu/engineering/academics/experiential-learning-co-op/graduate-co-ops/), and the Steinbright Career Development Center's website (https://drexel.edu/scdc/co-op/graduate/).

Additional Information

For more information about this program, please visit the ECE Department's Cybersecurity degree page (https://drexel.edu/engineering/academics/graduate-programs/masters/cybersecurity/).

Admission Requirements

Applicants must satisfy general requirements for graduate admission, including a minimum 3.00 GPA (on a 4.00 scale) for the last two years of undergraduate study, as well as for any subsequent graduate work. It is preferred, but not necessary, that applicants hold a bachelor's degree in an engineering or computer science discipline. Degrees must be earned from an accredited college or university. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's.

For full-time applicants, the GRE exam is optional. Students who do not hold a degree from a US institution must take the TOEFL or IELTS exam within two years of application submission.

Additional Information

For more information on how to apply, visit Drexel's Admissions page for Cybersecurity (https://drexel.edu/grad/programs/coe/cybersecurity/).

Degree Requirements

The Master of Science in Cybersecurity program encompasses a minimum of 45.0 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		
INFO 517	Principles of Cybersecurity	3.0
INFO 725	Information Policy and Ethics	3.0
SE 578	Security Engineering *	3.0
or INFO 712	Information Assurance	
Cybersecurity Track-Specific Technical Electives		**27.0**
Choose from lists below depending on track		
Cybersecurity Non-Track Technical Electives **		**9.0**
Optional Co-op Experience ***		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

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Students in the Information Systems Track must take INFO 712.
Students in the Computer Science Track and Electrical & Computer Engineering must take SE 578.

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If enrolled in the Computer Science Track, choose 3 courses (9.0 credits) from either Electrical & Computer Engineering Track or Information Systems Track Technical Electives list.
If enrolled in the Information Systems Track, choose 3 courses (9.0 credits) from either the Computer Science or Electrical & Computer Engineering Tracks.
If enrolled in the Electrical & Computer Engineering Track, choose 3 courses (9.0 credits) from either the Computer Science or Information Systems Tracks,

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Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

Computer Science Track Electives

CS 500	Fundamentals of Databases	3.0
CS 501	Introduction to Programming	3.0
CS 502	Data Structures and Algorithms	3.0
CS 503	Systems Basics	3.0
CS 504	Introduction to Software Design	3.0
CS 510	Introduction to Artificial Intelligence	3.0
CS 521	Data Structures and Algorithms I	3.0

CS 522	Data Structures and Algorithms II	3.0
CS 523	Cryptography	3.0
CS 540	High Performance Computing	3.0
CS 543	Operating Systems	3.0
CS 544	Computer Networks	3.0
CS 550	Programming Languages	3.0
CS 551	Compiler Construction	3.0
CS 590	Privacy	3.0
CS 610	Advanced Artificial Intelligence	3.0
CS 612	Knowledge-based Agents	3.0
CS 613	Machine Learning	3.0
CS 621	Approximation Algorithms	3.0
CS 630	Cognitive Systems	3.0
CS 643	Advanced Operating Systems	3.0
CS 645	Network Security	3.0
CS 647	Distributed Systems Software	3.0
CS 650	Program Generation and Optimization	3.0
CS 741	Computer Networks II	3.0
CS 751	Database Theory	3.0
CS 759	Complexity Theory	3.0
CS 770	Topics in Artificial Intelligence	3.0
SE 575	Software Design	3.0
SE 576	Software Reliability and Testing	3.0
SE T680	Special Topics in Software Engineering	3.0

Electrical & Computer Engineering Track Electives

ECE 610	Machine Learning & Artificial Intelligence	3.0
ECE 612	Applied Machine Learning Engineering	3.0
ECE 613	Neuromorphic Computing	3.0
ECE 506	Hands on Computer Networks	3.0
ECE 687	Pattern Recognition	3.0
ECEC 500	Fundamentals Of Computer Hardware	3.0
ECE T580	Special Topics in ECE	0.0-12.0
ECE 630	Software Defined Radio Laboratory	3.0
ECEC 571	Introduction to VLSI Design	3.0
ECEC 576	Hardware Security & Trust	3.0
ECEC T580	Special Topics in ECEC	0.0-12.0
ECES 681	Fundamentals of Computer Vision	3.0
ECEC 501	Computational Principles of Representation and Reasoning	3.0
ECEC 502	Principles of Data Analysis	3.0
ECEC 503	Principles of Decision Making	3.0
ECEC 511	Combinational Circuit Design	3.0
ECEC 512	Sequential Circuit Design	3.0
ECEC 513	Design for Testability	3.0
ECEC 520	Dependable Computing	3.0
ECEC 531	Principles of Computer Networking	3.0
ECEC 600	Fundamentals of Computer Networks	3.0
ECEC 621	High Performance Computer Architecture	3.0
ECEC 622	Parallel Programming	3.0
ECEC 623	Advanced Topics in Computer Architecture	3.0
ECEC 632	Performance Analysis of Computer Networks	3.0
ECEC 633	Advanced Topics in Computer Networking	3.0
ECEC 641	Web Security I	3.0
ECEC 642	Web Security II	3.0
ECEC 643	Web Security III	3.0
ECEC 661	Digital Systems Design	3.0
ECES 511	Fundamentals of Systems I	3.0
ECES 512	Fundamentals of Systems II	3.0
ECES 513	Fundamentals of Systems III	3.0
ECES 521	Probability & Random Variables	3.0
ECES 522	Random Process & Spectral Analysis	3.0

ECES 523	Detection & Estimation Theory	3.0
ECES 558	Digital Signal Processing for Sound & Hearing	3.0
ECES 559	Processing of the Human Voice	3.0
ECES 604	Optimal Estimation & Stochastic Control	3.0
ECES 607	Estimation Theory	3.0
ECES 620	Multimedia Forensics and Security	3.0
ECES 621	Communications I	3.0
ECES 622	Communications II	3.0
ECES 623	Communications III	3.0
ECES 631	Fundamentals of Deterministic Digital Signal Processing	3.0
ECES 632	Fundamentals of Statistical Digital Signal Processing	3.0
ECES 641	Bioinformatics	3.0
ECES 642	Optimal Control	3.0
ECES 643	Digital Control Systems Analysis & Design	3.0
ECES 644	Computer Control Systems	3.0
ECES 651	Intelligent Control	3.0
ECES 682	Fundamentals of Image Processing	3.0
ECES 685	Image Reconstruction Algorithms	3.0
ECES 811	Optimization Methods for Engineering Design	3.0
ECES 812	Mathematical Program Engineering Design	3.0
ECES 813	Computer-Aided Network Design	3.0
ECES 818	Machine Learning & Adaptive Control	3.0
ECES 821	Reliable Communications & Coding I	3.0
ECES 822	Reliable Communications & Coding II	3.0
ECES 823	Reliable Communications & Coding III	3.0
ECET 501	Fundamentals of Communications Engineering	3.0
ECET 511	Physical Foundations of Telecommunications Networks	3.0
ECET 512	Wireless Systems	3.0
ECET 513	Wireless Networks	3.0
ECET 602	Information Theory and Coding	3.0
ECET 603	Optical Communications and Networks	3.0
ECET 604	Internet Laboratory	3.0

Information Systems Track Electives

CS 501	Introduction to Programming	3.0
CS 502	Data Structures and Algorithms	3.0
CS 503	Systems Basics	3.0
CS 504	Introduction to Software Design	3.0
CS 570	Programming Foundations	3.0
CT 500	Introduction to the Digital Environment	3.0
CT 600	Cloud Technology	3.0
CT 605	Cloud Security and Virtual Environments	3.0
CT 610	Disaster Recovery, Continuity Planning and Digital Risk Assessment	3.0
CT 620	Security, Policy and Governance	3.0
DSCI 501	Quantitative Foundations of Data Science	3.0
DSCI 511	Data Acquisition and Pre-Processing	3.0
DSCI 521	Data Analysis and Interpretation	3.0
DSCI 632	Applied Cloud Computing	3.0
INFO 508	Information Innovation through Design Thinking	3.0
INFO 532	Software Development	3.0
INFO 540	Perspectives on Information Systems	3.0
INFO 590	Foundations of Data and Information	3.0
INFO 600	Web Systems & Architecture	3.0
INFO 605	Database Management Systems	3.0
INFO 606	Advanced Database Management	3.0
INFO 607	Applied Database Technologies	3.0
INFO 608	Human-Computer Interaction	3.0
INFO 615	Designing with Data	3.0
INFO 616	Social and Collaborative Computing	3.0
INFO 620	Information Systems Analysis and Design	3.0
INFO 623	Social Network Analytics	3.0

INFO 624	Information Retrieval Systems	3.0
INFO 629	Applied Artificial Intelligence	3.0
INFO 633	Information Visualization	3.0
INFO 634	Data Mining	3.0
INFO 646	Information Systems Management	3.0
INFO 648	Healthcare Informatics	3.0
INFO 655	Intro to Web Programming	3.0
INFO 659	Introduction to Data Analytics	3.0
INFO 662	Metadata and Resource Description	3.0
INFO 670	Cross-platform Mobile Development	3.0
INFO 680	US Government Information	3.0
INFO 690	Understanding Users: User Experience Research Methods	3.0
INFO 691	Prototyping the User Experience	3.0
INFO 692	Explainable Artificial Intelligence	3.0
INFO 710	Information Forensics	3.0
INFO 712	Information Assurance *	3.0

*

INFO 712 may not be used toward both track specific technical elective and core requirement.

*

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 [ECE]. A list of pre-approved technical electives can be found on the ECE Department website.

**

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.

Sample Plan of Study

Full Time, No CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
INFO 517	3.0	SE 578 or INFO 712*	3.0	INFO 725	3.0	VACATION	
Track Elective	3.0	Track Electives	6.0	Track Elective	3.0		
Non-Track Elective	3.0			Non-Track Elective	3.0		
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**				
Track Electives	9.0	Track Electives	6.0				
		Non-Track Elective	3.0				
	9		**9**				
Total Credits 45							

*

Students in the Information Systems Track must take INFO 712.
Students in the Computer Science Track and Electrical & Computer Engineering must take SE 578.

Full Time With CO-OP (Information Systems Track)

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	INFO 725	3.0	Track Elective Courses	6.0	INFO 712 or SE 578*	3.0
INFO 517	3.0	Track Elective Courses	6.0	Non-Track Elective Course	3.0	Track Elective Courses	6.0
Track Elective Course	3.0						

Non-Track Elective Course	3.0						
	10		9		9		9
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**		
COOP EXPERIENCE		COOP EXPERIENCE		Track Elective Courses	6.0		
				Non-Track Elective Course	3.0		
	0		0		9		

Total Credits 46

*
Students in the Information Systems Track must take INFO 712.
Students in the Computer Science Track and Electrical & Computer Engineering must take SE 578.

Full Time With CO-OP (Computer Science & ECE Tracks)

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	INFO 725	3.0	Track Elective Courses	6.0	Track Elective Courses	9.0
INFO 517	3.0	SE 578 or INFO 712*	3.0	Non-Track Elective Course	3.0		
Track Elective Course	3.0	Track Elective Course	3.0				
Non-Track Elective Course	3.0						
	10		9		9		9
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**		
COOP EXPERIENCE		COOP EXPERIENCE		Track Elective Courses	6.0		
				Non-Track Elective Course	3.0		
	0		0		9		

Total Credits 46

*
Students in the Information Systems Track must take INFO 712.
Students in the Computer Science Track and Electrical & Computer Engineering must take SE 578.

Graduate Co-op/Career Opportunities

Graduate Co-Op

Students may choose to participate in the Graduate Co-op Program, working on curriculum related projects. Graduate Co-op enables graduate students to alternate class terms with a six-month period of hands-on experience, gaining access to employers in their chosen industries. Whether co-op takes students throughout the United States or abroad, they are expanding their professional networks, enhancing their resumes, and bringing that experience back to the classroom and their peers.

Further information on the Graduate Co-Op Program (https://drexel.edu/scdc/co-op/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 (https://research.coe.drexel.edu/ece/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 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 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:

- software defined radio network testbeds for rapidly prototyping new communications and network systems,
- electromagnetic anechoic chamber and reverberation chambers for testing new wireless technologies,
- experimental cell tower for field testing new wireless technologies.

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. The lab offers laboratory coursework in wireless network security, collaborative intelligent radio networks, and fundamental analog and digital communication systems.

Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (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.

Multimedia & Information Security Laboratory

The Multimedia & Information Security Laboratory (MISL) conducts research that provides information verification and security in scenarios when an information source cannot be trusted.

The majority of MISL's research is in digital multimedia forensics. Digital multimedia forensics involves the developing mathematical techniques to identify multimedia forgeries such as falsified images and videos. This research is particularly important because widely available editing software enables multimedia forgers to create perceptually realistic forgeries. MISL performs research on anti-forensic operations designed to fool forensic techniques. By studying anti-forensics, researchers can identify and address weaknesses in existing forensic techniques as well as develop techniques capable of identifying the use of anti-forensics.

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

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.

Privacy, Security and Automation Lab

Drexel University's Privacy, Security, and Automation Laboratory (PSAL) researches on topics at the intersection between artificial intelligence, privacy and security, and human-computer interaction.

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.

Cybersecurity 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.

Steven Weber, PhD *(University of Texas-Austin) Department Head*. Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Christopher C. Yang, PhD *(University of Arizona)*. Professor. Web search and mining, security informatics, knowledge management, social media analytics, cross-lingual information retrieval, text summarization, multimedia retrieval, information visualization, information sharing and privacy, artificial intelligence, digital library, and electronic commerce.

Electrical Engineering MSEE

Major: Electrical Engineering
Degree Awarded: Master of Science in Electrical Engineering (MSEE)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.1001
Standard Occupational Classification (SOC) code: 17-2071

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.

A student's plan of study must contain a selection of courses from the department's offerings and may include appropriate graduate elective courses from other engineering departments or from physics or mathematics. Further information can be obtained from the department website or from the graduate advisor.

Students are also encouraged to engage in thesis research. The combined thesis and research cannot exceed 9.0 credits. The MS program is organized so that a student may complete the degree requirements in less than 2 years of full-time study or 2-3 years of part-time study.

Students within the Master of Science in Electrical Engineering are eligible to take part in the Graduate Co-op Program, which combines classroom coursework with a 6-month, full-time work experience. For more information, visit the Steinbright Career Development Center's website (http://www.drexel.edu/scdc/co-op/graduate/).

Additional Information

For more information, please visit the MS in Electrical Engineering program (https://drexel.edu/engineering/academics/graduate-programs/masters/electrical-engineering/) and Electrical and Computer Engineering Department (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) website.

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 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 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/).

Degree Requirements

The Master of Science in Electrical Engineering curriculum encompasses 45.0 or 46.0 (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.

Required Courses		
Electrical Engineering (ECEE, ECEP, ECES, ECET) Courses at 500-900 level		21.0
General Electrical and Computer Engineering (ECE, ECEC, ECEE, ECEP, ECES, ECET) Courses at 500-900 level		9.0
Elective Courses *		15.0
Optional Co-op Experience **		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

*****
500-900 level courses in the following areas: AE, BIO, BMES, CHE, CHEM, CIVE, CMGT, CS, ECE, ECEC, ECEE, ECEP, ECES, ECET, EGMT, ENGR, ENVE, ET, MATE, MATH, MEM, OPR, PHYS, PROJ, SYSE

******
Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

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.

Additional Information

For more information on curricular requirements, visit the Department of Electrical and Computer Engineering' (http://www.ece.drexel.edu/)s website.

Sample Plan of Study

Full Time, No CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EE Courses	6.0	EE Courses	6.0	EE Course	3.0	VACATION	
Elective	3.0	Elective	3.0	Electives	6.0		
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**				
EE Course	3.0	EE Course	3.0				
General ECE Courses	6.0	Elective	3.0				
		General ECE Course	3.0				
	9		**9**				
Total Credits 45							

Full Time With CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	EE Courses	6.0	EE Course	3.0	EE Course	3.0
EE Courses	6.0	Elective	3.0	Electives	6.0	General ECE Courses	6.0
Elective	3.0						
	10		**9**		**9**		**9**

Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COOP EXPERIENCE		COOP EXPERIENCE		EE Course	3.0
				Elective	3.0
				General ECE Course	3.0
	0		**0**		**9**

Total Credits 46

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 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:

- Delay mitigating codes for network coded systems
- Distributed estimation in sensor networks via expectation propagation
- Turbo speaker identification
- Performance and convergence of expectation propagation
- 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 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 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:

- software defined radio network testbeds for rapidly prototyping new communications and network systems,
- electromagnetic anechoic chamber and reverberation chambers for testing new wireless technologies,
- experimental cell tower for field testing new wireless technologies.

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. The lab offers laboratory coursework in wireless network security, collaborative intelligent radio networks, and fundamental analog and digital communication systems.

Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (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.

Multimedia & Information Security Lab [MISL]

The Multimedia and Information Security Lab (MISL) develops algorithms to detect fake images and videos, along with algorithms to determine the true source an image or video. This research is particularly important because widely available editing software enables multimedia forgers to create perceptually realistic forgeries. Our goal at MISL, is to conduct research that provides information verification and security in scenarios when an information source cannot be trusted.

The research conducted at MISL is part of a new area, known as multimedia forensics, which lies at the intersection of many areas in machine learning and artificial intelligence, signal processing, image and video processing, game theory, etc. Our algorithms work by identifying or learning visually imperceptible traces left in images and videos by processing operations. We use these traces to detect editing or forgery as well as to link an image or video back to the camera that captured it. We also perform research on anti-forensic operations designed to fool forensic techniques. By studying anti-forensics, researchers can identify and address weaknesses in existing forensic techniques as well as develop techniques capable of identifying the use of anti-forensics.

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

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.

Program Level Outcomes

- Apply knowledge of mathematics, science, and engineering
- Design and conduct experiments, as well as to analyze and interpret data
- 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
- Function on multidisciplinary teams
- Identify, formulate, and solve engineering problems
- Understand professional and ethical responsibility
- Communicate effectively
- Understand the impact of engineering solutions in a global, economic, environmental, and societal context
- Recognize the need for, and an ability to engage in life-long learning
- Attain knowledge of contemporary issues
- Use the techniques, skills, and modern engineering tools necessary for engineering practice

Electrical Engineering Faculty

Tom Chmielewski, PhD *(Drexel University)*. 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, ScD *(Drexel University)*. Professor. Digital and microwave photonics; nonlinear microwave circuits; RFIC; medical imaging.

Anup Das, PhD *(Universit of Singapore)*. Assistant Professor. Design of algorithms for neuromorphic computing, particularly using spiking neural networks, dataflow-based design of neuromorphic computing system, design of scalable computing system; hardware-software co-design and management, and thermal and power management of many-core embedded systems

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

Adam K. Fontecchio, PhD *(Brown University) Director, Center for the Advancement of STEM Teaching and Learning Excellence (CASTLE)*. Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park) Associate Department Head for Graduate Affairs*. Professor. Biological and biomedical applications of nanoscale magnetic systems.

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

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

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

Youngmoo Kim, PhD *(MIT) Director, Expressive and Creative Interactive Technologies (ExCITe) Center*. Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Fei Lu, PhD *(University of Michigan)*. Assistant Professor. Power electronics; wireless power transfer technology for the high-power electric vehicles and the low-power electronic devices.

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, PhD *(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.

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

Christopher Peters, PhD *(University of Michigan)*. 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

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)*. Associate 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 Dean for Undergraduate Affairs*. 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)*. Associate 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.

Jonathan E. Spanier, PhD *(Columbia University) Department Head, Mechanical Engineering and Mechanics*. Professor. Light-matter interactions in electronic materials, including ferroelectric semiconductors, complex oxide thin film science; laser spectroscopy, including Raman scattering.

Matthew Stamm, PhD *(University of Maryland, College Park)*. Associate Professor. Information Security; multimedia forensics and anti-forensics; information verification; adversarial dynamics; signal processing

Baris Taskin, PhD *(University of Pittsburgh)*. Professor. Very large-scal integration (VLSI) systems, computer architecture, circuits and systems, electronic design automation (EDA), energy efficient computing.

John Walsh, PhD *(Cornell University)*. Associate Professor. Bounding the region of entropic vectors and its implications for the limits of communication networks, big data distributed storage systems, and graphical model based machine learning; efficient computation and analysis of rate regions for network coding and distributed storage; code construction, polyhedral computation, hierarchy, and symmetry

Steven Weber, PhD *(University of Texas-Austin) Department Head*. Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice de Oliveira, PhD *(Georgia Institute of Technology)*. Associate Professor. Software-defined networking; social and economic networks; network security; design and analysis of protocols, algorithms and architectures in computer networks, particularly solutions for the Internet of Things

Emeritus Faculty

Eli Fromm, PhD *(Jefferson Medical College)*. Professor Emeritus. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania)*. Professor Emeritus. Computerized instruments and measurements; undergraduate engineering education.

Electrical Engineering PhD

Major: Electrical Engineering
Degree Awarded: Doctor of Philosophy (PhD)
Calendar Type: Quarter
Minimum Required Credits: 90.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.1001
Standard Occupational Classification (SOC) code: 17-2071

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.

A student's plan of study must contain a selection of courses from the department's offerings and may include appropriate graduate elective courses from other engineering departments or from physics or mathematics. Further information can be obtained from the department website or from the graduate advisor.

Students are also encouraged to engage in thesis research. The combined thesis and research cannot exceed 9.0 credits.

Additional Information

For more information, please visit the Doctorate in Electrical Engineering program (https://drexel.edu/engineering/academics/graduate-programs/doctoral/electrical-engineering/) and Electrical and Computer Engineering Department (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) website.

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 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 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/).

Degree Requirements

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 Graduate College of Drexel University (http://www.drexel.edu/graduatecollege/)policies regarding Doctor of Philosophy Program Requirements. The student must be a PhD candidate for at least one year before he/she can defend his/her doctoral thesis.

Program Requirements

Post-Bachelor's PhD Student

ECE 997	Dissertation Research	9.0
or ECE 998	Ph.D. Dissertation	
Students must complete 81.0 graduate credits (500+ level) from approved College of Engineering departments *		81.0
Total Credits		**90.0**

*

Approved graduate coursework (500+ level) from Any College of Engineering, any College of Computing and Informatics, MATH, PHYS, COOP, ISTM, MTED, OPR, BMES, BIO, CHEM, ENVS, ENVP, LING, SCTS, DIGM, BST, EPI, or CIE course.
Additional courses may be considered upon approval from the Department of Electrical and Computer Engineering.

Post-Master's PhD Student

ECE 997	Dissertation Research	9.0
or ECE 998	Ph.D. Dissertation	

Students must complete 36.0 graduate credits (500+ level) from approved College of Engineering departments *	36.0
Total Credits	**45.0**

*

Approved graduate coursework (500+ level) from Any College of Engineering, any College of Computing and Informatics, MATH, PHYS, COOP, ISTM, MTED, OPR, BMES, BIO, CHEM, ENVS, ENVP, LING, SCTS, DIGM, BST, EPI, or CIE course.
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Sample Plan of Study

Post-Bachelor's PhD Student

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ECE 997 or 998	9.0	Graduate Coursework	9.0	Graduate Coursework	9.0	VACATION	
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
Graduate Coursework	9.0	Graduate Coursework	9.0	Graduate Coursework	9.0	VACATION	
	9		**9**		**9**		**0**
Third Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
Graduate Coursework	9.0	Graduate Coursework	9.0	Graduate Coursework	9.0	VACATION	
	9		**9**		**9**		**0**
Fourth Year							
Fall	**Credits**						
Graduate Coursework	9.0						
	9						
Total Credits 90							

Post-Master's PhD Student

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ECE 997 or 998	9.0	Graduate Coursework	9.0	Graduate Coursework	9.0	VACATION	
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**				
Graduate Coursework	9.0	Graduate Coursework	9.0				
	9		**9**				
Total Credits 45							

Facilities

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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:

- software defined radio network testbeds for rapidly prototyping new communications and network systems,
- electromagnetic anechoic chamber and reverberation chambers for testing new wireless technologies,
- experimental cell tower for field testing new wireless technologies.

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. The lab offers laboratory coursework in wireless network security, collaborative intelligent radio networks, and fundamental analog and digital communication systems.

Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (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.

Multimedia & Information Security Lab [MISL]

The Multimedia and Information Security Lab (MISL) develops algorithms to detect fake images and videos, along with algorithms to determine the true source an image or video. This research is particularly important because widely available editing software enables multimedia forgers to create perceptually realistic forgeries. Our goal at MISL, is to conduct research that provides information verification and security in scenarios when an information source cannot be trusted.

The research conducted at MISL is part of a new area, known as multimedia forensics, which lies at the intersection of many areas in machine learning and artificial intelligence, signal processing, image and video processing, game theory, etc. Our algorithms work by identifying or learning visually imperceptible traces left in images and videos by processing operations. We use these traces to detect editing or forgery as well as to link an image or video back to the camera that captured it. We also perform research on anti-forensic operations designed to fool forensic techniques. By studying anti-forensics, researchers can identify and address weaknesses in existing forensic techniques as well as develop techniques capable of identifying the use of anti-forensics.

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

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 Engineering Faculty

Tom Chmielewski, PhD *(Drexel University)*. 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, ScD *(Drexel University)*. Professor. Digital and microwave photonics; nonlinear microwave circuits; RFIC; medical imaging.

Anup Das, PhD *(Universit of Singapore)*. Assistant Professor. Design of algorithms for neuromorphic computing, particularly using spiking neural networks, dataflow-based design of neuromorphic computing system, design of scalable computing system; hardware-software co-design and management, and thermal and power management of many-core embedded systems

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

Adam K. Fontecchio, PhD *(Brown University) Director, Center for the Advancement of STEM Teaching and Learning Excellence (CASTLE)*. Professor. Electro-optics; remote sensing; active optical elements; liquid crystal devices.

Gary Friedman, PhD *(University of Maryland-College Park) Associate Department Head for Graduate Affairs*. Professor. Biological and biomedical applications of nanoscale magnetic systems.

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

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

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

Youngmoo Kim, PhD *(MIT) Director, Expressive and Creative Interactive Technologies (ExCITe) Center*. Professor. Audio and music signal processing, voice analysis and synthesis, music information retrieval, machine learning.

Fei Lu, PhD *(University of Michigan)*. Assistant Professor. Power electronics; wireless power transfer technology for the high-power electric vehicles and the low-power electronic devices.

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, PhD *(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.

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

Christopher Peters, PhD *(University of Michigan)*. 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

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)*. Associate 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 Dean for Undergraduate Affairs*. 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)*. Associate 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.

Jonathan E. Spanier, PhD *(Columbia University) Department Head, Mechanical Engineering and Mechanics*. Professor. Light-matter interactions in electronic materials, including ferroelectric semiconductors, complex oxide thin film science; laser spectroscopy, including Raman scattering.

Matthew Stamm, PhD *(University of Maryland, College Park)*. Associate Professor. Information Security; multimedia forensics and anti-forensics; information verification; adversarial dynamics; signal processing

Baris Taskin, PhD *(University of Pittsburgh)*. Professor. Very large-scal integration (VLSI) systems, computer architecture, circuits and systems, electronic design automation (EDA), energy efficient computing.

John Walsh, PhD *(Cornell University)*. Associate Professor. Bounding the region of entropic vectors and its implications for the limits of communication networks, big data distributed storage systems, and graphical model based machine learning; efficient computation and analysis of rate regions for network coding and distributed storage; code construction, polyhedral computation, hierarchy, and symmetry

Steven Weber, PhD *(University of Texas-Austin) Department Head*. Professor. Mathematical modeling of computer and communication networks, specifically streaming multimedia and ad hoc networks.

Jaudelice de Oliveira, PhD *(Georgia Institute of Technology)*. Associate Professor. Software-defined networking; social and economic networks; network security; design and analysis of protocols, algorithms and architectures in computer networks, particularly solutions for the Internet of Things

Emeritus Faculty

Eli Fromm, PhD *(Jefferson Medical College)*. Professor Emeritus. Engineering education; academic research policy; bioinstrumentation; physiologic systems.

Edwin L. Gerber, PhD *(University of Pennsylvania)*. Professor Emeritus. Computerized instruments and measurements; undergraduate engineering education.

Master of Engineering

Major: Engineering
Degree Awarded: Master of Engineering (ME)
Calendar Type: Quarter
Minimum Required Credits: 48.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0101
Standard Occupational Classification (SOC) code: 17.2199

About the Program

Note: This program is not accepting external applicants at this time.

This ME program is a highly customizable program primarily used for international and visiting students studying engineering at Drexel whose plan of study must be customized. This program may be offered by any department and will be reviewed by the department Advisor to make certain the plan of study meets degree requirements.

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. This degree program may not be the best choice for those who wish to earn a PhD in Engineering.

Admission Requirements

This program allows for maximum flexibility for international visiting students and students on study abroad. 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. This is a highly customizable degree program and may include a mix of courses, Co-op, research and thesis. The average time required to complete the master’s degree is two years of full-time study or three years of part-time study. This is primarily used for visiting students.

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.) The department Advisor will work closely with the student to develop an plan of study that meets the program requirements.

Engineering Management MS

Major: Engineering Management
Degree Awarded: Master of Science (MS)

Calendar Type: Quarter
Minimum Required Credts: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 15.1501
Standard Occupational Classification (SOC) code: 11-9041

About the Program

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. Drexel's Engineering Management graduate degree program provides students with leadership skills that prepares them well for career progression across a wide domain of industries, international and domestic, within technology-based organizations, advancing to project/lead engineer, functional manager, director, program manager, plant manager and even up to CEO.

The nationally ranked 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 courses are available both online and face to face. The program is also certified by the American Society for Engineering management (ASEM). Students that complete the program will also earn either a Certified Associate in Engineering Management (CAEM) or a Certified Professional Engineering Management (CPEM) Certificate from the ASEM society. Drexel is one of a few universities nationwide to have this distinction with ASEM (https://asem.org/Graduate-Program-Cert/).

Engineering management is a multidisciplinary program offering a core curriculum and specialization in a selected area of technology or management. Majors in engineering management should 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.

Certificate in Engineering Management

In addition to the master's program, the college offers a five-course Graduate Certificate in Engineering Management (p. 141).

Students can obtain the Graduate Certificate in Engineering Management credential, and subsequently apply those credits toward completion of a master's in engineering management. Some graduate degree programs within the College of Engineering also allow for students to earn an engineering management certificate to apply for the certificate, with Advisor approval, in order to simultaneously earn this certificate while pursuing their primary degree.

Additional Information

For more information about the program, visit the Engineering Management (http://online.drexel.edu/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 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 (at least one professional).
- Resume
- A personal statement explaining why you wish to earn the degree and why you are prepared to succeed.
- International students must submit an Internet-based TOEFL (IBT = score of 94 or higher).

At least three years of relevant professional work experience are recommended but not required.

Interested students should complete the Drexel University Online admission application (http://online.drexel.edu/online-degrees/engineering-degrees/ms-egmt/#admissionscriteria) for admission into this online program.

Note, interested students can apply for admission to this program in any term (Fall, Winter, Spring and Summer) as there is rolling admission throughout the year. However, students attending full time cannot apply for admission in the summer term. Full time students can apply for all other terms (Fall, Winter and Spring). This summer term restriction does not apply to part time / online students. These students can apply for admission in any term (Fall, Winter, Spring and Summer)

Degree Requirements

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 may be waived for students who have taken equivalent courses elsewhere.

Core Courses		
Engineering Management Leadership		
EGMT 501	Leading and Managing Technical Workers	3.0
EGMT 502	Analysis and Decision Methods for Technical Managers	3.0
EGMT 504	Design Thinking for Engineering Communications	3.0
EGMT 581	Human Relations and Organizational Behavior	3.0
Quantitative Analysis		
EGMT 571	Engineering 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
Marketing & Business Development Electives		
EGMT 614	Marketing: Identifying Customer Needs	
EGMT 615	New Product Conceptualization, Justification, and Implementation	
EGMT 616	Value Creation through New Product Development	
EGMT 618	Intrapreneurship for Engineers	
EGMT 660	Sustainable Business Practices for Engineers	
Project Management Electives		
EGMT 620	Engineering Project Management	
EGMT 625	Project Planning, Scheduling and Control	
EGMT 630	Global Engineering Project Management	
Systems Engineering & Systems Thinking Electives		
EGMT 635	Visual System Mapping	
EGMT 650	Systems Thinking for Leaders	
SYSE 685	Systems Engineering Management	
SYSE 688	Systems Engineering Analysis	
SYSE 690	Modeling, Simulation and Other Tools	
Engineering Quality, Law & Ethics Electives		
EGMT 575	Quality Systems Engineering	
EGMT 610	Ethics & Business Practices for Engineers	
EGMT 652	Engineering Law	
Other Approved Electives		
EGMT 645	Managing Engineering Disasters	
SYSE 520	Global Sustainment and Integrated Logistics	
SYSE 521	Integrated Risk Management	
SYSE 522	Engineering Supply Chain Systems	
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	
SYSE 650	Transition of the Integrated System from Design to Production	
Optional Co-op Experience ***		**0-1**

COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

*
EGMT 572 requires EGMT 571 as a prerequisite or a waiver must be approved by the program administration 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.

**
Students may select electives from other disciplines outside of Engineering Management with prior approval from their advisor.

***
Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

Sample Plan of Study

Part Time, Two Courses Per Term

First Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EGMT 501	3.0	EGMT 502	3.0	EGMT 531	3.0	EGMT 504	3.0
EGMT 571	3.0	EGMT 572	3.0	EGMT 573	3.0	EGMT 535	3.0
	6		**6**		**6**		**6**
Second Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EGMT 581	3.0	Electives	6.0	EGMT 692	3.0	Elective*	3.0
Elective	3.0			Elective	3.0		
	6		**6**		**6**		**3**
Total Credits 45							

*
Note: Second Year Summer is less than the 4.5-credit minimum required (considered half-time status) of graduate programs to be considered financial aid eligible. As a result, aid will not be disbursed to students this term.

Part Time, One Course Per Term*

First Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EGMT 501	3.0	EGMT 502	3.0	EGMT 531	3.0	EGMT 535	3.0
	3		**3**		**3**		**3**
Second Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EGMT 571	3.0	EGMT 572	3.0	EGMT 573	3.0	EGMT 504	3.0
	3		**3**		**3**		**3**
Third Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EGMT 581	3.0	Elective	3.0	EGMT 692	3.0	Elective	3.0
	3		**3**		**3**		**3**
Fourth Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**		
Elective	3.0	Elective	3.0	Elective	3.0		
	3		**3**		**3**		
Total Credits 45							

*
Note: This plan of study is less than the 4.5-credit minimum required (considered half-time status) of graduate programs to be considered financial aid eligible. As a result, aid will not be disbursed to students following this plan.

Full Time, No CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EGMT 501	3.0	EGMT 502	3.0	EGMT 531	3.0	EGMT 535	3.0
EGMT 504	3.0	EGMT 572	3.0	EGMT 573	3.0	EGMT 581	3.0
EGMT 571	3.0	Elective	3.0	Elective	3.0	Elective	3.0
	9		**9**		**9**		**9**

Second Year	
Fall	**Credits**
EGMT 692	3.0
Electives	6.0
	9

Total Credits 45

Full Time with CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	EGMT 502	3.0	EGMT 531	3.0	EGMT 535	3.0
EGMT 501	3.0	EGMT 572	3.0	EGMT 573	3.0	EGMT 581	3.0
EGMT 504	3.0	Elective	3.0	Elective	3.0	Elective	3.0
EGMT 571	3.0						
	10		**9**		**9**		**9**

Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COOP EXPERIENCE		COOP EXPERIENCE		EGMT 692	3.0
				Electives	6.0
	0		**0**		**9**

Total Credits 46

Program Level Outcomes

- Lead complex engineering and capital intensive organizations with globally dispersed organizational structures.
- Solve industry-related problems by applying their knowledge of business, mathematics, science and engineering.
- Develop leadership skills that can be applied effectively in technology-based organizations.
- Interpret quantitative and subjective data to make sound engineering and managerial decisions.
- Apply data analytics and decision tools to solve complex technical and operational problems to meet both business and customer needs.
- Develop and lead effective teams and projects.
- Communicate effectively across the entire enterprise.
- Understand the ethical responsibilities of practicing engineering leaders and the impact of their decisions within a global and societal context.

Engineering Management Faculty

James Breen, MBA, PE *(Drexel University)*. Adjunct Instructor. Vice President of Manufacturing Network Strategy at Johnson & Johnson.

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)*. Adjunct Instructor. Public speaking, technical writing, organizational behavior, and business writing courses.

Miray Pereira, MBA *(Rutgers University)*. Adjunct Instructor. 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.

Fredric Plotnick, PhD, JD, PE *(Drexel University; Widener University)*. Adjunct Professor. CEO and principal consultant of Engineering & Property Management Consultants, Inc.

Stephen Smith, PhD *(Drexel University)*. Associate Teaching Professor. Development of online learning and distance teaching/learning techniques for engineering.

Walter Sobkiw, BS *(Drexel University)*. Adjunct Faculty. Author of "Systems Engineering Design Renaissance" and "Systems Practices as Common Sense."

Fernando Tovia, PhD *(University of Arkansas)*. Adjunct Instructor. Core quantitative analysis,strategic planning, supply chain management and manufacturing systems.

John Via, DEngr *(Southern Methodist University)*. Teaching Professor. Pharmaceutical, Bio-pharmaceutical, and Medical Device development and manufacturing

Emeritus Faculty

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

Engineering Technology MSET

Major: Engineering Technology
Degree Awarded: Master of Science in Engineering Technology (MSET)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.4101
Standard Occupational Classification (SOC) code: 17-3029

About the Program

Effective May 15, 2020, new students are no longer being accepted into this program, however similar options are available. Contact Gerry Willis at gtm23@drexel.edu **or 215-895-6253 for additional information.**

Engineering Technology provides a broad grasp of technologies, tools, and processes that are critical to a modern industrial workplace. The discipline emphasizes application over theory, and it is designed for individuals who want marketable and immediately applicable skills for technology-intensive organizations.

The discipline of Engineering Technology is closely aligned with Engineering Management, as both degrees develop advanced-level practitioners who are skilled in solving technical and organizational problems through the application of engineering principles and technology. The MSET curriculum provides technical expertise, and Engineering Management provides business and leadership skills that technical workers need to compete successfully in the global marketplace. Engineering Management prepares professionals for supervisory responsibilities in areas such as research and development, production, engineering design, and technical marketing. The MSET program allows students to gain a deep understanding of both the technical and business concerns of an organization, leading to advanced positions in leadership.

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 that will add to the knowledge of the discipline and solve problems in an industrial environment
- Develop the communication skills required for technical managers

Additional Information

For more information, view the College of Engineering's Engineering Technology program webpage (https://drexel.edu/engineering/academics/undergraduate-programs/bachelors/engineering-technology/) or contact Gerry Willis at 215-895-6253 or gtm23@drexel.edu.

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/grad/resources/international/) page.

Prerequisite courses

The following prerequisite courses must be completed at the undergraduate level with a minimum grade of C:

- Calculus I
- Calculus II
- Physics I (can be algebra based)
- Physics II (can be algebra based)
- AC/DC Circuit Analysis
- Digital Electronics
- Chemistry I or Materials
- Business Statistics

Additional Information

Visit the Graduate Admissions (https://drexel.edu/grad/programs/coe/) 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		
EGMT 571	Engineering Statistics	3.0
EGMT 610	Ethics & Business Practices for Engineers	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 681	Nanomaterials and Nanoengineering	3.0
ET 725	Sensors and Measurement Systems	3.0
ET 732	Modern Energy Conversion Technologies	3.0
Electives		**9.0**
Select three of the following:		
EGMT 572	Statistical Data Analysis	
ET 605	Materials for Emerging Technologies	
ET 635	Engineering Quality Methods	
ET 675	Reliability Engineering	
ET 685	Precision Manufacturing	
ET 730	Lean Manufacturing Principles	
ET 733	Renewable Energy Technology	
ET 755	Sustainable and Green Manufacturing	
PROJ 501	Introduction to Project Management	
SYSE 685	Systems Engineering Management	
Capstone Course		**9.0**
ET 775	Master's Project and Thesis in Engineering Technology *	
Total Credits		**45.0**

*
This is a three (3) credit course that is repeated three (3) times.

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- Use the knowledge, skills, and tools, including a knowledge of mathematics, science and engineering, to identify and solve a broad range of engineering technology problems
- Design and conduct experiments and measurements, to analyze and interpret data and to apply experimental results to improve systems, components, or processes
- Design systems, components, and processes to meet requirements within realistic constraints
- Function effectively as a member or leader on a technical team

- Communicate effectively with both technical and non-technical audiences
- Recognize the need for, and an ability to engage in life-long learning
- Have an understanding of professional and ethical responsibility and the impact of engineering technology solutions in a societal and global context
- Have a commitment to quality, timeliness, and continuous improvement

Engineering Technology Faculty

M. Eric Carr, MsCpE *(Drexel University)*. Instructor. Computer Engineering, Digital Design, Programmable Devices, Genetic Algorithms, Programming, Additive Manufacturing, Maker Movement.

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.

Donald Fehlinger, PhD *(Drexel University)*. Assistant Teaching Professor. Phase Change Heat Transfer, Engineering Education.

Irina Ciobanescu Husanu, PhD *(Drexel University)*. Assistant Clinical 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.

Environmental Engineering MSENE

Major: Environmental Engineering
Degree Awarded: Master of Science in Environmental Engineering (MSENE)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.1401
Standard Occupational Classification (SOC) code: 17-2081

About the Program

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 Engineering MS graduates may include students with expertise in one or more of the following sub-disciplines:

- air pollution,
- hazardous and solid waste,
- subsurface contaminant hydrology,
- water resources,
- water and wastewater, and
- sustainability treatment

Environmental engineers also try to minimize the effect of human activities on the physical and living environment so society can 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.

Additional Information

For more information, visit the MS in Environmental Engineering (https://drexel.edu/engineering/academics/graduate-programs/masters/environmental-engineering/) program or the Department of Civil, Architectural and Environmental Engineering (https://drexel.edu/engineering/academics/departments/civil-architectural-environmental-engineering/) webpage.

Admission Requirements

Applicants to the MS in Environmental Engineering must have a minimum of a Bachelor of Science degree. 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 (optional)
- 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.

For additional information on how to apply, visit Drexel's Admissions page for Environmental Engineering (https://drexel.edu/academics/grad-professional-programs/engineering/environmental-engineering/). (https://drexel.edu/academics/grad-professional-programs/engineering/environmental-engineering/)

Degree Requirements

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.

Students entering the program without an ABET accredited BS degree in engineering will be required to take additional undergraduate coursework depending on their background and their career objectives.

Core Courses (15.0 credits)		
ENVE 660	Chemical Kinetics in Environmental Engineering	3.0
ENVS 501	Chemistry of the Environment	3.0
Approved Statistics course		**3.0-4.0**
BMES 510	Biomedical Statistics	
or ENVE 750	Data-based Engineering Modeling	
or ENVS 506	Biostatistics	
Approved Policy course		**3.0**
CIVE 564	Sustainable Water Resource Engineering	
or ECON 616	Public Finance and Cost Benefit Analysis	
or PLCY 503	Theory and Practice of Policy Analysis	
or PLCY 504	Methods of Policy Analysis	
Approved Life Sciences course		**3.0**
ENVE 516	Fundamentals of Environmental Biotechnology	
or ENVS 511	Evolutionary Ecology	
or ENVS 530	Aquatic Ecology	
Specialization Courses (select one area to complete) *		**9.0-12.0**
Environmental Treatment Processes		
ENVE 546 & ENVE 661 & ENVE 662 & ENVE 665	Solid Waste Systems and Env Engr Op-Chem & Phys and Enviro Engr Unit Oper-Bio and Hazardous Waste & Groundwater Treatment	
Human Risks		
AE 550	Indoor Air Quality **	
or EOH 612	Environmental Exposure Science	
EOH 510	Principles and Practice of Environmental and Occupational Health	
ENVE 727	Risk Assessment	
Water Resources		
CIVE 564 & CIVE 565 & ENVE 571	Sustainable Water Resource Engineering and Urban Ecohydraulics and Environmental Life Cycle Assessment	
CIVE 664	Open Channel Hydraulics **	
or ENVE 681	Analytical and Numerical Techniques in Hydrology	
Environmental Modeling		
ENVE 555	Geographic Information Systems **	
or ENVE 571	Environmental Life Cycle Assessment	
ENVE 681 & ENVE 750	Analytical and Numerical Techniques in Hydrology and Data-based Engineering Modeling	
Approved Advanced Math course:		

MEM 591	Applied Engr Analy Methods I	
or CHE 502	Mathematical Methods in Chemical Engineering	
or MATE 535	Numerical Engineering Methods	
Air Quality		
AE 550 & EOH 510 & ENVE 560	Indoor Air Quality and Principles and Practice of Environmental and Occupational Health and Fundamentals of Air Pollution Control	
Cognate Discipline Track ***		**12.0**
Electives or Thesis		**9.0-6.0**
Total Credits		**45.0-46.0**

*

Students must take 4 courses in an approved specialization, such as environmental treatment processes, human risks, water resources, environmental modeling, or air quality.

**

One of these is required.

***

Students must complete a course sequence of 12.0 credits aside from their specialization. This might include a second specialization course sequence or a sequence of elective courses as approved by the student's advisor and the departmental graduate advisor in any of the following subjects: AE, CHE, CHEC, CHEM, CIVE, ENVE, ENSS, ENVP, ENVS, MATH, MEM (500-699).

Sample Plan of Study

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ENVS 501	3.0	ENVE 660	3.0	Cognate Discipline course	3.0	VACATION	
Cognate Discipline course	3.0	Cognate Discipline course	3.0	Life Science course	3.0		
Statistics course	3.0	Environmental Policy course	3.0	Specialization Track course	3.0		
	9		**9**		**9**		**0**

Second Year			
Fall	**Credits**	**Winter**	**Credits**
Cognate Discipline course	3.0	Elective or Thesis courses	6.0
Specialization Track courses	6.0	Specialization Track course	3.0
	9		**9**

Total Credits 45

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

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science and mathematics
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare, as well as global, cultural, social, environmental and economic factors
- Communicate effectively with a range of audiences
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and societal contexts
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks and meet objectives

- Develop and conduct appropriate experimentation, analyze and interpret data and use engineering judgment to draw conclusions
- Acquire and apply new knowledge as needed, using appropriate learning strategies

Civil, Architectural and Environmental Engineering Faculty

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

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

Shannon Capps, PhD *(Georgia Institute of Technology)*. Associate Professor. Atmospheric chemistry; data assimilation; advanced sensitivity analysis; inverse modeling.

Zhiwei Chen, PhD *(University of South Florida)*. Assistant Professor. Mobility system modeling, simulation, optimization, control, and social impact analysis, with applications to modular, connected, and automated vehicle systems, mobility as a service, public transit systems.

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

Arvin Ebrahimkhanlou, PhD *(University of Texas at Austin)*. Assistant Professor. Non-destructive evaluation, structural health monitoring, artificial intelligence, robotics.

Yaghoob (Amir) Farnam, PhD *(Purdue University)*. Associate Professor. Advanced and sustainable infrastructure materials; multifunctional, self-responsive and bioinspired construction materials; advanced multiscale manufacturing; characterization, and evaluation of construction materials; durability of cement-based materials.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute and State University)*. Professor. Geotechnical and geoenvironmental engineering; soil improvement; soil improvement; recycled materials in geotechnics.

Patrick Gurian, PhD *(Carnegie-Mellon University)*. 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-Champaign) Program Head for Environmental Engineering; L. D. Betz Professor of Environmental Engineering*. Water treatment and wastewater resuse; risk analysis; microbial risk assessment; environmental modeling and statistics; microbiology; environmental health.

Simi Hoque, PhD *(University of California - Berkeley) Program Head for Architectural Engineering*. Professor. Computational methods to reduce building energy and environmental impacts, urban metabolism, thermal comfort, climate resilience.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Durability of polymeric construction materials; advanced construction materials; and performance of geosynthetics.

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

L. James Lo, PhD *(University of Texas at Austin)*. Associate Professor. Architectural fluid mechanics; building automation and autonomy; implementation of natural and hybrid ventilation in buildings; airflow distribution in buildings; large-scale air movement in an urban built environment; building and urban informatics; data-enhanced sensing and control for optimal building operation and management; novel data gathering methods for building/urban problem solving; interdisciplinary research on occupant behaviors in the built environment.

Franco Montalto, PhD *(Cornell University)*. Professor. Water in the built environment; planning, design, and restoration of natural and nature-based systems, including green stormwater infrastructure; urban ecohydrology; hydrologic and hydraulic modeling; urban flooding; urban sustainability; and climate change and climate resilience.

Mira S. Olson, PhD *(University of Virginia)*. Associate Professor. Peace engineering; source water quality protection and management; contaminant and bacterial fate and transport; community engagement.

Miguel A. Pando, PhD *(Virginia Polytechnic Institute and State University)*. Associate Professor. Slope stability and landslides; natural hazards; geotechnical earthquake engineering and liquefaction; laboratory and field measurement of soil and rock properties; soil erosion and scour; soil-structure-interaction; earth-based construction materials.

Matthew Reichenbach, PhD *(University of Austin at Texas)*. Assistant Teaching Professor. Design and behavior of steel structures, bridge engineering, structural stability

Fernanda Cruz Rios, PhD *(Arizona State University)*. Assistant Professor. Circular economy, life cycle assessment, convergence research, sustainable buildings and cities.

Michael Ryan, PhD *(Drexel University) Associate Department Head of Graduate Studies*. Associate Teaching Professor. Microbial Source Tracking (MST); Quantitative Microbial Risk Assessment (QMRA); dynamic engineering systems modeling; molecular microbial biology; phylogenetics; metagenomics; bioinformatics; environmental statistics; engineering economics; microbiology; potable and wastewater quality; environmental management systems.

Christopher Sales, PhD *(University of California, Berkeley)*. Associate Professor. Environmental microbiology and biotechnology; biodegradation of environmental contaminants; microbial processes for energy and resource recovery from waste; application of molecular biology, analytical chemistry and bioinformatic techniques to study environmental biological systems.

Robert Swan, PhD *(Drexel University) Associate Department Head for Undergraduates*. Teaching Professor. Geotechnical and geosynthetic engineering; soil/geosynthetic interaction and performance; laboratory and field geotechnical/geosynthetic testing.

Sharon Walker, PhD *(Yale University) Dean, College of Engineering*. Distinguished Professor. Water quality systems engineering; fate and transport of nanomaterials; pathogen adhesion phenomena.

Michael Waring, PhD *(University of Texas at Austin) Department Head, Civil, Architectural, and Environmental Engineering*. Professor. Indoor air quality, indoor aerosols, indoor air modeling, indoor chemistry, healthy buildings, and building sustainability intelligent ventilation, air cleaning, indoor disease transmission.

Jin Wen, PhD *(University of Iowa) Associate Dean for Research and Innovation, College of Engineering*. Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Building-grid integration; Occupant Centric Control; and Indoor Air Quality.

Emeritus Faculty

A. Emin Aktan, PhD *(University of Illinois, Urbana-Champaign)*. Professor Emeritus. Health monitoring and management of large infrastructures with emphasis on health monitoring.

Eugenia Ellis, PhD, AIA *(Virginia Polytechnic Institute and State University)*. Professor Emerita. Natural and electrical light sources and effects on biological rhythms and health outcomes; ecological strategies for smart, sustainable buildings of the nexus of health, energy, and technology.

Ahmad Hamid, PhD *(McMaster University)*. Professor Emeritus. Engineered masonry; seismic behavior, design and retrofit of masonry structures; development of new materials and building systems.

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

Joseph P. Martin, PhD *(Colorado State University)*. Professor Emeritus. Geotechnical and geoenvironmental engineering; hydrology; transportation; waste management.

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

Aspasia Zerva, PhD *(University of Illinois, Urbana-Champaign)*. Professor. Earthquake engineering; mechanics; seismology; structural reliability; system identification; advanced computational methods in structural analysis.

Environmental Engineering PhD

Major: Environmental Engineering
Degree Awarded: Doctor of Philosophy (PhD)
Calendar Type: Quarter
Minimum Required Credits: 90.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.1401
Standard Occupational Classification (SOC) code: 17-2081

About the Program

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 Engineering PhD graduates may include students with expertise in one or more of the following sub-disciplines:

- air pollution,
- hazardous and solid waste,

- subsurface contaminant hydrology,
- water resources,
- water and wastewater, and
- sustainability treatment

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.

Additional Information

For more information, visit the Department of Civil, Architectural and Environmental Engineering (https://drexel.edu/engineering/academics/departments/civil-architectural-environmental-engineering/) webpage.

Admission Requirements

Applicants to the PhD in Environmental Engineering must have a minimum of a Bachelor of Science degree. 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 (optional)
- 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.

For additional information on how to apply, visit Drexel's Admissions page for Environmental Engineering (https://drexel.edu/academics/grad-professional-programs/engineering/environmental-engineering/). (https://drexel.edu/academics/grad-professional-programs/engineering/environmental-engineering/)

Degree Requirements

The following general requirements must be satisfied to complete the PhD in Environmental Engineering:

- Establishment of plan of study with PhD advisor
- Completion of 90.0 quarter credit hours (or 45 credit hours post-MS), including taking certain qualifying courses
- Passing of PhD candidacy exam
- Approval of PhD dissertation proposal
- Defense of PhD dissertation

Students entering the PhD program with an approved Master of Science (MS) degree must take 45 credit hours of coursework and research to be approved by their PhD advisor. Students entering the PhD program without an approved MS degree can either complete the 45-credit hour Master of Science in Environmental Engineering (MSENE) degree followed by an additional 45 credit hours post MSENE, or they can choose not to obtain the MSENE and complete only the required “core” courses for the PhD degree within the completion of a total of 90 required credit hours. Students with previous graduate coursework, may transfer no more than 15 quarter credits (equivalent to 12 semester credits) from approved institutions if deemed equivalent to courses offered within the department.

All PhD students are required to meet all milestones of the program. The total credit amount, candidacy exam, and dissertation are University Requirements. Additional requirements are determined by the department offering the degree.

Qualifying Courses

To satisfy the qualifying requirements, students must earn a grade of B+ or better in the five required “core” courses taken at Drexel and must earn an overall GPA of 3.5 or better in these courses.

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 by the PhD advisor following the student's first year in the PhD program. For more information visit the Environmental Engineering's PhD Program Requirements page (https://drexel.edu/engineering/academics/graduate-programs/doctoral/environmental-engineering/).

Candidacy Exam

After approximately one year of study beyond the MS degree or completion of the required “core” courses, if their GPA is # 3.5, PhD students can and must take a candidacy examination, consisting of written and oral parts. Successful completion of the candidacy exam enables a student to progress from the designation of PhD student to PhD candidate. The candidacy exam represents the first exam in a series of three that comprise the PhD curriculum.

The Environmental Engineering candidacy examination serves to define the student's research domain and to evaluate the student's knowledge and understanding of various fundamental and foundational results in that domain. The student is expected to be able to read, understand, analyze, and explain advanced technical results in a specialized area of Environmental Engineering at an adequate level of detail. The candidacy examination will evaluate those abilities by asking a student to summarize literature and/or undertake a small research project. The student will prepare a written summary of review and/or project results, present the outcome orally, and answer questions about the report or presentation. The candidacy examination committee will evaluate the written report, the oral presentation, and the student's answers. The candidacy committee membership must follow the requirements of the Graduate College and must be approved by the Graduate College.

Students with a GPA < 3.5 do not meet eligibility requirements to sit for the candidacy exam. In this case, a student may petition the Graduate Advisor to take a Preliminary Written Exam (PWE). A committee will be formed consisting of three members selected from the pool of faculty in the field of research interest of the student and the pool of faculty who taught the courses taken by the student during the preceding terms. An exam will be developed consisting of a series of questions/problems prepared by the three written exam committee members. The written exam, while fixed in duration, may be composed of several different problem-solving assignments. Additionally, the exam may be closed book or open book or a combination thereof. The student will consult with the advisor to become acquainted with the specific rules of the exam. The exam will be graded by the PWE Committee to determine if the student may sit for the candidacy exam.

Dissertation Proposal

After successfully completing the candidacy examination, the PhD candidate must prepare a dissertation proposal that outlines, in detail, the specific problems that will be solved during the research that is conducted to complete the PhD dissertation. The quality of the dissertation proposal should be at the level of a peer-reviewed proposal to a federal funding agency, or a publishable scientific paper. The candidate is responsible for sending the dissertation proposal to the PhD committee no less than two weeks before the scheduled oral presentation. The PhD committee membership need not be the same as the candidacy exam committee, but it follows the same requirements and must be approved by the Graduate College. The oral presentation involves a presentation by the candidate followed by a period during which the committee will ask questions. The committee will then determine if the dissertation proposal has been accepted. The dissertation proposal can be repeated at most once if the proposal was not accepted.

A dissertation proposal must be approved within two years of becoming a PhD candidate. After approval of the dissertation proposal, the committee may meet to review the progress of the research.

Dissertation Defense

After successfully completing the dissertation proposal, 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 no less than two weeks prior to the scheduled oral defense. The oral presentation by the candidate is 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. The committee will then determine if the candidate has passed or failed the examination. If not passed, the candidate will be granted one more chance to pass the final defense.

The PhD degree is awarded for original research on a significant Environmental Engineering problem. Graduate students will work closely with individual faculty members to purse the PhD degree. 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.

Program Requirements

Post Bachelor of Science Degree		
Required Core Courses		
ENVE 660	Chemical Kinetics in Environmental Engineering	3.0
ENVS 501	Chemistry of the Environment	3.0
Required Statistics Course		**3.0-4.0**
BMES 510	Biomedical Statistics	
or ENVE 750	Data-based Engineering Modeling	
or ENVS 506	Biostatistics	
or other courses as approved by the graduate advisor		
Required Environmental Policy Course		**3.0**
CIVE 564	Sustainable Water Resource Engineering	
or ECON 616	Public Finance and Cost Benefit Analysis	
or PLCY 503	Theory and Practice of Policy Analysis	
or PLCY 504	Methods of Policy Analysis	
or other courses as approved by the graduate advisor		
Required Life Science Course		**3.0**
ENVE 516	Fundamentals of Environmental Biotechnology	
or ENVS 511	Evolutionary Ecology	
or ENVS 530	Aquatic Ecology	

or other courses as approved by the graduate advisor		
Technical Elective Requirements		**0.0-30.0**
To be determined by the PhD faculty advisor and approved by the graduate advisor		
500+ level courses in AE, CIVE, ENVE, ENVS, PLCY or other courses approved by the graduate advisor		
Research Requirements		**74.0-140.0**
Please note that the number of research credits may be reduced based on the number of Technical Electives that are required.		
CIVE 997	Research	
Dissertation Requirements		**1.0-12.0**
CIVE 998	Ph.D. Dissertation	
Total Credits		**90.0-198.0**

Post Master of Science Degree

Technical Elective Requirements		**0.0-30.0**
To be determined by the PhD faculty advisor and approved by the graduate advisor		
500+ level courses in AE, CIVE, ENVE, ENVS, PLCY or other courses approved by the graduate advisor		
Research Requirements		**44.0-100.0**
Please note that the number of research credits may be reduced based on the number of Technical Electives that are required.		
CIVE 997	Research	
Dissertation Requirements		**1.0-12.0**
CIVE 998	Ph.D. Dissertation	
Total Credits		**45.0-142.0**

Sample Plan of Study

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 advisor and uploaded to the E-Forms system no later than the end of the first term (you must be connected to the Drexel VPN for access to Eforms). The Eforms system will be used to track program progression and milestones. Sample Plans of Study are presented below:

Post Bachelor of Science Degree

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ENVE 516	3.0	ENVE 660	3.0	CIVE 564	3.0	Vacation	0.0
ENVE 750	3.0	Technical Electives	6.0	Technical Electives	6.0		
ENVS 501	3.0						
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	6.0	CIVE 997	6.0	CIVE 997	9.0	Vacation	0.0
Technical Electives	3.0	Technical Electives	3.0				
	9		**9**		**9**		**0**
Third Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	9.0	CIVE 997	9.0	CIVE 997	9.0	Vacation	0.0
	9		**9**		**9**		**0**
Fourth Year							
Fall	**Credits**						
CIVE 997	6.0						
CIVE 998	3.0						
	9						

Total Credits 90

Post Master of Science Degree

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
CIVE 997	3.0	CIVE 997	3.0	CIVE 997	3.0	Vacation	0.0
Technical Electives	6.0	Technical Electives	6.0	Technical Electives	6.0		
	9		**9**		**9**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**				
CIVE 997	9.0	CIVE 997	6.0				

	CIVE 998	3.0	
	9	**9**	

Total Credits 45

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

Program Level Outcomes

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- Communicate effectively with a range of audiences
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- Acquire and apply new knowledge as needed, using appropriate learning strategies

Civil, Architectural and Environmental Engineering Faculty

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

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

Shannon Capps, PhD *(Georgia Institute of Technology)*. Associate Professor. Atmospheric chemistry; data assimilation; advanced sensitivity analysis; inverse modeling.

Zhiwei Chen, PhD *(University of South Florida)*. Assistant Professor. Mobility system modeling, simulation, optimization, control, and social impact analysis, with applications to modular, connected, and automated vehicle systems, mobility as a service, public transit systems.

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

Arvin Ebrahimkhanlou, PhD *(University of Texas at Austin)*. Assistant Professor. Non-destructive evaluation, structural health monitoring, artificial intelligence, robotics.

Yaghoob (Amir) Farnam, PhD *(Purdue University)*. Associate Professor. Advanced and sustainable infrastructure materials; multifunctional, self-responsive and bioinspired construction materials; advanced multiscale manufacturing; characterization, and evaluation of construction materials; durability of cement-based materials.

Patricia Gallagher, PhD *(Virginia Polytechnic Institute and State University)*. Professor. Geotechnical and geoenvironmental engineering; soil improvement; soil improvement; recycled materials in geotechnics.

Patrick Gurian, PhD *(Carnegie-Mellon University)*. 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-Champaign) Program Head for Environmental Engineering; L. D. Betz Professor of Environmental Engineering*. Water treatment and wastewater resuse; risk analysis; microbial risk assessment; environmental modeling and statistics; microbiology; environmental health.

Simi Hoque, PhD *(University of California - Berkeley) Program Head for Architectural Engineering*. Professor. Computational methods to reduce building energy and environmental impacts, urban metabolism, thermal comfort, climate resilience.

Y. Grace Hsuan, PhD *(Imperial College)*. Professor. Durability of polymeric construction materials; advanced construction materials; and performance of geosynthetics.

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

L. James Lo, PhD *(University of Texas at Austin)*. Associate Professor. Architectural fluid mechanics; building automation and autonomy; implementation of natural and hybrid ventilation in buildings; airflow distribution in buildings; large-scale air movement in an urban built environment; building and urban informatics; data-enhanced sensing and control for optimal building operation and management; novel data gathering methods for building/urban problem solving; interdisciplinary research on occupant behaviors in the built environment.

Franco Montalto, PhD *(Cornell University)*. Professor. Water in the built environment; planning, design, and restoration of natural and nature-based systems, including green stormwater infrastructure; urban ecohydrology; hydrologic and hydraulic modeling; urban flooding; urban sustainability; and climate change and climate resilience.

Mira S. Olson, PhD *(University of Virginia)*. Associate Professor. Peace engineering; source water quality protection and management; contaminant and bacterial fate and transport; community engagement.

Miguel A. Pando, PhD *(Virginia Polytechnic Institute and State University)*. Associate Professor. Slope stability and landslides; natural hazards; geotechnical earthquake engineering and liquefaction; laboratory and field measurement of soil and rock properties; soil erosion and scour; soil-structure-interaction; earth-based construction materials.

Matthew Reichenbach, PhD *(University of Austin at Texas)*. Assistant Teaching Professor. Design and behavior of steel structures, bridge engineering, structural stability

Fernanda Cruz Rios, PhD *(Arizona State University)*. Assistant Professor. Circular economy, life cycle assessment, convergence research, sustainable buildings and cities.

Michael Ryan, PhD *(Drexel University) Associate Department Head of Graduate Studies*. Associate Teaching Professor. Microbial Source Tracking (MST); Quantitative Microbial Risk Assessment (QMRA); dynamic engineering systems modeling; molecular microbial biology; phylogenetics; metagenomics; bioinformatics; environmental statistics; engineering economics; microbiology; potable and wastewater quality; environmental management systems.

Christopher Sales, PhD *(University of California, Berkeley)*. Associate Professor. Environmental microbiology and biotechnology; biodegradation of environmental contaminants; microbial processes for energy and resource recovery from waste; application of molecular biology, analytical chemistry and bioinformatic techniques to study environmental biological systems.

Robert Swan, PhD *(Drexel University) Associate Department Head for Undergraduates*. Teaching Professor. Geotechnical and geosynthetic engineering; soil/geosynthetic interaction and performance; laboratory and field geotechnical/geosynthetic testing.

Sharon Walker, PhD *(Yale University) Dean, College of Engineering*. Distinguished Professor. Water quality systems engineering; fate and transport of nanomaterials; pathogen adhesion phenomena.

Michael Waring, PhD *(University of Texas at Austin) Department Head, Civil, Architectural, and Environmental Engineering*. Professor. Indoor air quality, indoor aerosols, indoor air modeling, indoor chemistry, healthy buildings, and building sustainability intelligent ventilation, air cleaning, indoor disease transmission.

Jin Wen, PhD *(University of Iowa) Associate Dean for Research and Innovation, College of Engineering*. Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Building-grid integration; Occupant Centric Control; and Indoor Air Quality.

Emeritus Faculty

A. Emin Aktan, PhD *(University of Illinois, Urbana-Champaign)*. Professor Emeritus. Health monitoring and management of large infrastructures with emphasis on health monitoring.

Eugenia Ellis, PhD, AIA *(Virginia Polytechnic Institute and State University)*. Professor Emerita. Natural and electrical light sources and effects on biological rhythms and health outcomes; ecological strategies for smart, sustainable buildings of the nexus of health, energy, and technology.

Ahmad Hamid, PhD *(McMaster University)*. Professor Emeritus. Engineered masonry; seismic behavior, design and retrofit of masonry structures; development of new materials and building systems.

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

Joseph P. Martin, PhD *(Colorado State University)*. Professor Emeritus. Geotechnical and geoenvironmental engineering; hydrology; transportation; waste management.

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

Aspasia Zerva, PhD *(University of Illinois, Urbana-Champaign)*. Professor. Earthquake engineering; mechanics; seismology; structural reliability; system identification; advanced computational methods in structural analysis.

Internet of Things MS

Major: Internet of Things
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.1001
Standard Occupational Classification (SOC) code: 15-1143

About the Program

The world envisioned by the Internet of Things (IoT) includes high densities of sensors and actuators all communicating with one another to collect and process data for a wide variety of applications. In the context of future smart cities, applications can be envisioned at the personal scale, building scale and campus/city scale. Personal scale IoT technologies include new wearables for medical applications including respiration monitoring, contraction monitoring and new wearable actuation systems for telemedicine applications. Building scale IoT technologies include intelligent lighting, occupancy sensing and smart ventilation control for energy efficient residential and commercial buildings. City scale IoT technologies include new sensors for environmental sensing such as air, water and soil quality sensors as well as structural health monitoring for major urban infrastructure like buildings and bridges.

Addressing these societal challenges will require engineers trained with core knowledge in wireless communications and networks supplemented by hands-on laboratory experience. They can supplement this core knowledge with electives in computer engineering and embedded systems, radio frequency electronics, cybersecurity and machine learning and data analytics. They must also be able to apply these technologies in applications such as biomedical devices, intelligent buildings and smart power grids.

The Master of Science in the Internet of Things (IoT) curriculum encompasses 45.0 or 46.0, with the optional Graduate Co-op (https://drexel.edu/engineering/academics/experiential-learning-co-op/graduate-co-ops/), 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.

Additional Information

For more information, visit the MS IoT program (https://drexel.edu/engineering/academics/graduate-programs/masters/internet-of-things/) web page.

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).

Degree Requirements

IoT Technical Elective courses		**12.0**
ECE 610	Machine Learning & Artificial Intelligence	
ECE 612	Applied Machine Learning Engineering	
ECE 613	Neuromorphic Computing	
ECE 630	Software Defined Radio Laboratory	
ECE 687	Pattern Recognition	
ECEC 531	Principles of Computer Networking	
ECEC 623	Advanced Topics in Computer Architecture	
ECEC 661	Digital Systems Design	
ECEE 517	Microwave Networks & Transmission Media	
ECEE 518	Microwave Passive Components	
ECEE 519	Microwave Active Subsystems	
ECEP 601	Modeling & Analysis of Power Distribution Systems	
ECEP 602	Power Distribution Automation and Control	

ECEP 603	Service and Power Quality in Distribution Systems	
ECEP 610	Power System Dynamics	
ECEP 611	Power System Security	
ECEP 612	Economic Operation of Power Systems	
ECET 511	Physical Foundations of Telecommunications Networks	
ECET 512	Wireless Systems	
ECET 602	Information Theory and Coding	
ECET 604	Internet Laboratory	
ECE Technical Elective courses *		21.0
General Electrical and Computer Engineering Courses **		12.0
Optional Coop Experience * **		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

*

500-level or higher courses from ECEE, ECEP, ECEC, ECES, ECET, and ECE.

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500-level or higher courses from ECEC, ECEE, ECEP, ECES, ECET, ECE, AE, CHE, CIVE, CAEE, CMGT, EGEO, EGMT, ENGR, ENVE, ET, MATE, MEM, PENG, SYSE, BMES, MATH, PHYS, CHEM, BIO, and CS.

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Co-op is an option for this degree for full-time on-campus students. To prepare for the graduate co-op experience, students will complete: COOP 500. The total credits required for this degree with the co-op experience is 46.0.
If a student completed COOP 101 as a Drexel Undergraduate co-op student, the student does not need to take COOP 500.
Students not participating in the co-op experience will need 45.0 credits to graduate.

Sample Plan of Study

Full time, no Co-op

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
IoT Technical Elective	3.0	IoT Technical Elective	3.0	IoT Technical Elective	6.0	Vacation	
ECE Technical Elective	6.0	ECE Technical Elective	6.0	ECE Technical Elective	3.0		
	9		**9**		**9**		**0**

Second Year

Fall	Credits	Winter	Credits
ECE Technical Elective	3.0	ECE Technical Elective	3.0
General Technical Elective	6.0	General Technical Elective	6.0
	9		**9**

Total Credits 45

Full-time, with graduate Co-op

First Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
COOP 500	1.0	IoT Technical Elective	3.0	IoT Technical Electives	6.0	ECE Technical Elective	3.0
IoT Technical Elective	3.0	ECE Technical Electives	6.0	ECE Technical Elective	3.0	General Technical Electives	6.0
ECE Technical Electives	6.0						
	10		**9**		**9**		**9**

Second Year

Fall	Credits	Winter	Credits	Spring	Credits
COOP EXPERIENCE		COOP EXPERIENCE		ECE Technical Elective	3.0
				General Technical Electives	6.0
	0		**0**		**9**

Total Credits 46

Part-time, no Co-op

First Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
IoT Technical Elective	3.0	IoT Technical Elective	3.0	IoT Technical Elective	3.0	Vacation	
ECE Technical Elective	3.0	ECE Technical Elective	3.0	ECE Technical Elective	3.0		
	6		**6**		**6**		**0**
Second Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
IoT Technical Elective	3.0	ECE Technical Elective	3.0	ECE Technical Elective	3.0	Vacation	
ECE Technical Elective	3.0	General Technical Elective	3.0	General Technical Elective	3.0		
	6		**6**		**6**		**0**
Third Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**				
ECE Technical Elective	3.0	General Technical Elective*	3.0				
General Technical Elective	3.0						
	6		**3**				

Total Credits 45

*
Note: This term is less than the 4.5-credit minimum required (considered half-time status) of graduate programs to be considered financial aid eligible. As a result, aid will not be disbursed to students this term.

Machine Learning Engineering MSMLE

Major: Machine Learning Engineering
Degree Awarded: Master of Science in Machine Learning Engineering (MSMLE)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.0903
Standard Occupational Classification (SOC) code: 15-1132

About the Program

The MS in Machine Learning is designed to provide a strong academic background in machine learning and prepare students for a career as a machine learning expert engineer or similar position. Using a curriculum based on core machine learning topics, aligned mathematical theory and signal processing, this graduate program provides a solid mathematical and theoretical understanding of how machine learning algorithms are designed, implemented and applied to practical problems. Students will gain the ability to implement machine learning systems using standard programming languages, software frameworks and systems both as an individual and as a member of a development team.

Students are also encouraged to engage in thesis research. The combined thesis and research cannot exceed 9.0 credits. The MS program is organized so that a student may complete the degree requirements in less than 2 years of full-time study or 2-3 years of part-time study.

Students within the Master of Science in Machine Learning Engineering are eligible to take part in the Graduate Co-op Program (https://drexel.edu/engineering/academics/experiential-learning-co-op/graduate-co-ops/), which combines classroom coursework with a 6-month, full-time work experience. For more information, visit the Steinbright Career Development Center's website (https://nam10.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.drexel.edu%2Fscdc%2Fco-op%2Fgraduate%2F&data=04%7C01%7Cjj976%40drexel.edu%7Cef8e52a12801425bc33d08d914a15a84%7C3664e6fa47bd45a696708c4f080f8ca6%7C0%7C0%7C637563505497502208%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=qAiIae%2BwxtoJ1e7H4TJZzvTnWn66%2BUVbCVJObBVu2BM%3D&reserved=0).

Additional Information

For more information about the MS in Machine Learning Engineering (https://drexel.edu/engineering/academics/graduate-programs/masters/machine-learning-engineering/) program, please visit the Department of Electrical and Computer Engineering (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) website.

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. Students will be required to hold a BS in electrical engineering, computer engineering, or computer science; or a bachelor's degree in an aligned area (e.g. statistics, neuroscience, etc.) in addition to an appropriate technical background which will be reviewed during the admissions process.

Full-time applicants are encouraged to take the GRE exam. Students who do not hold a degree from a US institution must take the TOEFL or IELTS exam within two years of application submission.

Degree Requirements

Core Courses		**12.0**
ECE 610	Machine Learning & Artificial Intelligence	
ECE 612	Applied Machine Learning Engineering	
ECE 687	Pattern Recognition	
ECES 521	Probability & Random Variables	
Aligned Mathematical Theory		**6.0**
Choose 2 courses		
ECES 522	Random Process & Spectral Analysis	
ECES 523	Detection & Estimation Theory	
ECES 811	Optimization Methods for Engineering Design	
ECET 602	Information Theory and Coding	
MATH 504	Linear Algebra & Matrix Analysis	
MATH 510	Applied Probability and Statistics I	
Applications		**3.0**
Choose 1 course		
ECE 686	Cell & Tissue Image Analysis	
ECES 620	Multimedia Forensics and Security	
ECES 641	Bioinformatics	
ECES 650	Statistical Analysis of Genomics	
ECES 660	Machine Listening and Music IR	
Signal Processing		**3.0**
Choose 1 course		
ECES 631	Fundamentals of Deterministic Digital Signal Processing	
ECES 681	Fundamentals of Computer Vision	
ECES 682	Fundamentals of Image Processing	
Engineering Electives		**9.0**
Choose any 3 graduate-level courses from the College of Engineering		
Transformational Electives		**6.0**
Choose 2 elective courses that promote the development of leadership, communication, and ethics		
COM 610	Theories of Communication and Persuasion	
EDGI 510	Culture, Society & Education in Comparative Perspective	
EDGI 522	Education for Global Citizenship, Sustainability, and Social Justice	
Mastery (Thesis and Non-Thesis Option) *		**6.0**
ECE 898	Master's Thesis	
Optional Co-op Experience **		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

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Thesis Option: A minimum of two terms of laboratory-based research that leads to a publicly defended MS thesis. Students will be advised by a faculty member, and when applicable, a representative of industry or government sponsor.
Non-thesis Option: In lieu of research and thesis, students will complete six additional credits of coursework from the Mathematical Theory, Applications, or Signal Processing area.

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Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

Sample Plan of Study

Thesis Option

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ECE 687	3.0	ECE 612	3.0	ECE 610	3.0	VACATION	
ECES 521	3.0	Aligned Mathematical Theory courses	6.0	Applications course	3.0		
Signal Processing course	3.0			Engineering elective	3.0		
	9		**9**		**9**		**0**

Second Year			
Fall	**Credits**	**Winter**	**Credits**
ECE 898	3.0	ECE 898	3.0
Engineering elective	3.0	Engineering elective	3.0
Transformational elective	3.0	Transformational elective	3.0
	9		**9**

Total Credits 45

Non-Thesis Option

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ECE 687	3.0	ECE 612	3.0	ECE 610	3.0	VACATION	
ECES 521	3.0	Aligned Mathematical Theory courses	6.0	Applications course	3.0		
Signal Processing course	3.0			Engineering elective	3.0		
	9		**9**		**9**		**0**

Second Year			
Fall	**Credits**	**Winter**	**Credits**
Aligned Mathematical Theory, Applications, or Signal Processing	3.0	Aligned Mathematical Theory, Applications, or Signal Processing	3.0
Engineering elective	3.0	Engineering elective	3.0
Transformational elective	3.0	Transformational elective	3.0
	9		**9**

Total Credits 45

Full Time With CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	Signal Processing or Aligned Mathematical Theory Courses	6.0	ECE 610	3.0	ECE 612	3.0
ECE 687	3.0	Engineering Elective Course	3.0	Applications Course	3.0	Aligned Mathematical Theory, Applications, or Signal Processing Course	3.0
ECES 521	3.0			Engineering Elective Course	3.0	Transformational Elective Course	3.0
Signal Processing or Aligned Mathematical Theory Course	3.0						
	10		**9**		**9**		**9**

Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COOP EXPERIENCE		COOP EXPERIENCE		Aligned Mathematical Theory, Applications, or Signal Processing Course	3.0

	Engineering Elective Course	3.0
	Transformational Elective Course	3.0
0	**0**	**9**

Total Credits 46

Materials Science and Engineering MSMSE

Major: Materials Science and Engineering
Degree Awarded: Master of Science in Materials Science and Engineering (MSMSE)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.1801
Standard Occupational Classification (SOC) code: 17-2131

About the Program

The graduate master of science (MS) program in Materials Science and Engineering (MSE) aims to provide an education which encompasses both the breadth and depth of the most recent knowledge base in the materials science and engineering field in a format suitable for individuals seeking careers in academia and/or industry. In addition, the program provides students with research training through research credits and/or thesis research.

The graduate student body reflects a broad spectrum of undergraduate backgrounds. Because of the expansion into interdisciplinary areas, qualified physical and biological sciences and other engineering program graduates may also join the program. Students without an undergraduate degree in Materials Science and Engineering (MSE) are required to take MATE 503 *Introduction to Materials Engineering*.

The MS program in Materials Science and Engineering (MSE) is offered both on a regular full-time and on a part-time basis.

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 engineers find employment in such organizations as Hewlett-Packard, Boeing, Intel, 3M, Global Foundries, Chemours, Lockheed-Martin, Johnson and Johnson, Merck, AstraZeneca, Arkema, W.L. Gore, Army Research Laboratory, Los Alamos National Laboratory, Air Products, Micron, Motorola and Corning.

Additional Information

For more information, visit the Materials Science and Engineering program (https://drexel.edu/engineering/academics/graduate-programs/masters/materials-science-engineering/) and the Department of Materials Science and Engineering (https://drexel.edu/engineering/academics/departments/materials-science-engineering/) webpage.

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/) webpage.

Degree Requirements

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 selected core courses.

Thesis Options

Students pursuing the thesis option are required to undertake a 9.0 credit thesis on a topic of materials research supervised by a faculty member. Alternatively, MS students can select the non-thesis option, in which case the thesis may be replaced by 9.0 credits of coursework.

All students pursuing the thesis option are required to propose an advisor-supported research thesis topic during their first year. 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.

There is no general exam required for MS students. If an MS student wishes to continue for a PhD, then the student must apply and be admitted to the PhD program. (There is no guarantee that an MS student will be 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
Four additional Selected Core (SC) 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 563	Ceramics	
MATE 610	Mechanical Behavior of Solids	
MATE 661	Biomedical Materials I	
Any additional related courses if approved by the graduate advisor.		
Technical Electives *		**18.0**
Thesis and Alternatives		**9.0**
9.0 credits MATE 898 (MS thesis) or 9.0 credits of Technical Electives (TE).		
Optional Coop Experience **		0-1
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

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Of the 18.0 technical elective credits, which may include up to 9.0 credits of MATE 897, at least 9.0 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 their advisor). At least 9.0 of these 18.0 technical electives must be exclusive of independent study courses or research credits.
Any graduate-level course in a STEM field (Engineering, Physical Sciences, or Computing/Data), as approved by the MSE Graduate Advisor, excluding MATE 536 (Materials Seminar), MATE 503 (Introduction to Materials Engineering) and MATE 504 (Art of Being a Scientist).

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Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500. The total credits required for this degree with the co-op experience is 46.
Students not participating in the co-op experience will need 45.0 credits to graduate.

Sample Plan of Study

MS-MSE Thesis Option

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
MATE Selected Core Course	3.0	MATE 510	3.0	MATE Selected Core Courses	6.0
MATE Technical Electives	6.0	MATE 512	3.0	Technical Elective	3.0
		MATE Technical Elective	3.0		
	9		**9**		**9**
Second Year					
Fall	**Credits**	**Winter**	**Credits**		
MATE 898 (or Technical Elective)	3.0	MATE 898 (or Technical Elective)	6.0		
Technical Electives	6.0	MATE Selected Core Course	3.0		
	9		**9**		
Total Credits 45					

MS-MSE CO-OP Option

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	MATE 510	3.0	MATE Selected Core Courses	6.0	Technical Elective	3.0
MATE Selected Core Course	3.0	MATE 512	3.0	Technical Elective	3.0	Technical Elective	3.0
MATE Technical Electives	6.0	MATE Technical Elective	3.0			Technical Elective	3.0
	10		**9**		**9**		**9**

Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COOP EXPERIENCE	0.0	COOP EXPERIENCE	0.0	MATE Selected Core Course	3.0
				Technical Electives	6.0
	0		**0**		**9**

Total Credits 46

Facilities

Nanobiomaterials and Cell Engineering Laboratory
This laboratory contains a 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, spectrafluorometer, piezoelectric d33 meter, wire-bonder, and laser displacement meter.

Layered Solids Laboratory
This laboratory contains a vacuum hot-press; creep testers, Ar-atmosphere glove-box, high-speed saw, and assorted high temperature furnaces; metallographic preparation facilities; high temperature closed-loop servo-hydraulic testing machines.

Mechanical Testing Laboratory
This laboratory contains mechanical and closed-loop servo-hydraulic testing machines, hardness testers, Charpy and Izod impact testers, equipment for fatigue testing, metallographic preparation facilities and a rolling mill with twin 6" diameter rolls.

Macromolecular Materials Laboratory
This laboratory contains a hybrid rheometer, inert environment glove box, size exclusion chromatography with multi-angle laser light scattering, HPLC and RI detector & MALS, centrifuge, rotovapor, and vacuum oven used for developing innovative synthetic platforms to generate functional soft materials with complex macromolecular architectures.

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 (ALD), chemical vapor deposition (CVD), 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 spectroscopy, scanning electron microscopy with electron beam lithography, and a scanning probe microscope.

Nanomaterials Laboratory
This laboratory contains instrumentation for synthesizing, testing and manipulation of nanomaterials carbon and two dimensional carbides under microscope, high-temperature autoclaves, Sievert’s apparatus; glove-boxes; high-temperature vacuum and other furnaces for the synthesis of nano-carbon coatings and nanotubes; tube furnaces for synthesis of carbides and nitrides; potentiostat/galvanostat for electrochemical testings; ultraviolet-visible (UV-VIS) spectrophotometry; Raman spectrometers; Differential scanning calorimeter (DSC) and thermogravimetric analyzer (TGA) up to 1500 °C with mass spectrometer, Zeta potential analyzer; attrition mill, bath and probe sonicators, centrifuges; electro-spinning system for producing nano-fibers.

Functional Inorganic Materials Synthesis Laboratory
The laboratory contains equipment for the synthesis of inorganic and hybrid materials, including gas cabinets for NH_3 and H_2, a CVD furnace, and spin-coater; UV-Vis spectrophotometer; and a photodegradation test station with Xe 1000 W lamp.

Films and Heterostructures Laboratory
This laboratory contains an oxide molecular beam epitaxy (MBE) thin film deposition system; physical properties measurement system (PPMS) for electronic transport and magnetometry measurements from 2 to 400 K, up to 9 T fields; 2 tube furnaces; spectroscopic ellipsometer.

Powder Processing Laboratory
This laboratory contains vee blenders, ball-mills, sieve shaker + sieves for powder classification, several furnaces.

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); tabletop tensile tester; strip biaxial tensile tester; vacuum evaporator; spin coater; 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 high purity liquid chromatography (HPLC) system; refractometer; electro-spinning and touch-spinning systems for producing nanofibers.

X-ray Tomography Laboratory
This laboratory contains a high resolution X-ray micro-tomography instrument and a cluster of computers for 3D microstructure reconstruction; mechanical stage, a positioning stage and a cryostage for *in-situ* testing.

MSE Undergraduate Teaching Laboratory
Contains an FTIR spectrometer, metallographic sample preparation, equipment, polymer 3D printers, polymer extruder and injection molder, Vickers hardness tester, inverted metallograph, multiple furnaces.

Materials Characterization Core (MCC)
The Department of Materials Science & Engineering relies on the Materials Characterization Core facilities within the University for materials characterization and micro- and nano-fabrication. These facilities contain a number of state-of-the-art materials characterization instruments, including high resolution and variable pressure field-emission scanning electron microscopes (SEMs) with Energy Dispersive Spectroscopy (EDS) for elemental analysis, Orientation Image Microscopy (OIM) for texture analysis, various *in-situ* and *in-operando* stages (cryo mat, heating, tensile, 3- and 4-point bending, and electrochemistry); two Transmission Electron Microscopes (TEMs) with STEM capability and TEM sample preparation equipment; a dual-beam focused ion beam (FIB) system for nano-characterization and nano fabrication; a Nanoindenter; an X-ray Photoelectron Spectrometer (XPS)/Electron Spectroscopy for Chemical Analysis (ESCA) system; X-Ray Diffractometers (XRD); and an X-ray microscope (NanoCT) with an *in-situ* tensile/compression temperature controlled stage.

More details of these instruments, information on how to access them, and instrument usage rates can be found at Drexel University's Materials Characterization Core webpage.

Program Level Outcomes

- 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.
- 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 possess written and verbal communication skills appropriate for professional materials engineers and/or scientists.

Materials Science and Engineering Faculty

Michel Barsoum, PhD *(Massachusetts Institute of Technology)*. Distinguished Professor. Processing and characterization of novel ceramics and ternary compounds, especially the MAX and 2-D MXene phases.

Hao Cheng, PhD *(Northwestern University)*. Associate Professor. Drug delivery, molecular self-assembly, cell-nanomaterial interactions, regenerative medicine and cell membrane engineering.

Yury Gogotsi, DSc, PhD *(National Academic of Sciences, Ukraine)*. Distinguished University & Charles T. and Ruth M. Bach Professor. affiliate faculty. Synthesis and surface modification of inorganic nanomaterials.

Yong-Jie Hu, PhD *(Penn State University)*. Assistant Professor. Computational design and evaluation of mechanical, thermodynamic, and electronic properties using first-principles calculations, molecular dynamic simulations, the CALPHAD approach, multiscale modeling, and machine learning approaches.

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) Graduate Advisor*. Professor. Soft and hybrid materials for optical, energy, and bio applications; polymeric materials, nanocomposites, structure and properties.

Andrew Magenau, PhD *(University of Southern Mississippi)*. Assistant Professor. Structurally complex materials exhibiting unique physical properties designed and fabricated using an assortment of methodologies involving directed self-assembly, externally applied stimuli, structure-function correlation, and applied engineering principles suited for technologies in regenerative medicine, biological interfacing, catalytic, electronic, and optical applications

Steven May, PhD *(Northwestern University) Department Head*. Professor. Synthesis of complex oxide films, superlattices, and devices; magnetic, electronic, and quantum materials; x-ray and neutron scattering.

Ekaterina Pomerantseva, PhD *(Moscow State University, Russia)*. Associate 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) Associate Dean, Faculty Affairs College of Engineering*. 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) Department Head, Mechanical Engineering and Mechanics*. Professor. Light-matter interactions in electronic materials, including ferroelectric semiconductors, complex oxide thin film science; laser spectroscopy, including Raman scattering.

Jörn Venderbos, PhD *(Leiden University)*. Assistant Professor. Theory of quantum materials: topological Insulators, topological semimetals, materials prediction and design, strongly correlated electron materials, complex electronic ordering phenomena, unconventional superconductors

Jill Wenderott, PhD *(University of Michigan)*. Anne Stevens Assistant Professor. Functional heteroanionic materials, hybrid thin films; materials for energy and environmental applications; in situ X-ray studies of materials synthesis.

Christopher Weyant, PhD *(Northwestern University)*. Teaching Professor. Engineering education

Antonios Zavaliangos, PhD *(Massachusetts Institute of Technology) A.W. Grosvenor Professor*. Professor. Constitutive modeling; powder compaction and sintering; pharmaceutical tableting, X-ray tomography.

Emeritus Faculty

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.

Michele Marcolongo, PhD, PE *(University of Pennsylvania)*. Professor Emerita. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Materials Science and Engineering PhD

Major: Materials Science and Engineering
Degree Awarded: Doctor of Philosophy (PhD)
Calendar Type: Quarter
Minimum Required Credits: 90.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.1801
Standard Occupational Classification (SOC) code: 17-2131

About the Program

The PhD program in Materials Science and Engineering (MSE) aims to provide an education which encompasses both the breadth and depth of the most recent knowledge base in the materials science and engineering field in a format suitable for individuals seeking careers in academia and/or industry.

In addition, the program provides students with in-depth research training through their thesis project.

The graduate student body reflects a broad spectrum of undergraduate backgrounds. Because of the expansion into interdisciplinary areas, qualified physical and biological sciences graduates, and graduates from other engineering disciplines may also join the program. Students without a degree in Materials Science and Engineering (MSE) are required to take MATE 503 *Introduction to Materials Engineering*.

Career Opportunities

PhD program graduates go on to careers in engineering firms, consulting firms, law firms, private industry, business, research laboratories, academia, and national laboratories. Materials scientists and engineers find employment in such organizations as Hewlett-Packard, Intel, 3M, Global Foundries, Chemours, Lockheed-Martin, Johnson and Johnson, Merck, AstraZeneca, Arkema, W. L. Gore, Army Research Laboratory, Los Alamos National Laboratory, Air Products, Micron, and Corning.

Additional Information

For more information visit the Materials Science and Engineering PhD program (https://drexel.edu/engineering/academics/graduate-programs/doctoral/materials-science-engineering/) and the Department of Materials Science and Engineering (https://drexel.edu/engineering/academics/departments/materials-science-engineering/) webpage.

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/) webpage.

Degree Requirements

Curriculum

A student must have at least the required 90.0 quarter credits for the PhD degree. An MS degree *is not* a prerequisite for the PhD degree, but can count for 45.0 quarter credits if the courses are approved by the graduate advisor. For students without an MS degree, but with previous graduate coursework, they may transfer no more than 15.0 credits (equivalent to 12.0 semester credits) from approved institutions provided they follow the rules and regulations described in the Materials Requirements of Graduate Degrees.

The required 90.0 credits for a PhD degree are tabulated below:

- Required core courses: 6.0 credits
- Additional required courses: 7.0 credits (MATE 504 & MATE 536 [1.0 credit for first 6 terms])
- Selected core courses: 12.0 credits
- Optional courses: 9.0 credits
- Research or additional option courses: 47.0 credits
- Dissertation: 9.0 credits (MATE 998)
  Total: 90.0 credits

Program Requirements

Required Core Courses: *		
MATE 510	Thermodynamics of Solids	3.0
MATE 512	Introduction to Solid State Materials	3.0
Additional Required Courses:		
MATE 504	The Art of Being a Scientist	2.0
MATE 536	Materials Seminar Series **	6.0
MATE 998	Ph.D. Dissertation	9.0
Selected Core (SC) Courses: Choose 4		**12.0**
MATE 501	Structure and Properties of Polymers	
MATE 507	Kinetics	
MATE 514	Structure, Symmetry, and Properties of Materials	
MATE 515	Experimental Technique in Materials	
MATE 535	Numerical Engineering Methods	
MATE 563	Ceramics	
MATE 610	Mechanical Behavior of Solids	
MATE 661	Biomedical Materials I	
Related MATE courses may be counted as SC as approved by the graduate advisor		
MATE Technical Electives (TE):		**9.0**
MATE 541	Introduction to Transmission Electron Microscopy and Related Techniques	
MATE 542	Nuclear Fuel Cycle & Materials	
MATE 544	Nanostructured Polymeric Materials	
MATE 572	Materials for High Temperature and Energy	
MATE 576	Recycling of Materials	
MATE 582	Materials for Energy Storage	
MATE 583	Environmental Effects on Materials	
MATE 585	Nanostructured Carbon Materials	
MATE 602	Soft Materials	
MATE 603	Advanced Polymer Characterization	

MATE 604	Principles of Polymerization I	
MATE 702	Natural Polymers	
MATE T580	Special Topics in MATE	
Other MATE courses that may be available		
Out-of-department courses, as approved by the MSE graduate advisor		
MATE 897	Research	46.0-140.0
Total Credits		**90.0-184.0**

Students must successfully pass degree-required exams including final dissertation defense and submission of the final dissertation.

*

PhD students must achieve a minimum "B-" grade in each of the required core courses. Waiver of any of the six (6) core courses must be approved by the MSE Department graduate advisor and the student's thesis advisor in advance.

**

MATE 536 is a 1.0 credit course that must be repeated 6 times.

An introductory course, MATE 503, is required for students without an undergraduate materials science and engineering degree.

Additional courses are encouraged for students entering the department with an MS degree. Students choose a doctoral thesis topic after consultation with the faculty. Students are required to consider topics early in the program. An oral thesis presentation and defense are scheduled at the completion of the thesis work.

In addition to the graduate seminar, which is required of all graduate students, doctoral program students must pass an oral candidacy examination and a thesis proposal defense. The exam is designed to improve and assess the communication skills and the analytical abilities of the student. The following procedures should be followed to complete the PhD.

Candidacy Exam Requirement

All MSE PhD students are required to take the PhD Candidacy Examinations administered by the MSE Department.

Additional Information

For more information, visit the Department of Materials Science and Engineering (https://drexel.edu/engineering/academics/departments/materials-science-engineering/) webpage.

Sample Plan of Study

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
MATE 504	2.0	MATE 510	3.0	MATE 536	1.0	MATE 897	9.0
MATE 536	1.0	MATE 536	1.0	MATE 897	2.0		
MATE Selected Core Courses (SC)	6.0	MATE 897	2.0	MATE Selected Core Course (SC)	3.0		
		MATE Selected Core Course (SC)	3.0	MATE Technical Elective Course (TE)	3.0		
	9		**9**		**9**		**9**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
MATE 536	1.0	MATE 512	3.0	MATE 536	1.0	MATE 897	9.0
MATE 897	2.0	MATE 536	1.0	MATE 897	8.0		
MATE Technical Elective Courses (TE)	6.0	MATE 897	5.0				
	9		**9**		**9**		**9**
Third Year							
Fall	**Credits**	**Winter**	**Credits**				
MATE 897	9.0	MATE 998	9.0				
	9		**9**				
Total Credits 90							

At least 90.0 credits are required for the PhD degree, which is based on the completion of a dissertation. Typical PhD students complete between 144.0-216.0 credits in the course of their PhD studies.

Facilities

Nanobiomaterials and Cell Engineering Laboratory
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Soft Matter Research and Polymer Processing Laboratories
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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.

Michele Marcolongo, PhD, PE *(University of Pennsylvania)*. Professor Emerita. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Mechanical Engineering and Mechanics MSME

Major: Mechanical Engineering and Mechanics
Degree Awarded: Master of Science in Mechanical Engineering (MSME)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional (CIP) code: 14.1901
Standard Occupational Classification (SOC) code: 17-2141

About the Program

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 courses often associate with one or more areas of specialization: design and manufacturing, mechanics, systems and control, and thermal and fluid sciences.

The MS degree program is offered on both a full-time and a part-time basis. Graduate courses are often scheduled in the late afternoon and evening so full-time students and part-time students can take the same courses. Students have the option to participate in the Graduate Co-op program (https://drexel.edu/engineering/academics/experiential-learning-co-op/graduate-co-ops/) at the master’s level.

For more information please visit the MS in Mechanical Engineering webpage (https://drexel.edu/engineering/academics/graduate-programs/masters/mechanical-engineering/) or the Mechanical Engineering and Mechanics (MEM) Department (https://drexel.edu/engineering/academics/departments/mechanical-engineering/).

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 and Mechanics.

Degree 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.

Program Requirements *		
Core Courses (select 2 courses in each of 2 Core Areas):		12.0
Core Area: Mechanics		
Subject Area: Solid Mechanics		
MEM 660	Theory of Elasticity I	
MEM 663	Continuum Mechanics	
Subject Area: Advanced Dynamics		
MEM 666	Advanced Dynamics I	
MEM 667	Advanced Dynamics II	
Core Area: Systems & Control		
Subject Area: Robust Control Systems		
MEM 633	Robust Control Systems I	
MEM 634	Robust Control Systems II	
Subject Area: Non-Linear Control Theory		
MEM 636	Theory of Nonlinear Control I	
MEM 637	Theory of Nonlinear Control II	
Core Area: Thermal & Fluid Sciences		
Subject Area: Heat Transfer		
MEM 611	Conduction Heat Transfer	
MEM 612	Convection Heat Transfer	
MEM 613	Radiation Heat Transfer	
Subject Area: Fluid Mechanics **		
MEM 621	Foundations of Fluid Mechanics	
MEM 622	Boundry Layers-Laminar & Turbulent	
Core Area: Manufacturing		
MEM 619	Microfluidics and Lab-on-a-Chip	
MEM 678	Nondestructive Evaluation Methods	
MEM 679	Data Analysis and Machine Learning for Science and Manufacturing	
MEM 687	Manufacturing Processes I	
Mathematics Courses		
MEM 591	Applied Engr Analy Methods I	3.0
Choose one of the following:		3.0
MEM 592	Applied Engr Analy Methods II	
MEM 593	Applied Engr Analy Methods III	
Technical Electives (including 9.0 credits for thesis option) ***		27.0
Optional Coop Experience †		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

*****

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.drexel.edu/mem/academics/graduate/grad-manual/).

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Consult the Thermal and Fluid Sciences area advisor for other options.

***
Technical Electives

- Students can take all 9 electives from MEM graduate courses. At least 2 electives must be MEM Electives.
- Any MEM graduate course is eligible to serve as electives. This includes those core courses that you do not use as core courses but use as elective courses.
- This also includes MEM I699 *Independent Study and Research*, and MEM 898 *Master's Thesis*.
- If students do not want to take all 9 elective technical courses from MEM, they may take a maximum of 7 non-MEM courses.
- Each non-MEM course to be used as technical elective needs be approved by listing it on the Plan of Study (GR-1 form) and the Graduate Advisor signing the form to approve it.
- To ensure you will receive the MSME degree, please consult with the Graduate Advisor before taking non-MEM graduate courses.
- Graduate courses at the 600- level from these four College of Engineering Departments (CAE, CBE, ECE and MSE) are automatically approved to serve as non-MEM technical elective courses.
- Students may register for MEM I699 *Independent Study and Research* (3.0 credits per term) to serve as electives, up to 9.0 credits.
- Students on the thesis-option typically register for MEM 898 *Master's Thesis* for 3 terms, and they count as 3 elective courses.

†
Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

Sample Plan of Study

Thesis Option

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
MEM 591	3.0	MEM Math Elective	3.0	MEM Selected Core Course	3.0
MEM Selected Core Course	3.0	MEM Selected Core Course	3.0	MEM Selected Core Course	3.0
MEM Technical Elective	3.0	MEM Technical Elective	3.0	MEM 898	3.0
	9		**9**		**9**
Second Year					
Fall	**Credits**	**Winter**	**Credits**		
Technical Elective	6.0	Technical Electives	6.0		
MEM 898	3.0	MEM 898	3.0		
	9		**9**		

Total Credits 45

Non-Thesis Option

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
MEM 591	3.0	MEM Math Elective	3.0	MEM Selected Core Course	3.0
MEM Selected Core Course	3.0	MEM Selected Core Course	3.0	MEM Selected Core Course	3.0
MEM Technical Elective	3.0	MEM Technical Elective	3.0	Technical Elective	3.0
	9		**9**		**9**
Second Year					
Fall	**Credits**	**Winter**	**Credits**		
Technical Elective	9.0	Technical Electives	9.0		
	9		**9**		

Total Credits 45

*
Students enrolled in the non-thesis master's program take electives in place of MEM 898.

Graduate CO-OP Option

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
MEM 591	3.0	MEM Math Elective	3.0	MEM Selected Core Course	3.0	Technical Electives	9.0

MEM Selected Core Course	3.0	MEM Selected Core Course	3.0	MEM Selected Core Course	3.0		
MEM Technical Elective	3.0	MEM Technical Elective	3.0	Technical Elective	3.0		
COOP 500[**]	1.0						
	10		**9**		**9**		**9**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**		
CO-OP EXPERIENCE		CO-OP EXPERIENCE		Technical Electives	9.0		
	0		**0**		**9**		
Total Credits 46							

*

Students enrolled in the non-thesis master's program take electives in place of MEM 898.

**

CO-OP is an option for this degree for full-time on campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500. The total credits required for this degree with the co-op experience is 46.

Facilities

Advanced Design and Manufacturing Laboratory

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.

Biofabrication Laboratory

Utilizes cells or biologics as basic building blocks in which biological models, systems, devices and products are manufactured. Biofabrication techniques encompass a broad range of physical, chemical, biological, and/or engineering processes, with various applications in tissue science and engineering, regenerative medicine, disease parthenogenesis and drug testing studies, biochips and biosensors, cell printing, patterning and assembly, and organ printing.

The Biofabrication Lab at Drexel University integrates computer-aided tissue engineering, modern design and manufacturing, biomaterials and biology in modeling, design and biofabrication of tissue scaffolds, tissue constructs, micro-organ, tissue models. The ongoing research focuses on bio-tissue modeling, bio-blueprint modeling, scaffold informatics modeling, biomimetic design of tissue scaffold, additive manufacturing of tissue scaffolds, cell printing and organ printing.

Biological Systems Analysis Laboratory

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

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 Diagnostics Laboratory

High-speed cameras, spectrometers, and laser systems are used to conduct research in low temperature hydrocarbon oxidation, cool flames, and 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.

Combustion, Fuel Chemistry, and Emissions Laboratory

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.

Complex Fluids and Multiphase Transport Laboratory

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.

Dynamic Multifunctional Materials Laboratory

The focus of theDynamic Multifuncational Materials Laboratory (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

The Electrochemical Energy Systems Laboratory (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.

Heat Transfer Laboratory

The heat transfer laboratory is outfitted with an array of instrumentation and equipment for conducting single- and multi-phase heat transfer experiments in controlled environments. Present efforts are studying the heat and mass transfer processes in super-critical fluids and binary refrigerants.

Lab-on-a-Chip and BioMEMS Lab

Develops miniature devices for biological and medical applications using microfabrication and microfluidics technologies. Our research projects have highly multidisciplinary nature and thus require the integration of engineering, science, biology and medicine. Projects are conducted in close collaboration with biologists and medical doctors. Our research methodology includes design and fabrication of miniature devices, experimental characterization, theoretical analysis, and numerical simulation.

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.

Multiscale Thermofluidics Laboratory

Develops novel scalable nanomanufacturing techniques using biological templates to manipulate micro- and nano- scale thermal and fluidic phenomena. Current work includes enhancing phase-change heat transfer with super-wetting nanostructured coatings and transport and separation through nanoporous membranes.

Nyheim Plasma Institute

The Nyheim Plasma Institute (NPI) was formed in 2002 (originally the A.J. Drexel Plasma Institute) to stimulate and coordinate research projects related to plasma and other modern high-energy engineering techniques. Today the NPI is an active multidisciplinary organization involving 23 faculty members from 6 engineering departments working in close collaboration with the School of Biomedical Engineering, College of Arts and Sciences, and the College of Nursing and Health Professions.

Precision Instrumentation and Metrology Laboratory

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.

Space Systems Laboratory

The objective of the Space Systems Laboratory (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

Research in the Theoretical and Applied Mechanics Group (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.

Vascular Kinetics Laboratory
The Vascular Kinetics Laboratory (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 Faculty

Joshua Agar, PhD *(University of Illinois, Urbana Champaign)*. Assistant Professor. Machine learning methods for multifunctional material design and fabrication.

Jennifer Atchison, PhD *(Drexel University)*. Associate Teaching Professor. Engineering Education, Functional Fabrics, and Nanofibers

Jonathan Awerbuch, DSc *(Technion, Israel Institute of Technology)*. Professor. Mechanics of composites; fracture and fatigue; impact and wave propagation; structural dynamics.

Ania-Ariadna Baetica, PhD *(California Institute of Technology)*. Assistant Professor. Control theory and systems biology for biotechnological and medial applications.

Nicholas P. Cernansky, PhD *(University of California-Berkeley) Hess Chair Professor of Combustion*. Professor Emeritus. 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.

Wesley Chang, PhD *(Princeton University)*. Assistant Professor. Electrochemical energy technologies.

Young I. Cho, PhD *(University of Illinois-Chicago)*. Professor. Heat transfer; fluid mechanics; non-Newtonian flows; biofluid mechanics; rheology.

Juan De la Fuente-Valeez, PhD *(Arizona State University)*. Assistant Teaching Professor. Mechatronics, control and automation.

Genevieve Dion, MFA *(University of the Arts) Director, Center for Functional Fabrics*. Professor. Industrial designer, wearable artist, new materials technology research.

Dimitrios Fafalis, PhD *(Columbia University)*. Assistant Teaching Professor. Mathematical modeling of natural and synthetic materials; computational mechanics, biomedical engineering and 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.

Yury Gogotsi, DSc, PhD *(National Academic of Sciences, Ukraine)*. Distinguished University & Charles T. and Ruth M. Bach Professor. affiliate faculty. Synthesis and surface modification of inorganic nanomaterials.

Li-Hsin Han, PhD *(University of Texas at Austin)*. Assistant Professor. Polymeric, micro/nano-fabrication, biomaterial design, tissue engineering, rapid prototyping, free-form fabrication, polymer micro actuators, photonics

Andrei Jablokow, PhD *(University of Wisconsin, Madison) Associate Department Head for Undergraduate Affairs, Mechanical Engineering and Mechanics*. Associate Teaching Professor. Engineering education; kinematics; geometric modeling.

Euisun Kim, PhD *(Georgia Institute of Technology)*. Associate Teaching Professor. Engineering education; robotic rehabilitation systems; bio-inspired designs.

E. Caglan Kumbur, PhD *(Pennsylvania State University) Associate Department Head for Graduate Affairs*. 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 Emeritus. Dynamic systems analysis; stochastic optimal control; control of electric power plants and systems.

Alan Lau, PhD *(Massachusetts Institute of Technology)*. Professor. Deformation and fracture of nano-devices and macroscopic structures; damage-tolerant structures and microstructures.

Roger Marino, PhD *(Drexel University)*. Professor Emeritus. Engineering education; land development; product Development

Matthew McCarthy, PhD *(Columbia University)*. Associate 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)*. Professor. Gas-phase reaction kinetics; thermodynamics; biofuels.

Moses Noh, PhD *(Georgia Institute of Technology)*. Associate Professor. MEMS; BioMEMS; lab-on-a-chip; microfabrication; microfluidics.

Jonathan E. Spanier, PhD *(Columbia University) Department Head, Mechanical Engineering and Mechanics*. Professor. Light-matter interactions in electronic materials, including ferroelectric semiconductors, complex oxide thin film science; laser spectroscopy, including Raman scattering.

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.

Tein-Min Tan, PhD *(Purdue University)*. Professor Emeritus. Mechanics of composites; computational mechanics and finite-elements methods; structural dynamics.

James Tangorra, PhD *(Massachusetts Institute of Technology)*. 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.

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.

Emeritus Faculty

Leon Y. Bahar, PhD *(Lehigh University)*. Professor Emeritus. Analytical methods in engineering, coupled thermoelasticity, interaction between analytical dynamics and control systems.

Michele Marcolongo, PhD, PE *(University of Pennsylvania)*. Professor Emerita. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Gordon D. Moskowitz, PhD *(Princeton University)*. Professor Emeritus. Biomechanics, dynamics, design, applied mathematics.

Sorin Siegler, PhD *(Drexel University)*. Professor. Orthopedic biomechanics; robotics; dynamics and control of human motion; applied mechanics.

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)*. Professor Emeritus. Treatment of damage evolution processes in multi-phased high-temperature materials, including ceramics and ceramic-matrix composites.

Mechanical Engineering and Mechanics PhD

Major: Mechanical Engineering and Mechanics
Degree Awarded: Doctor of Philosophy (PhD)
Calendar Type: Quarter
Minimum Required Credits: 90.0
Co-op Option: None
Classification of Instructional (CIP) code: 14.1901
Standard Occupational Classification (SOC) code: 17-2141

About the Program

The PhD degree offered by the Mechanical Engineering and Mechanics (MEM) Department (https://drexel.edu/engineering/academics/departments/mechanical-engineering/) offers courses often associated 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 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.

For more information, please visit the PhD in Mechanical Engineering (https://drexel.edu/engineering/academics/graduate-programs/doctoral/mechanical-engineering/) webpage.

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 and Mechanics.

Degree Requirements

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 and Mechanics.

PhD Program Requirements

Candidacy Requirements

The PhD candidacy exam consists of two parts: a course examination part and an oral examination part.

- For the course examination part, an earned grade of A- or higher on 2 courses from the MEM Selected Core Course list is required. These 2 courses should be from a two-course sequence (or any two of a three-course sequence, such as MEM 611 / MEM 612 / MEM 613) in (1) Mechanics, (2) Thermal and Fluid Sciences, and/or (3) Dynamic Systems and Controls Cores. Note that grades earned in (4) Design and Manufacturing Courses cannot be the basis for fulfilling this requirement. However, completion of MEM 619, MEM 687, MEM 678 and MEM 679 may be counted towards the core courses.
- For the oral examination part, 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 and identify areas for future research and development. In three weeks after the papers have been assigned to the student, the student submits a written report not exceeding 15 single-spaced pages, excluding references. 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 are to evaluate the student's knowledge in the scientific fields related to the research area, including related background and fundamental material, and to assess the student's ability to integrate information germane to success in research.

The candidacy may be completed at any time following matriculation but must be attempted no later than the end of the second academic year, for full-time students, and successfully completed not later than the end of the third academic year, for full-time students. The composition of the Candidacy Committee should be selected with the approval of the Program Manager of Graduate Studies. Special circumstances should also be discussed with the Program Manager.

Students Entering with MS degree in Mechanical Engineering from Drexel University

PhD Tailored Requirements †		**36.0**
Technical Electives		
Electives Approved by Program Manager of Graduate Studies and Student's Thesis Advisor		
MEM 998	Ph.D. Dissertation	9.0-144.0
Total Credits		**45.0-180.0**

†

Because the nature of the research is wide ranging and instruction should be selected to be tailored to the needs of the students, the student must determine the number and selection of courses in a Plan of Study. This plan should encompass the total number of required credit hours. Both the Program Manager of Graduate Studies and the student's thesis supervisor must approve this plan.

Students Entering with an BS degree in Mechanical Engineering or other STEM field but not an MS degree

PhD Tailored Requirements †		**36.0**
Technical Electives		
Electives Approved by Program Manager of Graduate Studies and Student's Thesis Advisor		
MEM 998	Ph.D. Dissertation	9.0-144.0
MEM Requirements		
MEM Graduate Courses ***		
MEM Core Courses (select 2 courses in each of 2 Core Areas)		12.0
Core Area: Mechanics		
Subject Area: Solid Mechanics		

MEM 660	Theory of Elasticity I	
MEM 663	Continuum Mechanics	
Subject Area: Advanced Dynamics		
MEM 666	Advanced Dynamics I	
MEM 667	Advanced Dynamics II	
Core Area: Systems & Control		
Subject Area: Robust Control Systems		
MEM 633	Robust Control Systems I	
MEM 634	Robust Control Systems II	
Subject Area: Non-Linear Control Theory		
MEM 636	Theory of Nonlinear Control I	
MEM 637	Theory of Nonlinear Control II	
Core Area: Thermal & Fluid Sciences		
Subject Area: Heat Transfer		
MEM 611	Conduction Heat Transfer	
MEM 612	Convection Heat Transfer	
MEM 613	Radiation Heat Transfer	
Subject Area: Fluid Mechanics **		
MEM 621	Foundations of Fluid Mechanics	
MEM 622	Boundry Layers-Laminar & Turbulent	
Core Area: Manufacturing		
MEM 619	Microfluidics and Lab-on-a-Chip	
MEM 687	Manufacturing Processes I	
MEM 678	Nondestructive Evaluation Methods	
MEM 679	Data Analysis and Machine Learning for Science and Manufacturing	
Mathematics Courses		
MEM 591	Applied Engr Analy Methods I	3.0
Select one of the following		3.0
MEM 592	Applied Engr Analy Methods II	
MEM 593	Applied Engr Analy Methods III	
Technical Electives (including 9.0 credits for thesis option)		27.0
Total Credits		**90.0-225.0**

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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 Program Manual (http://www.drexel.edu/mem/academics/graduate/grad-manual/).

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Consult the Thermal and Fluid Sciences area advisor for other options.

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MEM Graduate Courses

- Students must take 18 MEM course credits (6 courses). Among these credits, 2 courses must be selected from MEM Core Course list and must be in one of the two-course sequences.
- Any MEM graduate course is eligible to serve as MEM courses. This includes those core courses that you do not use as core courses but use as elective courses.
- This also includes MEM I699 *Independent Study and Research.*
- Graduate courses at the 600- level from these four College of Engineering Departments (CAE, CBE, ECE and MSE) are automatically approved to serve as non-MEM technical elective courses.
- Students may register for MEM I699 *Independent Study and Research* (3.0 credits per term) to serve as electives, up to 9.0 credits.

†

Because the nature of the research is wide ranging and instruction should be selected to be tailored to the needs of the students, the student must determine the number and selection of courses in a Plan of Study. This plan should encompass the total number of required credit hours. Both the Program Manager of Graduate Studies and the student's thesis supervisor must approve this plan.

Students Entering with an MS degree in Mechanical Engineering, Aerospace Engineering, or other STEM field from an institution other than Drexel University

PhD Tailored Requirements †		**18.0**
Technical Electives		
Electives Approved by Program Manager of Graduate Studies and Student's Thesis Advisor		
MEM 998	Ph.D. Dissertation	9.0-144.0

MEM Requirements		
MEM Graduate Courses ***		12.0
MEM Core Courses (Select 2 courses in one of the Core Areas)		6.0
Core Area: Mechanics		
Subject Area: Solid Mechanics		
MEM 660	Theory of Elasticity I	
MEM 663	Continuum Mechanics	
Subject Area: Advanced Dynamics		
MEM 666	Advanced Dynamics I	
MEM 667	Advanced Dynamics II	
Core Area: Systems & Control		
Subject Area: Robust Control Systems		
MEM 633	Robust Control Systems I	
MEM 634	Robust Control Systems II	
Subject Area: Non-Linear Control Theory		
MEM 636	Theory of Nonlinear Control I	
MEM 637	Theory of Nonlinear Control II	
Core Area: Thermal & Fluid Sciences		
Subject Area: Heat Transfer		
MEM 611	Conduction Heat Transfer	
MEM 612	Convection Heat Transfer	
MEM 613	Radiation Heat Transfer	
Subject Area: Fluid Mechanics **		
MEM 621	Foundations of Fluid Mechanics	
MEM 622	Boundry Layers-Laminar & Turbulent	
Core Area: Manufacturing		
MEM 619	Microfluidics and Lab-on-a-Chip	
MEM 687	Manufacturing Processes I	
MEM 678	Nondestructive Evaluation Methods	
MEM 679	Data Analysis and Machine Learning for Science and Manufacturing	
Total Credits		**45.0-180.0**

*****

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 Program Manual (http://www.drexel.edu/mem/academics/graduate/grad-manual/).

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Consult the Thermal and Fluid Sciences area advisor for other options.

****

MEM Graduate Courses

- Students must take 18 MEM course credits (6 courses). Among these credits, 2 courses must be selected from MEM Core Course list and must be in one of the two-course sequences.
- Any MEM graduate course is eligible to serve as MEM courses. This includes those core courses that you do not use as core courses but use as elective courses.
- This also includes MEM I699 *Independent Study and Research.*
- Graduate courses at the 600- level from these four College of Engineering Departments (CAE, CBE, ECE and MSE) are automatically approved to serve as non-MEM technical elective courses.
- Students may register for MEM I699 *Independent Study and Research* (3.0 credits per term) to serve as electives, up to 9.0 credits.

†

Because the nature of the research is wide ranging and instruction should be selected to be tailored to the needs of the students, the student must determine the number and selection of courses in a Plan of Study. This plan should encompass the total number of required credit hours. Both the Program Manager of Graduate Studies and the student's thesis supervisor must approve this plan.

Further details can be obtained from the department's Graduate Programs Manual.

Sample Plan of Study

Students entering with MS degree in Mechanical Engineering from Drexel University

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
Graduate Technical Electives	9.0	Graduate Technical Electives	9.0	Graduate Technical Electives	9.0
	9		**9**		**9**
Second Year					
Fall	**Credits**	**Winter**	**Credits**		
Graduate Technical Electives	9.0	MEM 998	9.0		
	9		**9**		

Total Credits 45

Students Entering with and MS degree in Mechanical Engineering, Aerospace Engineering, or another STEM field from an institution other than Drexel University

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
MEM Selected Core Course	3.0	MEM Selected Core Course	3.0	Graduate Technical Electives	9.0
MEM Graduate Courses	6.0	MEM Graduate Courses	6.0		
	9		**9**		**9**
Second Year					
Fall	**Credits**	**Winter**	**Credits**		
Graduate Technical Electives	9.0	MEM 998	9.0		
	9		**9**		

Total Credits 45

Students entering with BS degree in Mechanical Engineering or other STEM field but not an MS degree

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
MEM 591	3.0	MEM Math Elective	3.0	MEM Selected Core Course	3.0
MEM Selected Core Course	3.0	MEM Selected Core Course	3.0	MEM Selected Core Course	3.0
MEM Technical Elective	3.0	MEM Technical Elective	3.0	MEM Technical Elective	3.0
	9		**9**		**9**
Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
MEM Technical Electives	9.0	MEM 898	9.0	Graduate Technical Electives	9.0
	9		**9**		**9**
Third Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
Graduate Technical Electives	9.0	Graduate Technical Electives	9.0	Graduate Technical Electives	9.0
	9		**9**		**9**
Fourth Year					
Fall	**Credits**				
MEM 998	9.0				
	9				

Total Credits 90

Facilities

Nanobiomaterials and Cell Engineering Laboratory

This laboratory contains a 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, spectrafluorometer, piezoelectric d33 meter, wire-bonder, and laser displacement meter.

Layered Solids Laboratory

This laboratory contains a vacuum hot-press; creep testers, Ar-atmosphere glove-box, high-speed saw, and assorted high temperature furnaces; metallographic preparation facilities; high temperature closed-loop servo-hydraulic testing machines.

Mechanical Testing Laboratory
This laboratory contains mechanical and closed-loop servo-hydraulic testing machines, hardness testers, Charpy and Izod impact testers, equipment for fatigue testing, metallographic preparation facilities and a rolling mill with twin 6" diameter rolls.

Macromolecular Materials Laboratory
This laboratory contains a hybrid rheometer, inert environment glove box, size exclusion chromatography with multi-angle laser light scattering, HPLC and RI detector & MALS, centrifuge, rotovapor, and vacuum oven used for developing innovative synthetic platforms to generate functional soft materials with complex macromolecular architectures.

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 (ALD), chemical vapor deposition (CVD), 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 spectroscopy, scanning electron microscopy with electron beam lithography, and a scanning probe microscope.

Nanomaterials Laboratory
This laboratory contains instrumentation for synthesizing, testing and manipulation of nanomaterials carbon and two dimensional carbides under microscope, high-temperature autoclaves, Sievert's apparatus; glove-boxes; high-temperature vacuum and other furnaces for the synthesis of nano-carbon coatings and nanotubes; tube furnaces for synthesis of carbides and nitrides; potentiostat/galvanostat for electrochemical testings; ultraviolet-visible (UV-VIS) spectrophotometry; Raman spectrometers; Differential scanning calorimeter (DSC) and thermogravimetric analyzer (TGA) up to 1500 °C with mass spectrometer, Zeta potential analyzer; attrition mill, bath and probe sonicators, centrifuges; electro-spinning system for producing nano-fibers.

Functional Inorganic Materials Synthesis Laboratory
The laboratory contains equipment for the synthesis of inorganic and hybrid materials, including gas cabinets for NH_3 and H_2, a CVD furnace, and spin-coater; UV-Vis spectrophotometer; and a photodegradation test station with Xe 1000 W lamp.

Films and Heterostructures Laboratory
This laboratory contains an oxide molecular beam epitaxy (MBE) thin film deposition system; physical properties measurement system (PPMS) for electronic transport and magnetometry measurements from 2 to 400 K, up to 9 T fields; 2 tube furnaces; spectroscopic ellipsometer.

Powder Processing Laboratory
This laboratory contains vee blenders, ball-mills, sieve shaker + sieves for powder classification, several furnaces.

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); tabletop tensile tester; strip biaxial tensile tester; vacuum evaporator; spin coater; 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 high purity liquid chromatography (HPLC) system; refractometer; electro-spinning and touch-spinning systems for producing nanofibers.

X-ray Tomography Laboratory
This laboratory contains a high resolution X-ray micro-tomography instrument and a cluster of computers for 3D microstructure reconstruction; mechanical stage, a positioning stage and a cryostage for *in-situ* testing.

MSE Undergraduate Teaching Laboratory
Contains an FTIR spectrometer, metallographic sample preparation, equipment, polymer 3D printers, polymer extruder and injection molder, Vickers hardness tester, inverted metallograph, multiple furnaces.

Materials Characterization Core (MCC)
The Department of Materials Science & Engineering relies on the Materials Characterization Core facilities within the University for materials characterization and micro- and nano-fabrication. These facilities contain a number of state-of-the-art materials characterization instruments, including high resolution and variable pressure field-emission scanning electron microscopes (SEMs) with Energy Dispersive Spectroscopy (EDS) for elemental analysis, Orientation Image Microscopy (OIM) for texture analysis, various *in-situ* and *in-operando* stages (cryo mat, heating, tensile, 3- and 4-point bending, and electrochemistry); two Transmission Electron Microscopes (TEMs) with STEM capability and TEM sample preparation equipment; a dual-beam focused ion beam (FIB) system for nano-characterization and nano fabrication; a Nanoindenter; an X-ray Photoelectron Spectrometer (XPS)/

Electron Spectroscopy for Chemical Analysis (ESCA) system; X-Ray Diffractometers (XRD); and an X-ray microscope (NanoCT) with an *in-situ* tensile/compression temperature controlled stage.

More details of these instruments, information on how to access them, and instrument usage rates can be found at Drexel University's Materials Characterization Core webpage.

Program Level Outcomes

- Demonstrate the ability to conduct independent research on a timely topic of modern Mechanical Engineering.
- Acquire a broader and deeper knowledge in the student's sub-discipline/field of specialization.
- Demonstrate the ability to express research content and findings orally and in writing.
- Demonstrate an understanding of the relationship of their work to published literature.
- Demonstrate the ability to interact effectively with colleagues.
- Demonstrate the ability to utilize experimental, theoretical, and computational tools for one's research.

Mechanical Engineering Faculty

Joshua Agar, PhD *(University of Illinois, Urbana Champaign)*. Assistant Professor. Machine learning methods for multifunctional material design and fabrication.

Jennifer Atchison, PhD *(Drexel University)*. Associate Teaching Professor. Engineering Education, Functional Fabrics, and Nanofibers

Jonathan Awerbuch, DSc *(Technion, Israel Institute of Technology)*. Professor. Mechanics of composites; fracture and fatigue; impact and wave propagation; structural dynamics.

Ania-Ariadna Baetica, PhD *(California Institute of Technology)*. Assistant Professor. Control theory and systems biology for biotechnological and medial applications.

Nicholas P. Cernansky, PhD *(University of California-Berkeley) Hess Chair Professor of Combustion*. Professor Emeritus. 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.

Wesley Chang, PhD *(Princeton University)*. Assistant Professor. Electrochemical energy technologies.

Young I. Cho, PhD *(University of Illinois-Chicago)*. Professor. Heat transfer; fluid mechanics; non-Newtonian flows; biofluid mechanics; rheology.

Juan De la Fuente-Valeez, PhD *(Arizona State University)*. Assistant Teaching Professor. Mechatronics, control and automation.

Genevieve Dion, MFA *(University of the Arts) Director, Center for Functional Fabrics*. Professor. Industrial designer, wearable artist, new materials technology research.

Dimitrios Fafalis, PhD *(Columbia University)*. Assistant Teaching Professor. Mathematical modeling of natural and synthetic materials; computational mechanics, biomedical engineering and 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.

Yury Gogotsi, DSc, PhD *(National Academic of Sciences, Ukraine)*. Distinguished University & Charles T. and Ruth M. Bach Professor. affiliate faculty. Synthesis and surface modification of inorganic nanomaterials.

Li-Hsin Han, PhD *(University of Texas at Austin)*. Assistant Professor. Polymeric, micro/nano-fabrication, biomaterial design, tissue engineering, rapid prototyping, free-form fabrication, polymer micro actuators, photonics

Andrei Jablokow, PhD *(University of Wisconsin, Madison) Associate Department Head for Undergraduate Affairs, Mechanical Engineering and Mechanics*. Associate Teaching Professor. Engineering education; kinematics; geometric modeling.

Euisun Kim, PhD *(Georgia Institute of Technology)*. Associate Teaching Professor. Engineering education; robotic rehabilitation systems; bio-inspired designs.

E. Caglan Kumbur, PhD *(Pennsylvania State University) Associate Department Head for Graduate Affairs*. 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 Emeritus. Dynamic systems analysis; stochastic optimal control; control of electric power plants and systems.

Alan Lau, PhD *(Massachusetts Institute of Technology)*. Professor. Deformation and fracture of nano-devices and macroscopic structures; damage-tolerant structures and microstructures.

Roger Marino, PhD *(Drexel University)*. Professor Emeritus. Engineering education; land development; product Development

Matthew McCarthy, PhD *(Columbia University)*. Associate 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)*. Professor. Gas-phase reaction kinetics; thermodynamics; biofuels.

Moses Noh, PhD *(Georgia Institute of Technology)*. Associate Professor. MEMS; BioMEMS; lab-on-a-chip; microfabrication; microfluidics.

Jonathan E. Spanier, PhD *(Columbia University) Department Head, Mechanical Engineering and Mechanics*. Professor. Light-matter interactions in electronic materials, including ferroelectric semiconductors, complex oxide thin film science; laser spectroscopy, including Raman scattering.

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.

Tein-Min Tan, PhD *(Purdue University)*. Professor Emeritus. Mechanics of composites; computational mechanics and finite-elements methods; structural dynamics.

James Tangorra, PhD *(Massachusetts Institute of Technology)*. 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.

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.

Emeritus Faculty

Leon Y. Bahar, PhD *(Lehigh University)*. Professor Emeritus. Analytical methods in engineering, coupled thermoelasticity, interaction between analytical dynamics and control systems.

Michele Marcolongo, PhD, PE *(University of Pennsylvania)*. Professor Emerita. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Gordon D. Moskowitz, PhD *(Princeton University)*. Professor Emeritus. Biomechanics, dynamics, design, applied mathematics.

Sorin Siegler, PhD *(Drexel University)*. Professor. Orthopedic biomechanics; robotics; dynamics and control of human motion; applied mechanics.

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)*. Professor Emeritus. Treatment of damage evolution processes in multi-phased high-temperature materials, including ceramics and ceramic-matrix composites.

Nanomaterials MS

Major: Nanomaterials
Degree Awarded: Master of Science in Nanomateriials (MS)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 15.1601
Standard Occupational Classification (SOC) code: 17-2199

About the Program

Note - this program is currently not accepting students.

The Department of Materials Science and Engineering (MSE) provides an excellent opportunity for students to gain an advanced understanding of nanomaterials in this Master of Science degree program. Students attend classes and carry out research within faculty research groups to solve problems related to energy, health, and other applications using novel approaches in the area of nanomaterials. The program is designed to expand interdisciplinary knowledge and integrate critical thinking and research within the student's academic experience.

Additional Information

For more information, visit the MS in Nanomaterials webpage (https://drexel.edu/engineering/academics/graduate-programs/masters/nanomaterials/).

Admission Requirements

Application Deadlines

- US Students
    - Jun. 1 (Fall Term)
    - Oct. 15 (Winter Term)
    - Jan. 15 (Spring Term)
- International Students:
    - June 1 (Fall Term only)
    - Consideration for a term other than fall requires special permission from the academic department prior to application.

Applications are accepted at any time.

Requirements

For details regarding the items below please review the Admission Application Instructions (http://drexel.edu/grad/apply/checklist/).

- Graduate Admission Application (http://drexel.edu/grad/apply/online-app/)
    - Applicants may only apply to one program.
    - All documents submitted by you or on your behalf in support of this application for admission to Drexel University become the property of the University, and will under no circumstances be released to you or any other party.
    - An application fee of $65 USD is required.
- Transcripts
    - Provide official transcripts from all colleges and universities attended.
    - International students: If you have already graduated from your previous institution at the time of your application, please email your graduation certificate(s) attached as PDF or Microsoft Word documents to enroll@drexel.edu.

Degree Requirements

Core Courses		
Select 15.0 credits from the list below. Other graduate courses related to Nanomaterials or Nanotechnology can be counted as Core Courses if approved by the graduate advisor. Any 500 or 600 level course from the following departments with approval from Nanomaterials graduate advisor: CHEM, PHYS, BIO, SCTS, ENSS, ENVS, FASH, ENTP, CS, CI, DSCI, MATE, CAEE, ECE, MEM, CHE, EGMT, BMES.		15.0
ECEE 607	Nanoscale Fields	
MATE 503	Introduction to Materials Engineering	
MATE 510	Thermodynamics of Solids	
MATE 512	Introduction to Solid State Materials	
MATE 515	Experimental Technique in Materials	
MATE 585	Nanostructured Carbon Materials	
MEM 517	Fundamentals of Nanomanufacturing	
PHYS 553	Nanoscience	
Academic Track: The remaining credits are completed within an academic track. Choose one of the below two options (Nanobiomaterials or Nanomaterials for Energy) or create a track (Emerging Applications of Nanomaterials) with approval of graduate advisor. Any 500 or 600 level course from the following departments with approval from Nanomaterials graduate advisor: CHEM, PHYS, BIO, SCTS, ENSS, ENVS, FASH, ENTP, CS, CI, DSCI, MATE, CAEE, ECE, MEM, CHE, EGMT, BMES.		**21.0-23.0**
Nanobiomaterials Track *		
BIO 500	Biochemistry I	
BMES 541	Nano and Molecular Mechanics of Biological Materials	
BMES 631	Tissue Engineering I	
BMES 632	Tissue Engineering II	
BMES 660	Biomaterials I	
BMES 661	Biomaterials II	
MATE 501	Structure and Properties of Polymers	
MATE 544	Nanostructured Polymeric Materials	
MATE 661	Biomedical Materials I	
MATE 897	Research	

Nanomaterials for Energy Track		
CHEM 555	Quantum Chemistry Of Molecules I	
CHEM 868	Topics in Analytical Chemistry	
CHE 532	Electrochemical Engineering	
ECEE 821	Nanoelectronics	
ET 681	Nanomaterials and Nanoengineering	
MATE 507	Kinetics	
MATE 542	Nuclear Fuel Cycle & Materials	
MATE 544	Nanostructured Polymeric Materials	
MATE 563	Ceramics	
MATE 572	Materials for High Temperature and Energy	
MATE 582	Materials for Energy Storage	
MATE 897	Research	
Emerging Applications of Nanomaterials Track: Students may create a track focused on emerging interdisciplinary topic in nanomaterials. The track must be approved by the graduate advisor. In keeping with the interdisciplinary nature of the MS degree, the track must contain courses from at least two different departments. Any 500 or 600 level course from the following departments with approval from Nanomaterials graduate advisor: CHEM, PHYS, BIO, SCTS, ENSS, ENVS, FASH, ENTP, CS, CI, DSCI, MATE, CAEE, ECE, MEM, CHE, EGMT, BMES.		
MATE 897	Research	
Research credits can be applied to any track (up to 12.0 credits)		
Thesis or Non-Thesis Option **		**9.0**
Thesis		
MATE 898 [WI]	Master's Thesis	
Non-Thesis		
Choose 9.0 credits from courses listed in the academic tracks above with advisor approval.		
Optional Co-op Experience ***		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-48.0**

*
Students selecting the Nanobiomaterials track will complete 45.0-47.0 credits.

**
Master's Thesis students take MATE 898 [WI] for 9.0 credits while Non-Thesis Master's students select 9.0 credits from courses listed within each concentration. Additionally, Non-Thesis Master's students may request approval from the graduate advisor to take special topics courses.

***
Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

Writing-Intensive Course Requirements

In order to graduate, all students must pass three writing-intensive courses after their freshman year. Two writing-intensive courses must be in a student's major. The third can be in any discipline. Students are advised to take one writing-intensive class each year, beginning with the sophomore year, and to avoid “clustering” these courses near the end of their matriculation. Transfer students need to meet with an academic advisor to review the number of writing-intensive courses required to graduate.

A "WI" next to a course in this catalog may indicate that this course can fulfill a writing-intensive requirement. For the most up-to-date list of writing-intensive courses being offered, students should check the Writing Intensive Course List (https://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/faculty-programs/#writing-intensive-list) at the University Writing Program (http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/). (http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/drexel-writing-center/) Students scheduling their courses can also conduct a search for courses with the attribute "WI" to bring up a list of all writing-intensive courses available that term.

Sample Plan of Study

Nanomaterials for Energy Track (Thesis Option)

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
ET 681	3.0	CHEM 555	3.0	MATE 507	3.0
Core Courses	6.0	Core Courses	6.0	MATE 572	3.0
				MATE 582	3.0
	9		**9**		**9**

Second Year			
Fall	**Credits**	**Winter**	**Credits**
ECEE 821	3.0	MATE 544	3.0
MATE 898*	3.0	MATE 898*	6.0
Core Course	3.0		
	9		**9**

Total Credits 45

*

Students enrolled in the Non-Thesis Master's program take electives in place of MATE 898 [WI] .

Nanobiomaterials Track (Thesis Option)

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
BMES 660	4.0	BMES 661	4.0	BMES 541	3.0
Core Courses	6.0	MATE 661	3.0	MATE 544	3.0
		Core Course	3.0	MATE 898	3.0
	10		**10**		**9**
Second Year					
Fall	**Credits**	**Winter**	**Credits**		
BIO 500	3.0	MATE 898*	3.0		
MATE 501	3.0	Core Courses	6.0		
MATE 898*	3.0				
	9		**9**		

Total Credits 47

*

Students enrolled in the Non-Thesis Master's program take electives in place of MATE 898 [WI] .

NANO CO-OP Option

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	Core Courses	6.0	Core Course	3.0	Academic Track	9.0
Core Courses	6.0	Academic Track	3.0	Academic Track	6.0		
Academic Track	3.0						
	10		**9**		**9**		**9**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**		
COOP EXPERIENCE		COOP EXPERIENCE		Academic Track	9.0		
	0		**0**		**9**		

Total Credits 46

Facilities

Nanobiomaterials and Cell Engineering Laboratory

This laboratory contains a 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.

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More details of these instruments, information on how to access them, and instrument usage rates can be found at Drexel University's Materials Characterization Core webpage.

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- 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.
- 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 possess written and verbal communication skills appropriate for professional materials engineers and/or scientists.

Peace Engineering MS

Major: Peace Engineering
Degree Awarded: Master of Science in Peace Engineering (MSPENG)
Calendar Type: Quarter
Minimum Required Credits: 48.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0401
Standard Occupational Classification (SOC) code: 17-2081

About the Program

Note - this program is currently not accepting students.

Peace Engineering will educate the next generation of professionals who are able to address challenges and implement solutions at the intersection of peacebuilding and engineering. The program is the result of a partnership between the U.S. Institute of Peace's PeaceTech Lab and Drexel's College of Engineering and serves the dual purpose of integrating engineering and technology into peacebuilding practice and infusing conflict-sensitivity into engineering design.

Peace Engineering will cultivate a new skillset in students by combining disciplines of study from engineering, the social dimensions of conflict, and the applied sciences. Students will learn to conduct conflict analyses and to develop ethically and technically just solutions. These solutions will be based in the understanding that conflict, and the ability to address its root causes, emerges from the dynamics and interactions of social, technical, and environmental systems. The program offers a combination of online and classroom courses, group seminars and experiential learning with partners such as the PeaceTech Lab, the U.S. Institute of Peace, community-based organizations, and government agencies.

Peace Engineering is for students interested in work with NGOs and non-profits, and in fields that are growing rapidly due to the increased awareness of conflict and its causes (e.g., climate change). Students interested in engineering change will be empowered by widespread availability of technology that connects communities and economies, and the tools that engineers have to make positive impact on humanity. Extraordinary opportunities exist for graduates to work in the multinational, government, and non-governmental organizations that have historically led peacebuilding, stabilization, relief, and development efforts. These include the UN, WHO, World Bank, the World Food Programme, FEMA, DOS, DOD, NGOs and a host of public services within any community. Perhaps more impressive are the opportunities that are being created by the birth of the Peace Tech Industry. Engineers with a deep understanding of conflict are well suited to organizations that range from contractors involved in stabilization and development efforts, to extraction and consumer product companies working in conflict prone communities, to social entrepreneurs and their venture philanthropists developing technologies that do good.

Additional Information

For more information, please visit the Peace Engineering website (https://drexel.edu/engineering/academics/departments/engineering-leadership-society/academic-programs/peace-engineering/).

Degree Requirements

Core Peacebuilding Requirements		**12.0**
PENG 501	Peace Engineering Seminar - Fall	
PENG 502	Peace Engineering Seminar - Winter	
PENG 503	Peace Engineering Seminar - Spring	
PENG 545	Introduction to Peacebuilding for Engineers	
PENG 550	Conflict Management for Engineers	
PENG 560	Peacebuilding Skills	
Core Engineering Requirements		**9.0**
ENVE 727	Risk Assessment	
PROJ 501	Introduction to Project Management	
SYSE 540	Systems Engineering for Peacebuilding	

Research Methods		**9.0**
CAEE 501	Community-Based Design	
ENVE 750	Data-based Engineering Modeling	
SCTS 502	Research Methods	
Experiential Learning		**6.0**
PENG 600	Peace Engineering Experiential Learning	
Social Dimensions of Conflict Electives *		**6.0**
Technical Focus Sequences **		**6.0**
Total Credits		**48.0**

*

Social Dimensions of Conflict Electives

Students must complete a minimum of six credits, at the graduate level, from the following approved courses.

- **Science, Technology and Society electives:** SCTS 501, SCTS 620, SCTS 641
- **Politics electives:** PSCI 510, PSCI 553, ENVP 552
- **Education electives**: EDGI 550, EDGI 533, EDGI 536

**

Technical Focus Sequences

Students must complete one sequence of at least 2 courses (6 credits) from the following approved sequences.

- **Systems Analysis**: SYSE 688, SYSE 690, EGMT 660
- **Software Development**: CS 502 SE 575, SE 576
- **Machine Learning and AI**: CS 510, CS 613, CS 610
- **Information Security**: INFO 517, INFO 712, INFO 710
- **Database Management**: INFO 605, INFO 606, INFO 607
- **Information Retrieval**: INFO 605, INFO 624, INFO 633
- **Data Mining**: INFO 605, INFO 634, INFO 633
- **Web and Mobile Development**: INFO 552, INFO 655
- **Game Design**: DIGM 505, DIGM 506
- **Serious gaming**: DIGM 530, DIGM 531
- **Interactivity:** DIGM 520, DIGM 521
- **WASH:** CIVE 564, CIVE 567, CIVE 561
- **Power systems and Distribution:** ECEP 501, ECEP 502, ECEP 601

Sample Plan of Study

One Year M.S.

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ENVE 750	3.0	ENVE 727	3.0	CAEE 501	3.0	PENG 600	6.0
PENG 501	1.0	PENG 502	1.0	PENG 503	1.0	PROJ 501	3.0
PENG 545	3.0	PENG 550	3.0	PENG 560	3.0		
SYSE 540	3.0	SCTS 502	3.0	Technical Focus Course 2*	3.0		
Social Dimensions of Conflict Elective	3.0	Social Dimensions of Conflict Elective	3.0	Planning for Experiential Learning			
		Technical Focus Course 1*	3.0				
	13		**16**		**10**		**9**

Total Credits 48

Two Year M.S.

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ENVE 750	3.0	ENVE 727	3.0	CAEE 501	3.0	VACATION	
PENG 501	1.0	PENG 502	1.0	PENG 503	1.0		
PENG 545	3.0	PENG 550	3.0	PENG 560	3.0		

SYSE 540	3.0	SCTS 502	3.0	Planning for Experiential Learning			
	10		10		7		0
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**		
PENG 600	6.0	Social Dimensions of Conflict Elective	3.0	Social Dimensions of Conflict Elective	3.0		
PROJ 501	3.0	Technical Focus Course 1*	3.0	Technical Focus Course 2*	3.0		
	9		6		6		
Total Credits 48							

*

Technical Focus Courses must both be part of the same sequence, while Social Dimensions of Conflict Electives can be any two of the courses listed in the Program Requirements.

1.

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- Demonstrate ability to collaborate with stakeholders to understand and analyze issues associated with a conflict;
- Assess factors contributing to conflict and determine how, when, and whether technology and engineering approaches can improve a conflict scenario;
- Design and evaluate engineering, technological, and data-driven approaches that can impact a conflict scenario within ethical constraints;
- Advocate, using written and oral methods, for engineering, technological and analytical solutions that advance conflict resolution and peacebuilding initiatives;
- Facilitate the adoption and implementation of engineering, technological and analytical approaches into strategic peacebuilding initiatives;
- Choose appropriate methods to collect and evaluate data, and synthesize information to inform and impact peacebuilding practices;
- Develop advanced technical expertise in one of six technical focus areas.

Robotics and Autonomy MS

Major: Robotics and Autonomy
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.4201
Standard Occupational Classification (SOC) code: 11-9041

About the Program

The graduate program in Robotics and Autonomy will educate professionals who are prepared to lead and conduct research, development and design in robotic systems and technologies. This MS degree is built upon four foundational concepts in robotics: perception, cognition, control and action. Roughly, these four capabilities comprise: 1) obtaining data from the robot’s surroundings (perception); 2) reasoning about how that data yields information about the robot’s environment (cognition); 3) mapping environmental information to a decision about how to react to the environment (control); and 4) translating that reaction decision into movement and an interaction with the physical environment (action).

The program is an interdepartmental program in Drexel’s College of Engineering that educates and trains students in the theory, integration and practical application of the core engineering and computer science disciplines that comprise robotics and autonomy. To be admitted, students must have a bachelor’s degree in a STEM field or demonstrate that they have acquired sufficient experience in a technical field to be able to satisfactorily complete engineering studies at the graduate level.

Students are also encouraged to engage in thesis research. The combined thesis and research cannot exceed 9.0 credits. The MS program is organized so that a student may complete the degree requirements in less than 2 years of full-time study or 2-3 years of part-time study.

Students within the Master of Science in Robotics and Autonomy are eligible to take part in the Graduate Co-op Program, which combines classroom coursework with a 6-month, full-time work experience. For more information, visit COE Graduate Co-op (https://drexel.edu/engineering/academics/experiential-learning-co-op/graduate-co-ops/) and the Steinbright Career Development Center's website (https://nam10.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.drexel.edu%2Fscdc%2Fco-op%2Fgraduate%2F&data=04%7C01%7Cjj976%40drexel.edu

%7Cef8e52a12801425bc33d08d914a15a84%7C3664e6fa47bd45a696708c4f080f8ca6%7C0%7C0%7C637563505497512205%7CUnknown
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%7C1000&sdata=G5hhpdjcnEWUGpVR28CLL2jxnjDgBOpuphNzPZkykis%3D&reserved=0).

Additional Information

For more information visit the MS in Robotics and Autonomy program (https://drexel.edu/engineering/academics/graduate-programs/masters/robotics-autonomy/) and the Electrical and Computer Engineering Department (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) website.

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 in an engineering discipline 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.

Full-time applicants must take the GRE exam. Students who do not hold a degree from a US institution must take the TOEFL or IELTS exam within two years of application submission.

Additional Information

For more information, visit the Department of Electrical and Computer Engineering (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) webpage.

Degree Requirements

Foundation Courses		**6.0**
Choose 2 courses in mathematics and/or signal processing		
Mathematics		
ECES 510	Analytical Methods in Systems	
ECES 521	Probability & Random Variables	
MATH 510	Applied Probability and Statistics I	
MATH 521	Numerical Analysis II	
MATH 623	Ordinary Differential Equations I	
MATH 630	Complex Variables I	
MEM 591	Applied Engr Analy Methods I	
MEM 592	Applied Engr Analy Methods II	
MEM 593	Applied Engr Analy Methods III	
Signal Processing		
ECES 522	Random Process & Spectral Analysis	
ECES 523	Detection & Estimation Theory	
ECES 604	Optimal Estimation & Stochastic Control	
ECES 631	Fundamentals of Deterministic Digital Signal Processing	
ECES 640	Genomic Signal Processing	
ECES 641	Bioinformatics	
Systems Courses		**6.0**
Choose 2 courses in robotics and autonomy from the perspective of full systems or use		
ECE 603	Computing and Control	
ECE 608	Decision-Making for Robotics	
ECE 610	Machine Learning & Artificial Intelligence	
ECE 612	Applied Machine Learning Engineering	
ECES 511	Fundamentals of Systems I	
ECES 512	Fundamentals of Systems II	
ECES 513	Fundamentals of Systems III	
ECES 561	Medical Robotics I	
ECES 562	Medical Robotics II	
MEM 572	Mechanics of Robot Manipulators	
MEM 573	Industrial Application of Robots	
Core Components		
Take 1 course in each of the four disciplines critical to robotics		
Perception		3.0
ECE 609	Mobile Sensing and Motion Planning	

ECE 687	Pattern Recognition	
ECES 681	Fundamentals of Computer Vision	
ECES 682	Fundamentals of Image Processing	
ECET 512	Wireless Systems	
ECET T580	Special Topics in ECET	
MEM 678	Nondestructive Evaluation Methods	
Cognition and Behavior		3.0
ECE 610	Machine Learning & Artificial Intelligence	
ECE 612	Applied Machine Learning Engineering	
ECE 617	Reinforcement Learning	
ECE 686	Cell & Tissue Image Analysis	
ECES 604	Optimal Estimation & Stochastic Control	
ECES 631	Fundamentals of Deterministic Digital Signal Processing	
Action		3.0
ECES 511	Fundamentals of Systems I	
ECES 512	Fundamentals of Systems II	
ECES 513	Fundamentals of Systems III	
MEM 530	Aircraft Flight Dynamics & Control I	
MEM 666	Advanced Dynamics I	
MEM 667	Advanced Dynamics II	
MEM 668	Advanced Dynamics III	
Control		3.0
ECE 603	Computing and Control	
ECE 612	Applied Machine Learning Engineering	
ECES 604	Optimal Estimation & Stochastic Control	
ECES 642	Optimal Control	
MEM 633	Robust Control Systems I	
MEM 634	Robust Control Systems II	
MEM 635	Robust Control Systems III	
MEM 636	Theory of Nonlinear Control I	
MEM 637	Theory of Nonlinear Control II	
MEM 638	Theory of Nonlinear Control III	
MEM 733	Applied Optimal Control I	
MEM 734	Applied Optimal Control II	
MEM 735	Advanced Topics in Optimal Control	
Technical Focus Areas		**9.0**
Take 3 courses in a maximum of two core component areas listed above		
Experiential Learning (optional)		
Transformational Electives		**6.0**
Choose 2 elective courses that promote the development of leadership, communication, and ethics *		
COM 610	Theories of Communication and Persuasion	
EDGI 510	Culture, Society & Education in Comparative Perspective	
EDGI 522	Education for Global Citizenship, Sustainability, and Social Justice	
Mastery		**6.0**
Thesis Option: A minimum of two terms of laboratory-based research that leads to a publicly defended MS thesis. Students will be advised by a faculty member, and when applicable, a representative of industry or government sponsor.		
Non-thesis Option: In lieu of the research and thesis, students will complete 6.0 credits of additional coursework in a Technical Focus Area. Graduate Co-op is encouraged for non-thesis students but is not required.		
Optional Co-op Experience *		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

*

Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500.
The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

Sample Plan of Study

Full Time, No CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
ECE 608	3.0	ECE 609	3.0	COM 610	3.0	VACATION	
ECES 511	3.0	ECE 612	3.0	ECE 603	3.0		
ECES 521	3.0	ECES 512	3.0	ECES 513	3.0		
	9		**9**		**9**		**0**

Second Year			
Fall	**Credits**	**Winter**	**Credits**
ECE 687	3.0	ECE 898	3.0
ECE 898	3.0	ECES 681	3.0
ECES 682	3.0	EDGI 510	3.0
	9		**9**

Total Credits 45

Full Time With CO-OP

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
COOP 500	1.0	ECE 609	3.0	ECE 603	3.0	ECE 612	3.0
ECE 608	3.0	ECES 512	3.0	ECE 610	3.0	ECE T580	3.0
ECES 511	3.0	EDGI 510	3.0	ECES 513	3.0	ECES 681	3.0
ECES 521	3.0						
	10		**9**		**9**		**9**

Second Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
COOP EXPERIENCE		COOP EXPERIENCE		COM 610	3.0
				ECES 682	3.0
				ECES 686	3.0
	0		**0**		**9**

Total Credits 46

Vince and Judy Vidas Program in Systems Engineering MSSYSE

Major: Systems Engineering
Degree Awarded: Master of Science in Systems Engineering (MSSYSE)
Calendar Type: Quarter
Minimum Required Credits: 45.0
Co-op Option: Available for full-time, on-campus master's-level students
Classification of Instructional Programs (CIP) code: 14.2701
Standard Occupational Classification (SOC) code: 17-2199

What is Systems Engineering?

Fundamentally, the function of systems engineering is to guide the engineering development of complex systems, or in some cases, new technology. Systems engineering is:

- A set of process, principles, fundamentals and tools, and often includes a cultural aspect, to guide the design of complicated systems.
- An emphasis on the total operation of the system -- necessitating a thorough understanding of requirements for operation and performance.
- Involves defining the system as functional relationships in the early conceptual stages of the process.
- Includes a rigorous analysis of alternatives to assure optimal system design in later stages.
- An integration of subsystem and emerging technology to develop a system that satisfies the defined requirements.

Systems Engineering involves the ability to think within the context of incorporation and understanding of the system linkages and interactions and between the subsystems and components that comprise the entirety of the system.

About the Program

The Master of Science in Systems Engineering is an interdisciplinary curriculum which integrates systems thinking, the ability to understand the complete system and the ability to execute the systems engineering process. The degree provide skills to enable systems development throughout the entire life-cycle, from conceptual development and engineering design through the operation and sustainment phases.

A master's degree in systems engineering is an excellent complement to any engineering or STEM bachelor's degree. The program continues with the Drexel College of Engineering tradition by preparing students to be successful in their careers. Study can be on a part-time or full-time basis, and the program is available both online and on campus.

Drexel's MS in Systems Engineering is certified by the International Council on Systems Engineering (INCOSE) (https://www.incose.org/), and is one of only a few programs in the world to hold this distinction. Graduates will automatically qualify for a Systems Engineering Professional (SEP) Certification from INCOSE without having to take the certification exam.

The MS Systems Engineering curriculum will do the following:

- Include models relevant to sustainable, high performance systems as they relate to effective systems engineering
- Expose students to Model-Based Systems Engineering (MBSE) using SysML and also covering major aspects of the systems domain
- Teach systems engineering processes and skills to integrate user needs, manage requirements, conduct technological evaluation, build elaborate system architectures, assess risk and establish financial and schedule constraints
- Prepare students to intelligently manage and contribute to any engineering challenge, including concept development, technology assessment, architecture selection, and proposal development. The courses stimulate and challenge students 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.
- Formulate and manage processes relevant to complex systems development.
- Design, implement, integrate, verify, validate, support and decommission systems.
- Use systems engineering tools and practices to identify and execute effective technical solutions.
- Develop system architectures (physical, structural, behavioral, etc) to represent systems design and development.
- Manage system-intensive projects within cost and schedule constraints.

Certificate Option

Students may complete a graduate certificate as a standalone pursuit or as a gateway to the full Master of Science in Systems Engineering. Students can apply certificate course credits toward completion of a Master's in Systems Engineering.

Additional Information

For more information, visit the MS in Systems Engineering (https://drexel.edu/engineering/academics/graduate-programs/masters/systems-engineering/) program, or visit the Certificate in Systems Engineering (p. 152) page.

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.) may also be acceptable. 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.

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 total score of 90 (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

Note, interested students can apply for admission to this program in any term (Fall, Winter, Spring and Summer) as there is rolling admission throughout the year. However, students attending full time cannot apply for admission in the summer term. Full time students can apply for all other terms (Fall, Winter and Spring). This summer term restriction does not apply to part time / online students. These students can apply for admission in any term (Fall, Winter, Spring and Summer).

Degree Requirements

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 may be waived for students who have taken equivalent courses elsewhere.

Core Courses (30 Credits)		
Systems Engineering Process		
SYSE 520	Global Sustainment and Integrated Logistics	3.0
SYSE 533	Systems Integration and Test	3.0
SYSE 682	Introduction to Systems Science	3.0
SYSE 685	Systems Engineering Management	3.0
Systems Engineering Analysis		
SYSE 640	Model Based Systems Engineering	3.0
SYSE 688	Systems Engineering Analysis	3.0
Data Analytics and Modeling		
EGMT 572	Statistical Data Analysis *	3.0
EGMT 573	Operations Research	3.0
SYSE 690	Modeling, Simulation and Other Tools	3.0
Systems Engineering Capstone		
SYSE 598	Capstone in Systems Engineering	3.0
**Electives (15 Credits) ** **		**15.0**
Complete any five of the following electives: **		
Engineering Statistics Elective *		
EGMT 571	Engineering Statistics *	
Systems Design & Development Electives		
SYSE 530	Systems Engineering Design	
SYSE 531	Systems Architecture Development	
SYSE 532	Software Systems Engineering	
SYSE 650	Transition of the Integrated System from Design to Production	
Systems Reliability & Logistics Electives		
SYSE 522	Engineering Supply Chain Systems	
SYSE 524	Systems Reliability, Availability & Maintainability Analysis	
SYSE 525	Statistical Modeling & Experimental Design	
EGMT 575	Quality Systems Engineering	
Systems Engineering Leadership Electives		
EGMT 501	Leading and Managing Technical Workers	
EGMT 635	Visual System Mapping	
EGMT 650	Systems Thinking for Leaders	
SYSE 521	Integrated Risk Management	
Power Systems & Energy Electives		
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	
Machine Learning & Artificial Intellgence Electives		
ECE 610	Machine Learning & Artificial Intelligence	
ECE 612	Applied Machine Learning Engineering	
ECE 687	Pattern Recognition	
ECES 521	Probability & Random Variables	

Other Approved Electives		
EGMT 504	Design Thinking for Engineering Communications	
EGMT 531	Engineering Economic Evaluation & Analysis	
EGMT 535	Financial Management	
EGMT 610	Ethics & Business Practices for Engineers	
EGMT 615	New Product Conceptualization, Justification, and Implementation	
EGMT 616	Value Creation through New Product Development	
EGMT 620	Engineering Project Management	
EGMT 625	Project Planning, Scheduling and Control	
EGMT 630	Global Engineering Project Management	
EGMT 645	Managing Engineering Disasters	
EGMT 652	Engineering Law	
SYSE 898	Master's Thesis in Systems Engineering ***	
Optional Co-op Experience †		**0-1**
COOP 500	Career Management and Professional Development for Master's Degree Students	
Total Credits		**45.0-46.0**

*
EGMT 572 requires EGMT 571 as a prerequisite or a waiver must be approved by the program administration if the student has previously taken a undergraduate or graduate statistics course. Otherwise, students will need to take EGMT 571 as one of their electives.

**
Students may select electives from other disciplines outside of Engineering Management with prior approval from their advisor.

***
If a student decides to pursue the Master's Thesis option, the student will complete the 30 core credits, 6 elective credits, 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.

†
Co-op is an option for this degree for full-time on-campus students. To prepare for the 6-month co-op experience, students will complete: COOP 500. The total credits required for this degree with the co-op experience is 46.0
Students not participating in the co-op experience will need 45.0 credits to graduate.

Sample Plan of Study

Part Time, 2 Courses per term

First Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
SYSE 682	3.0	EGMT 572	3.0	EGMT 573	3.0	SYSE 533	3.0
SYSE 685	3.0	SYSE 688	3.0	SYSE 640	3.0	Elective	3.0
	6		**6**		**6**		**6**
Second Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
SYSE 690	3.0	SYSE 520	3.0	SYSE 598	3.0	Elective*	3.0
Elective	3.0	Elective	3.0	Elective	3.0		
	6		**6**		**6**		**3**
Total Credits 45							

*Note: Second Year Summer is less than the 4.5-credit minimum required (considered half-time status) of graduate programs to be considered financial aid eligible. As a result, aid will not be disbursed to students this term.

Part Time, One Course Per Term*

First Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
SYSE 682	3.0	EGMT 572	3.0	EGMT 573	3.0	SYSE 533	3.0
	3		**3**		**3**		**3**
Second Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
SYSE 685	3.0	SYSE 688	3.0	SYSE 640	3.0	Elective	3.0
	3		**3**		**3**		**3**

Third Year (Part-Time)							
Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
SYSE 690	3.0	SYSE 520	3.0	SYSE 598	3.0	Elective	3.0
	3		3		3		3
Fourth Year (Part-Time)							
Fall	Credits	Winter	Credits	Spring	Credits		
Elective	3.0	Elective	3.0	Elective	3.0		
	3		3		3		

Total Credits 45

*Note: This plan of study is less than the 4.5-credit minimum required (considered half-time status) of graduate programs to be considered financial aid eligible. As a result, aid will not be disbursed to students following this plan.

Full Time, No CO-OP

First Year							
Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
SYSE 682	3.0	EGMT 572	3.0	EGMT 573	3.0	SYSE 533	3.0
SYSE 685	3.0	SYSE 520	3.0	SYSE 640	3.0	Electives	6.0
Elective	3.0	SYSE 688	3.0	Elective	3.0		
	9		9		9		9
Second Year							
Fall	Credits						
SYSE 598	3.0						
SYSE 690	3.0						
Elective	3.0						
	9						

Total Credits 45

Full Time with CO-OP

First Year							
Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
COOP 500	1.0	EGMT 572	3.0	EGMT 573	3.0	SYSE 533	3.0
SYSE 682	3.0	SYSE 520	3.0	SYSE 640	3.0	Elective	3.0
SYSE 685	3.0	SYSE 688	3.0	Elective	3.0		
Elective	3.0						
	10		9		9		6
Second Year							
Fall	Credits	Winter	Credits	Spring	Credits		
COOP EXPERIENCE		COOP EXPERIENCE		SYSE 598	3.0		
				SYSE 690	3.0		
				Elective	3.0		
	0		0		9		

Total Credits 43

Note: Second Year Summer is less than the 4.5-credit minimum required (considered half-time status) of graduate programs to be considered financial aid eligible. As a result, aid will not be disbursed to students this term.

Dual Degree Programs

Students with a previously completed master's degree at Drexel 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 45.0 credits of graduate coursework. Up to 15.0 credits from the first master's may be transferred into the second master's degree program, enabling students to complete the second master's degree with a minimum of 30.0 new graduate credits.

Career Opportunities

The MS in 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.

Program Level Outcomes

Upon completion of the program, graduates will be prepared to:

- Develop and implement models and tools to enhance and optimize complex systems.
- Develop and manage processes relevant to complex systems development.
- Design, implement, integrate, verify, validate, support and decommission complex systems.
- Use systems engineering tools and practices to identify and execute effective technical solutions.
- Develop System Architectures (physical, structural, behavioral, etc.) to represent systems design and development.
- Manage system-intensive projects within cost and schedule constraints.

Systems Engineering Faculty

Richard Grandrino, MBA *(Drexel University)*. Teaching Faculty. Manager for advanced logistics operations at Lockheed Martin

Zhang Liang, PhD *(University of Arizona)*. Assistant Teaching Professor. Intelligent Transportation Systems, Complex Systems, Self-Organizing Systems, Machine Learning.

Steven Mastro, PhD *(Drexel University)*. Adjunct Faculty. Machinery Research and Silencing Division of NAVSEA Philadelphia. Work focuses on advanced sensor and control technologies for condition-based maintenance, damage control, and automation.

Miray Pereira, MBA *(Rutgers University)*. Adjunct Instructor. 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 Faculty. Author of "Systems Engineering Design Renaissance" and "Systems Practices as Common Sense."

Fernando Tovia, PhD *(University of Arkansas)*. Adjunct Instructor. Core quantitative analysis,strategic planning, supply chain management and manufacturing systems.

John Via, DEngr *(Southern Methodist University)*. Teaching Professor. Pharmaceutical, Bio-pharmaceutical, and Medical Device development and manufacturing

Graduate Minor in Computational Engineering

About the Graduate Minor

The graduate minor in Computational Engineering gives students pursuing a technical graduate degree an opportunity to develop core computational and mathematical competencies to complement their master's degree coursework.

Successful completion of the minor requires that students take five courses (15.0 credits). At least three courses must come from the three core subject areas; the student must take at least one course in each of the three core subject areas. The remaining two courses may be either core courses or elective courses.

The distinction between core and elective courses is that core courses are intended to be accessible to any College of Engineering graduate student without prerequisites. Elective courses, on the other hand, may require additional prerequisites and may be suitable only for students in certain academic disciplines or with certain academic backgrounds.

Additional Information

For more information, please contact the Department of Electrical and Computer Engineering (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/).

Program Requirements

Programming, Data Structures, Algorithms Requirement		
Complete 1 of the following courses:		3.0
BMES 550	Advanced Biocomputational Languages	
CS 502	Data Structures and Algorithms	

CS 503	Systems Basics	
CS 521	Data Structures and Algorithms I	
CS 540	High Performance Computing	
CS 550	Programming Languages	
SE 575	Software Design	
SE 576	Software Reliability and Testing	
Numerical Methods, Linear Algebra, Modeling and Simulation, Optimization Requirement		
Complete 1 of the following courses:		3.0
BMES 672	Biosimulation I	
CHE 626	Transport Phenomena II	
ECES 811	Optimization Methods for Engineering Design	
ENVE 681	Analytical and Numerical Techniques in Hydrology	
HMP 815	Cost Benefit Analysis for Health Services	
MATE 535	Numerical Engineering Methods	
MATH 504	Linear Algebra & Matrix Analysis	
MATH 520	Numerical Analysis I	
MATH 521	Numerical Analysis II	
MATH 540	Numerical Computing	
MEM 591	Applied Engr Analy Methods I	
MEM 681	Finite Element Methods I	
MEM 711	Computational Fluid Mechanics and Heat Transfer I	
OPR 620	Operations Research I	
OPR 624	Advanced Mathematical Program	
OPR 922	Operations Research Methods I	
OPR 992	Applied Math Programming	
Probability, Statistics, Machine Learning Requirement		
Complete 1 of the following courses:		3.0
BMES 510	Biomedical Statistics	
CS 510	Introduction to Artificial Intelligence	
ECEC T680	Special Topics in ECEC (Pattern Recognition)	
ECES 521	Probability & Random Variables	
EGMT 571	Engineering Statistics	
ENVE 727	Risk Assessment	
ENVE 750	Data-based Engineering Modeling	
MATH 510	Applied Probability and Statistics I	
STAT 601	Business Statistics	
STAT 610	Statistics for Business Analytics	
STAT 924	Multivariate Analysis I	
STAT 931	Statistics for Economics	
STAT 932	Statistics for Behavioral Science	
Additional Elective Courses		
Complete 2 courses from the following list (or any 2 courses from the above lists):		6.0
AE 551	Building Energy Systems I	
BMES 517	Intermediate Biostatistics	
BMES 518	Interpretation of Biomedical Data	
BMES 673	Biosimulation II	
BST 551	Statistical Inference I	
BST 558	Applied Multivariate Analysis	
BST 701	Advanced Statistical Computing	
CS 522	Data Structures and Algorithms II	
CS 610	Advanced Artificial Intelligence	
CS 613	Machine Learning	
CS 621	Approximation Algorithms	
CS 623	Computational Geometry	
CS 630	Cognitive Systems	
CS 650	Program Generation and Optimization	
CS 676	Parallel Programming	
ECEC 622	Parallel Programming	
ECES 522	Random Process & Spectral Analysis	
ECES 523	Detection & Estimation Theory	
EGMT 572	Statistical Data Analysis	
EGMT 573	Operations Research	

MATH 511	Applied Probability and Statistics II	
MATH 512	Applied Probability and Statistics III	
MATH 522	Numerical Analysis III	
MEM 592	Applied Engr Analy Methods II	
MEM 593	Applied Engr Analy Methods III	
MEM 682	Finite Element Methods II	
MEM 712	Computational Fluid Mechanics and Heat Transfer II	
OPR 601	Managerial Decision Models and Simulation	
OPR 622	Operations Research II	
OPR 626	System Simulation	
OPR 924	Operations Research Methods II	
OPR 991	Simulation Theory and Applications	
STAT 628	Applied Regression Analysis	
STAT 630	Multivariate Analysis	
Total Credits		**15.0**

Post-Baccalaureate Certificate in Construction Management

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
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
Classification of Instructional Program (CIP) Code: 52.2001
Standard Occupational Classification (SOC) Code: 11-9021

About the Program

The certificate in Construction Management program teaches professionals the multidisciplinary skills required of effective senior construction managers. The program produces industry leaders that exhibit strong technical and managerial skills, apply scientific methodologies to problem solving, are critical thinkers, exercise creativity, and inject innovation into the process.

Students have the option of completing this 18.0 credit certificate in construction management as a standalone professional development credential, or as a step toward the MS in Construction Management program (https://drexel.edu/engineering/academics/graduate-programs/masters/construction-management/).

Admission Requirements

The admissions process for this program is the same as for the MS in Construction Management (https://drexel.edu/engineering/academics/graduate-programs/masters/construction-management/).

Program Requirements

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**

Additional Information

For more information, view the College of Engineering's Construction Management (https://drexel.edu/engineering/academics/departments/engineering-leadership-society/academic-programs/construction-management/) webpage or contact:

William Grogan
Email: wtg25@drexel.edu
Phone: 215.895.5943

Post-Baccalaureate Certificate in Engineering Management

Certificate Level: Graduate
Admissions Requirements: Undergraduate degree in engineering or the sciences
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 15.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 15.1501
Standard Occupational Classification (SOC) Code: 11-9040

About the Program

This program is a superb training ground for engineers and scientists who want to obtain a solid foundation in leadership as well as 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.

Courses completed in this certificate program can be applied towards earning a masters in Engineering Management (https://catalog.drexel.edu/graduate/collegeofengineering/engineeringmanagement/) and/or most other master degree programs within the College of Engineering.

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 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 personal essay (prompt provided in the online application)
- International students must submit an Internet-based TOEFL (IBT = score of 94 or higher).

At least three years of relevant professional work experience are recommended, but not required.

Note, interested students can apply for admission to this program to start any term (Fall, Winter, Spring and Summer).

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).

Program Requirements

Required Courses		
EGMT 501	Leading and Managing Technical Workers	3.0
EGMT 504	Design Thinking for Engineering Communications	3.0
EGMT 531	Engineering Economic Evaluation & Analysis	3.0
EGMT 535	Financial Management	3.0
Electives (Choose One)		**3.0**
EGMT 502	Analysis and Decision Methods for Technical Managers	
EGMT 536	Advanced Financial Management for Engineers	
EGMT 614	Marketing: Identifying Customer Needs	
EGMT 620	Engineering Project Management	
SYSE 685	Systems Engineering Management	
Total Credits		**15.0**

Sample Plan of Study

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EGMT 501	3.0	EGMT 504	3.0	EGMT 531	3.0	EGMT 535	3.0
	3		**3**		**3**		**3**
Second Year							
Fall	**Credits**						
Elective	3.0						
	3						
Total Credits 15							

Additional Information

To learn more about the certificate or to apply for admission, please visit the Engineering Management (https://www.online.drexel.edu/online-degrees/engineering-degrees/ms-egmt/?_gl=1*1mrottr*_ga*Mzk4ODYyNjIwLjE2MjYxMDM5OTY.*_ga_6KJ1PNLE19*MTY4Mzg1OTEwOC4xNC4xLjE2ODM4NTkyMDEuMzcuMC4w) program page.

Post-Baccalaureate Certificate in Engineering Technical Leadership

Certificate Level: Graduate
Admissions Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Minimum Number of Credits to Completion: 18.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 1.5 years
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 15.1501
Standard Occupational Classification (SOC) Code: 17-2112

About the Program

The Engineering Technical Leadership Graduate Certificate is designed to enhance the skills of engineers and technical personnel desiring or holding leadership positions in variety of industries, such as the Department of Defense (DoD) and associated contractors, manufacturing, biomedical, urban development, transportation, etc. It is specifically geared to enhance leadership skills for plant managers, general managers, technical directors, program managers, functional engineering managers and anyone in an engineering leadership role or position. In today's environment, managing the complexity of human and capital resources is a tremendous challenge. This certificate provides formalized training and education in leadership that is "hands-on" and application oriented, focused to teach skills, concepts and methodologies associated with the leadership domain.

Courses completed in this certificate program can be applied to a masters in Engineering Management (https://catalog.drexel.edu/graduate/collegeofengineering/engineeringmanagement/) or Systems Engineering (https://catalog.drexel.edu/graduate/collegeofengineering/systemsengineering/) and/or most other master degree programs within the College of Engineering.

Note: Students that are interested in the International Council on Systems Engineering (INCOSE) Systems Engineering Professional (SEP) certification should take SYSE 688 (Systems Engineering Analysis) as an elective course. Completion of two courses (SYSE 685 and SYSE 688) is required for INCOSE SEP certification. For more information about this certification refer to INCOSE SEP Certificatio (https://nam10.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.incose.org%2Fcertification%2Fbecoming-certified&data=05%7C02%7Crag28%40drexel.edu%7Cc8471637ac39404a7a4808dc5d8c5d49%7C3664e6fa47bd45a696708c4f080f8ca6%7C0%7C0%7C638488104642682196%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=ii6IJlld3Bv%2Bu2DaA%2FQaTCgfI4ieRXyV9k7fG6mAzRM%3D&reserved=0)n

Admission Requirements

BS in Electrical Engineering, Mechanical Engineering, Computer Science or equivalent STEM BS degree. A GPA of 3.0 and / or significant work experience.

Note, interested students can apply for admission to this program in any term (Fall, Winter, Spring and Summer).

Additional Information

For more information about this program, contact Professor Rick Grandrino at rag28@drexel.edu.

Program Requirements

EGMT 501	Leading and Managing Technical Workers	3.0
EGMT 502	Analysis and Decision Methods for Technical Managers	3.0
EGMT 650	Systems Thinking for Leaders	3.0
SYSE 685	Systems Engineering Management	3.0
Technical Elective 1 *		3.0
Technical Elective 2 *		3.0
Total Credits		**18.0**

*

Technical Elective courses must be graduate level 500, 600 or 700 level courses from the following: AE, CHE, CIVE, CMGT, ECE, ECEC, ECEP, ECES, EET, EGMT, ENGR, ENVE, MATE, MEM, SYSE

Sample Plan of Study

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
EGMT 501	3.0	EGMT 502	3.0	SYSE 685	3.0	VACATION	
	3		**3**		**3**		**0**
Second Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**		
Technical Elective 1*	3.0	EGMT 650	3.0	Technical Elective 2*	3.0		
	3		**3**		**3**		
Total Credits 18							

*

Technical Elective courses must be graduate level 500, 600 or 700 level courses from the following: AE, CHE, CIVE, CMGT, ECE, ECEC, ECEP, ECES, EET, EGMT, ENGR, ENVE, MATE, MEM, SYSE

Post-Baccalaureate Certificate in Hardware Systems Engineering

Certificate Level: Graduate
Admissions Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Minimum Number of Credits to Completion: 12.0
Instructional Delivery: Online; Face-to-face
Calendar Type: Quarter
Expected Time to Completion: 1 years
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 14.2701
Standard Occupational Classification (SOC) Code: 11-9041

About the Program

This graduate certificate will enhance the skills of engineers who work in areas of product design and development related to a variety of industries, but most relevant to Department of Defense (DoD) and related industries. In today’s environment, managing the complexity of hardware product development requires technical knowledge and know-how, as well as system engineering approaches with a focus on the product development lifecycle process. This graduate certificate program will leverage this competency to provide systems engineering thinking paired with technical depth in product development and design. This pairing will enhance the skill set and talent of engineers who work in the field of hardware product design and development.

Courses completed in this certificate program can be applied to a masters in Systems Engineering (https://catalog.drexel.edu/graduate/collegeofengineering/systemsengineering/?_gl=1*19jjol3*_ga*NjUyMzQyMzYyLjE2OTUzMjQ5NzA.*_ga_6KJ1PNLE19*MTcxODM3NDI4OS4zOTIuMS4xNzE4Mzc1NjcwLjU4LjAuMA..) and / or most other master degree programs within the College of Engineering.

Note students that are interested in the International Council on Systems Engineering (INCOSE) Systems Engineering Professional (SEP) certification should take SYSE 685 (Systems Engineering Management) and SYSE 688 (Systems Engineering Analysis) as their required and elective courses. Completion of these two courses (SYSE 685 and SYSE 688) is required for INCOSE SEP certification. For more information about this certification refer to INCOSE SEP Certification (https://nam10.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.incose.org%2Fcertification%2Fbecoming-certified&data=05%7C02%7Crag28%40drexel.edu%7Cc8471637ac39404a7a4808dc5d8c5d49%7C3664e6fa47bd45a696708c4f080f8ca6%7C0%7C0%7C638488104642682196%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=ii6IJlld3Bv%2Bu2DaA%2FQaTCgfI4ieRXyV9k7fG6mAzRM%3D&reserved=0). (https://www.incose.org/certification/becoming-certifiedhttps://www.incose.org/certification/becoming-certified/)

Admission Requirements

- BS in Electrical Engineering, Mechanical Engineering, Computer Science, or equivalent STEM BS degree
- A GPA of 3.0 and/or significant work experience

Note, interested students can apply for admission to this program in any term (Fall, Winter, Spring and Summer).

Program Requirements

SYSE 533	Systems Integration and Test	3.0
SYSE 650	Transition of the Integrated System from Design to Production	3.0

SYSE 685	Systems Engineering Management	3.0
or SYSE 688	Systems Engineering Analysis	
Technical Elective *		3.0
Total Credits		**12.0**

*

The Technical Elective course must be a graduate level course (500, 600 or 700 series) from ECE, ECEC, ECEE, ECEP, ECES, ECET, ENGR, ET, MATE, MEM, SYSE

Sample Plan of Study

First Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
SYSE 685 or 688	3.0	SYSE 650	3.0	Technical Elective*	3.0	SYSE 533	3.0
	3		**3**		**3**		**3**

Total Credits 12

*

Technical Elective courses must be graduate level 500, 600 or 700 level courses from ECE, ECEC, ECEE, ECEP, ECES, ECET, ENGR, ET, MATE, MEM, SYSE

Additional Information

To learn more about the certificate or to apply for admission, please visit the Systems Engineering (https://drexel.edu/engineering/academics/departments/engineering-leadership-society/academic-programs/systems-engineering/) (https://drexel.edu/engineering/academics/departments/construction-engineering-project-management-systems-engineering/academic-programs/graduate/engineering-management/certificate/)program page.

Post-Baccalaureate Certificate in Healthy Indoor Environments

Certificate Level: Graduate
Admission Requirements: ABET accredited undergraduate BS degree in Architectural Engineering or equivalent (i.e., Civil Engineering, Mechanical Engineering, others).
Certificate Type: Post-Baccalaureate
Minimum Number of Credits to Completion: 9.0
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time To Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 14.0401
Standard Occupational Classification (SOC) Code: 11-9041

About the Program

This program will educate post-baccalaureate students with the knowledge and skills necessary for assessing the state of existing buildings or designing new buildings through the lens of promoting healthy indoor environments and well-being of building occupants. It combines courses on indoor air quality, indoor airflow, outdoor pollution (which is transported indoors), and/or risk assessment to provide students with the engineering toolkit to conduct meaningful work in the healthy buildings and health-promoting HVAC industry markets. This certificate is responsive to the newly disseminated understanding of the role buildings play in reducing indoor disease transmission and elevating occupant performance and satisfaction. The certificate will train professionals such as architectural, environmental, civil, and mechanical engineers who do or want to work in the healthy buildings industry.

Visit the College of Engineering certificates (https://drexel.edu/engineering/academics/graduate-programs/certificates/#civil) web page to learn more.

Program Requirements

Required Courses		
AE 550	Indoor Air Quality	3.0
AE 561	Airflow Simulation in Built Environment	3.0
or ENVE 560	Fundamentals of Air Pollution Control	
ENVE 727	Risk Assessment	3.0
Total Credits		**9.0**

Sample Plan of Study

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
AE 550	3.0	AE 561 or ENVE 560	3.0	ENVE 727	3.0
	3		**3**		**3**

Total Credits 9

Post-Baccalaureate Certificate in Naval Engineering

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 12.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 14.2201
Standard Occupational Classification (SOC) Code: 11-9041

About the Program

The Post-Baccalaureate Certificate in Naval Engineering is designed for engineers from any discipline who work with the development, design, construction, operation, maintenance, or logistic support of US Naval ships and shipboard systems. Students will gain an overall view of shipboard engineering plants as well as learn to understand the basic design and operating principles of the propulsion, hull, mechanical, electrical (HM&E) systems, and auxiliary systems of today's naval forces. Students will also learn the Department of Defense approach to systems engineering as applied to naval operations.

Upon completion of the certificate, students will be able to apply these learned principles and techniques to their jobs and ascertain success within their industry. The certificate is designed for naval engineers and practitioners at any level who desire to broaden their skills and increase their knowledge of naval engineering systems and principles.

Courses completed in this certificate program can be applied to a masters in systems engineering (https://catalog.drexel.edu/graduate/collegeofengineering/systemsengineering/) and / or most other master degree programs within the College of Engineering.

Admission Requirements

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.

Note, interested students can apply for admission to this program in any term (Fall, Winter, Spring and Summer).

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. A minimum score of 94 must be achieved. Official documents of this exam must be submitted directly to the Graduate Admissions Office. Unofficial photocopies will not be accepted.

Other requirements include:

- Submission of an application
- Official, sealed college transcripts
- An essay
- Two or more letters of recommendation

For more information about this certificate, visit the College of Engineering certificates (https://drexel.edu/engineering/academics/graduate-programs/certificates/) web page.

Program Requirements

Required Courses		
SYSE 605	Naval Systems Engineering	3.0
SYSE 610	Naval Engineering for the 21st Century	3.0
Elective Courses (Choose 2)		**6.0**

SYSE 520	Global Sustainment and Integrated Logistics	
SYSE 524	Systems Reliability, Availability & Maintainability Analysis	
SYSE 533	Systems Integration and Test	
SYSE 640	Model Based Systems Engineering	
SYSE 688	Systems Engineering Analysis	
Total Credits		**12.0**

Sample Plan of Study

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
SYSE 605	3.0	SYSE 610	3.0	Elective Course 1	3.0	Elective Course 2	3.0
	3		**3**		**3**		**3**

Total Credits 12

Post-Baccalaureate Certificate in Peace Engineering

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 9.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 14.2701
Standard Occupational Classification (SOC) Code: 11-9041

About the Program

The Peace Engineering certificate will introduce students to the field of Peace Engineering and train students to develop systems-level analysis skills that are critical to the field’s practice. The certificate program was designed in response to requests from federal and academic institutions for Drexel University to provide technical training in Peace Engineering without requiring a BS in Engineering or full-time enrollment at Drexel.

Courses for the certificate are selected from the first-year courses used in the Peace Engineering MS program and are appropriate for anyone with a bachelor’s degree in an applied or social science, or with appropriate work experience. The certificate will be made available to other colleges and universities for use as a minor so that students can learn about Peace Engineering without the parent university having to begin a dedicated program.

Admission Requirements

Bachelor’s degree in an applied or social science, or appropriate work experience.

For more information about this certificate, visit the College of Engineering certificates (https://drexel.edu/engineering/academics/graduate-programs/certificates/) web page.

Program Requirements

PENG 540	Systems Engineering for Peacebuilding	3.0
PENG 545	Introduction to Peacebuilding for Engineers	3.0
PENG 550	Conflict Management for Engineers	3.0
Total Credits		**9.0**

Sample Plan of Study

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
PENG 545	3.0	PENG 550	3.0	PENG 540	3.0
	3		**3**		**3**

Total Credits 9

Post-Baccalaureate Certificate in Planning and Design of Sustainable Infrastructure

Certificate Level: Graduate

Admission Requirements: ABET accredited undergraduate BS degree in Civil Engineering or equivalent (i.e., Architectural Engineering, Mechanical Engineering, others).
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 9.0
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time To Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 04.0403
Standard Occupational Classification (SOC) Code: 19-3051

About the Program

This certificate in Planning and Design of Sustainable Infrastructure is a post-baccalaureate 9-credit MS certificate designed for individuals to develop and improve career-related skills in the area of sustainable engineering design. The program includes a set of community-based and environmental design and sustainability evaluation courses. Ideal candidates include sustainability specialists in different sectors, as well as individuals working on environmental evaluation in civil, architectural and environmental engineering, urban planning and construction management areas.

For more information about this certificate, visit the College of Engineering certificates (https://drexel.edu/engineering/academics/graduate-programs/certificates/) web page.

Program Requirements

Required Courses:		
CAEE 501	Community-Based Design	3.0
CIVE 542	Incorporating Sustainability Principles in Design	3.0
or CIVE 565	Urban Ecohydraulics	
CIVE 564	Sustainable Water Resource Engineering	3.0
or ENVE 571	Environmental Life Cycle Assessment	
Total Credits		**9.0**

Sample Plan of Study

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
CAEE 501	3.0	CIVE 542 or 565	3.0	CIVE 564 or ENVE 571	3.0
	3		**3**		**3**

Total Credits 9

Post-Baccalaureate Certificate in Power Systems Engineering

Certificate Level: Graduate
Admission Requirements: Bachelor's degree in electrical engineering
Certificate Type: Graduate Certificate
Number of Credits to Completion: 24.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 2 years
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 14.4801
Standard Occupational Classification (SOC) Code: 11-9041

About the Program

The objective of this certificate is to provide students/professionals with the knowledge to support related technical project including electrification, de-carbonation, and aging equipment retirement expansion. This program will prepare students/engineers to be equipped with the technical knowledge and to meet the needs of utility corporations to retain existing employees, to develop professionals in meeting the new rising technical challenges, and to attract new, young professionals to join the challenging workforce.

Admission Requirements

Students should have a bachelor's degree in electrical engineering with the necessary pre-requisites. Student's without a bachelor's degree in electrical engineering would require coursework exposure to circuits (i.e., RLC circuits, nodal analysis phasors) and linear algebra (i.e., vector and matrix computation).

Degree Requirements

Required Courses:		
ECEP 501	Power System Analysis	3.0
ECEP 601	Modeling & Analysis of Power Distribution Systems	3.0
ECEP 641	Protective Relaying	3.0
ECEP 642	Protective Relay Laboratory	3.0
ECEP 671	AC-DC and DC-AC Power Electronic Converters	3.0
ECEP T580	Special Topics in ECEP	3.0
Technical Electives (Select two): *		**6.0**
ECEP 502	Computer Analysis of Power Systems	
ECEP 602	Power Distribution Automation and Control	
ECEP 603	Service and Power Quality in Distribution Systems	
ECEP 612	Economic Operation of Power Systems	
ECEP 643	Solid State Protective Relaying	
ECEP 672	Power Electronic Experiments: Hardware and Software	
ECEP 673	Power Electronic Applications	
ECEP 821	Load Forecasting & Probability Methods	
Total Credits		**24.0**

*

Select three from the list below or any ECE department course with advisor approval.

Sample Plan of Study

First Year

						Summer	Credits
						ECEP 501	3.0
							3

Second Year

Fall	Credits	Winter	Credits	Spring	Credits	Summer	Credits
ECEP 601	3.0	ECEP 641	3.0	ECEP 642	3.0	Technical Elective*	3.0
	3		**3**		**3**		**3**

Third Year

Fall	Credits	Winter	Credits	Spring	Credits
ECEP 671	3.0	Technical Elective*	3.0	ECEP T580	3.0
	3		**3**		**3**

Total Credits 24

*

Select three from the Technical Electives list or any ECE department course with advisor approval.

Additional Information

For more information about this program, contact Anup Das PhD at ad3639@drexel.edu.

Post-Baccalaureate Certificate in Real Estate

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
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
Classification of Instructional Program (CIP) Code: 52.1501
Standard Occupational Classification (SOC) Code: 11-9141

About the Program

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 (p. 54) with a focus in Real Estate.

Program Requirements

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**

Additional Information

For more information contact:

Will Grogan
Email: wtg25@drexel.edu

Post-Baccalaureate Certificate in Smart Building Systems

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 9.0
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time to Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 14.0401
Standard Occupational Classification (SOC) Code: 11-9041

About the Program

This program will educate post-baccalaureate students with the knowledge and skills necessary for designing new or commissioning existing smart building systems for higher building performance. It integrates courses on the topics of intelligent buildings, building control systems, building energy analytics, human-building interaction, fault detection and diagnosis, machine learning/artificial intelligence etc. to provide students with the scientific and engineering knowledge necessary to make buildings smarter with improved occupant well-being and sustainability. The certificate will train professionals such as architectural, mechanical, electrical, civil, and environmental engineers who do or want to work in the smart buildings industry.

Admission Requirements

ABET accredited undergraduate BS degree in Architectural Engineering or equivalent (i.e., Civil Engineering, Mechanical Engineering, others).

Visit the College of Engineering certificates (https://drexel.edu/engineering/academics/graduate-programs/certificates/#civil) web page to learn more.

Program Requirements

Required Courses:		
AE 510	Intelligent Buildings	3.0
AE 551	Building Energy Systems I	3.0
or AE 552	Building Energy Systems II	

AE 555	Data Acquisition and Analytics in Built Environment	3.0
Total Credits		**9.0**

Sample Plan of Study

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
AE 555	3.0	AE 510	3.0	AE 551 or 552	3.0
	3		**3**		**3**

Total Credits 9

Post-Baccalaureate Certificate in Structures Forensics

Certificate Level: Graduate
Admission Requirements: ABET accreditated undergaduate BS degree in Civil Engineering or equivalent (i.e., Architectural Engineering, Mechanical Engineering, others).
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 9.0
Instructional Delivery: Campus
Calendar Type: Quarter
Expected Time To Completion: 1 year
Financial Aid Eligibility: Not aid eligible
Classification of Instructional Program (CIP) Code: 14.0803
Standard Occupational Classification (SOC) Code: 11-9041

About the Program

This program will educate graduate students with the knowledge and skills necessary for assessing existing structures and structural systems, starting with an in-depth education of mechanics, followed by the use of sensing systems for infrastructure assessment, along with elements of forensics where past structural failures are analyzed so as to prevent similar structural failures in new or existing structural systems.

This certificate is responsive to the condition of the aging US infrastructure. For instance, the average bridge age in US is above 40 years. The certificate will train professionals such as civil and architectural engineers and designers on advanced structural engineering concepts such as NDE, structural assessment, and forensics.

Visit the College of Engineering certificates (https://drexel.edu/engineering/academics/graduate-programs/certificates/#civil) web page to learn more.

Program Requirements

CIVE 540	Forensic Structural Engineering	3.0
CIVE 605	Advanced Mechanics of Materials	3.0
CIVE 615	Infrastructure Condition Evaluation	3.0
Total Credits		**9.0**

Sample Plan of Study

First Year					
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**
CIVE 615	3.0	CIVE 605	3.0	CIVE 540	3.0
	3		**3**		**3**

Total Credits 9

Post-Baccalaureate Certificate in Sustainability and Green Construction

Certificate Level: Graduate
Admission Requirements: Bachelor's degree
Certificate Type: Post-Baccalaureate
Number of Credits to Completion: 15.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 1 year
Financial Aid Eligibility: Not aid eligible

Classification of Instructional Program (CIP) Code: 52.2001
Standard Occupational Classification (SOC) Code: 11-9021

About the Program

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.

Program Requirements

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**

Additional Information

For more information, view the College of Engineering's Construction Management (https://drexel.edu/engineering/academics/departments/construction-engineering-project-management-systems-engineering/academic-programs/undergraduate/construction-management/) webpage or contact:

Will Grogan
Email: wtg25@drexel.edu
215-895-0925

Post-Baccalaureate Certificate in Systems Engineering

Certificate Level: Graduate
Admission Requirements: Bachelor's degree in engineering or other science
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
Classification of Instructional Program (CIP) Code: 14.2701
Standard Occupational Classification (SOC) Code: 17-2199

About the Program

The Graduate Certificate in Systems Engineering teaches students the process and art of systems engineering. Students 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.

This graduate certificate is certified by the International Council on Systems Engineering (INCOSE), and it is one of only several curricula in the world to hold this distinction. Graduates will automatically qualify for the CSEP (Certified Systems Engineering Professional) or ASEP (Associate Systems Engineering Professional) without having to take the certification exam. For more information about this certification, refer to INCOSE SEP Certification (https://www.incose.org/certification/).

Any students working or interested in the field of systems engineering should consider pursuing and completing this certificate.

Courses completed in this certificate program can be applied to a masters in systems engineering (https://catalog.drexel.edu/graduate/collegeofengineering/systemsengineering/) and / or most other master degree programs within the College of 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 the sciences (physics, mathematics, computer science, etc.) may also be acceptable. A 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required. Note, applicants can apply for admission to the certificate program, in any term (Fall, Winter, Spring or Summer) as there is open enrollment throughout the year.

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 total score of 94 (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

For more information about this certificate, visit the College of Engineering certificates (https://drexel.edu/engineering/academics/graduate-programs/certificates/) web page.

Program Requirements

SYSE 533	Systems Integration and Test	3.0
SYSE 640	Model Based Systems Engineering	3.0
SYSE 685	Systems Engineering Management	3.0
SYSE 688	Systems Engineering Analysis	3.0
Total Credits		**12.0**

Sample Plan of Study

First Year							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
SYSE 685	3.0	SYSE 640	3.0	SYSE 688	3.0	SYSE 533	3.0
	3		**3**		**3**		**3**

Total Credits 12

Post-Baccalaureate Certificate in Systems Engineering for Software Applications

Certificate Level: Graduate
Admission Requirements: Bachelor's degree in engineering or other science
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
Classification of Instructional Program (CIP) Code: 14.2701
Standard Occupational Classification (SOC) Code: 15-1243

About the Program

This graduate certificate is intended to enhance the skills of software engineers who work in areas of product design and development related to a variety of industries, but with a particular focus on the Department of Defense (DoD) and related business. In today's environment, managing the complexity of hardware product development and software interface coding requires technical knowledge and know how, as well as system engineering approaches with a focus on the product development lifecycle process. The courses associated with this certificate focus on software development but provide connection to development of hardware products and/or assets. The software enables integration and operation of the hardware and/or asset. This graduate certificate program will leverage this competency to provide systems engineering thinking paired with technical depth in software engineering design, development and integration. This pairing will enhance the skill set and talent of engineers who work in the field of hardware product design and development.

Note: Students interested in the International Council on Systems Engineering (INCOSE) Systems Engineering Professional (SEP) certification should take SYSE 688 *Systems Engineering Analysis*, as their elective course, as completion of two courses (SYSE 685 and SYSE 688) is needed for INCOSE SEP certification. For more information about this certification refer to INCOSE SEP Certification (https://www.incose.org/certification/becoming-certified/).

Courses completed in this certificate program can be applied to a masters in systems engineering (https://catalog.drexel.edu/graduate/collegeofengineering/systemsengineering/) and/or most other master degree programs within the College of Engineering.

Admission Requirements

BS in Electrical Engineering, Mechanical Engineering, Computer Science or equivalent STEM BS degree. Note, interested students can apply for admission to this program in any term (Fall, Winter, Spring and Summer) as there is enrolling admission throughout the year.

A GPA of 3.0 and / or significant work experience.

Additional Information

For more information about this program, contact Rick Grandrino at rag28@drexel.edu

Program Requirements

Required System Engineering Courses		
SYSE 532	Software Systems Engineering	3.0
SYSE 640	Model Based Systems Engineering	3.0
SYSE 685	Systems Engineering Management	3.0
COE or CCI Technical Elective (1 Course) *		3.0
Total Credits		**12.0**

*
The technical elective must be a graduate level course (500, 600 or 700 series) in CS, ECE, ECES, ECET or SE

Sample Plan of Study

First Year (Part-Time)							
Fall	**Credits**	**Winter**	**Credits**	**Spring**	**Credits**	**Summer**	**Credits**
SYSE 685 or 688	3.0	SYSE 640	3.0	SYSE 532	3.0	Technical Elective*	3.0
	3		**3**		**3**		**3**
Total Credits 12							

*
Technical Elective must be a graduate level courses (500, 600, or 700 level) in CS, ECE, ECES, ECET or SE.

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