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The College of Engineering

About the College

The College of Engineering prepares a new generation of engineers dedicated to discovery and the application of technology to promote economic development and improve quality of life.

Drexel University’s College of Engineering is guided by five core values that shape the curriculum and experience for all students: excellence in academics and research; personal, intellectual and professional development; diversity; innovation and exploration; internal and external collaborations and partnerships. We provide a research agenda for our PhD students that addresses society’s most pressing challenges regionally, nationally and globally. Our Master of Science students are trained in strategic leadership and entrepreneurial risk-taking to address the opportunities and challenges of a rapidly changing industry.

The graduate programs at Drexel College of Engineering integrate evolving engineering science with the growing fields of engineering applications and processes. As Drexel moves though the 21st century, the College of Engineering will continue to offer students a diverse academic learning and research environment, while continuing to build on its national reputation for excellence in engineering and research.

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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. Employment typically lasts six months. It is important to note that the GCP program does not guarantee a job. It is a market-driven process for the candidates as well as employers. GCP provides the tools and contacts; the student must qualify for the job on the basis of merit, qualifications, and skills.

Further information on the GCP program is available at the Drexel Steinbright Career Development Center. (http://www.drexel.edu/scdc/)

Architectural Engineering

Major: Architectural Engineering

Degree Awarded: Master of Science in Architectural Engineering (MSAE) or Doctor of Philosophy (PhD)

Calendar Type: Quarter

Total Credit Hours: 45.0 (MSAE); 90.0 (PhD)

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 or PhD graduates may include students with expertise in one or more of the following sub-disciplines (usually housed in civil/environmental engineering and elsewhere in traditional disciplinary constructs or newly developing fields of focus or expertise):

- 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.

Admission Requirements

Applicants to the MS or PhD in Architectural Engineering must meet the following requirements:
• A BS in Engineering OR
• For students without an Engineering degree, the following courses, or their approved equivalents from other departments, will meet these requirements:
  • 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;
• 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.

Degree Requirements (MS)

The goal of the MS in Architectural Engineering (AE) is to produce graduates who have a solid understanding of the Architectural Engineering discipline as well as an understanding of the interrelationships between the major AE sub-disciplines. Graduates will have demonstrated the ability and capacity to apply that understanding and skill, and the curriculum and project requirements are designed to provide to the students and then ask them to demonstrate the ability to effectively engage in professional-level performance.

Required Courses

Core Courses for all AE students

- AE 510 Intelligent Buildings 3.0
- AE 550 Comfort Analysis and Indoor Air Quality 3.0
- AE 544 Building Envelope Systems 3.0
- AE 551 Building Energy Systems I 3.0
- MEM 591 Applied Engr Analy Methods I 3.0
- MEM 592 Applied Engr Analy Methods II 3.0

Building Energy Theme

Complete three of the following: 9.0

- AE 552 Building Energy Systems II
- CHE 513 Chemical Engineering Thermodynamics I
- CHE 525 Transport Phenomena I
- MEM 611 Conduction Heat Transfer
- MEM 612 Convection Heat Transfer
- MEM 621 Foundations of Fluid Mechanics

Indoor Air Quality (IAQ) Theme

Complete three of the following: 9.0

- AE T780 Special Topics in AE
- CHE 525 Transport Phenomena I
- ENVE 560 Fundamentals of Air Pollution Control
- ENVE 660 Chemical Kinetics in Environmental Engineering
- ENVS 501 Chemistry of the Environment
- MEM 621 Foundations of Fluid Mechanics

Additional Electives ** 9.0

Total Credits 45.0

Degree Requirements (PhD)

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

• 90.0 quarter credit hours total (or 45 credit hours post-MS)
• Plan of study established with Advisor
• Qualifying courses
• Candidacy exam
• Approval of dissertation proposal
• Defense of dissertation
• Full-time residency for one continuous academic year is usually desired for the PhD degree to ensure students the opportunity for intellectual association with other scholars.

Students entering with a master’s degree may be exempted from some or all of the courses in the breadth requirement; however, they are still required to meet all milestones of the program. Individual courses may also be transferred with approval of the Graduate Advisor. The total credit amount, candidacy exam, and dissertation are University Requirements. Additional requirements are determined by the department offering the degree.

MSAE coursework plus research and courses defined by the dissertation Committee 90.0

Qualifying Courses

To satisfy the qualifying requirements, students must earn a grade of B+ or better in the first 6 Architectural Engineering graduate courses taken at Drexel, and must earn an overall GPA of 3.5 or better in these courses. Normally these courses comprise at least 4 "core" courses and either 2 more courses, either "core" or in one of the Architectural Engineering themes taken as part of the PhD program; however, they may in some cases include more advanced courses (e.g., if the student has received transfer credit for a core course).

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

Candidacy Exam

After approximately one year of study beyond the master’s degree, doctoral students take a candidacy examination, consisting of written and oral parts. The Architectural Engineering candidacy examination serves to define the student’s research domain and to evaluate the student’s knowledge and understanding of various fundamental and seminal results in that domain. At this point the student is expected to be able to read, understand, analyze, and explain advanced technical results in a specialized area of Architectural Engineering at an adequate level of detail. The candidacy examination will evaluate those abilities using a defined set of published manuscripts. The student will prepare a written summary of the contents of the material, present the summary orally, and answer questions about the material. The examination committee will
evaluate the written summary, the oral presentation, and the student's answers.

**Thesis Proposal**

After completing the candidacy examination successfully, the PhD candidate must prepare a thesis proposal that outlines, in detail, the specific problems that will be solved in the PhD dissertation. The quality of the research proposal should be at the level of, for example, a peer-reviewed proposal to a federal funding agency, or a publishable scientific paper. The candidate is responsible for sending the research proposal to the PhD committee two weeks before the oral presentation. The PhD committee need not be the same as the candidacy exam committee, but it follows the same requirements and must be approved by the Office of Graduate Studies. The oral presentation involves a 30-40-minute presentation by the candidate followed by an unspecified period during which the committee will ask questions.

After the question and answer period, the candidate will be asked to leave the room and the committee will determine if the research proposal has been accepted. The research proposal can be repeated at most once. A thesis proposal must be approved within two years of becoming a PhD candidate.

After approval of the proposal, the committee meets from time to time to review the progress of the research.

**Thesis Defense**

After completing the research proposal successfully, the PhD candidate must conduct the necessary research and publish the results in a PhD dissertation. The dissertation must be submitted to the PhD committee two weeks prior to the oral defense and at least 90 days before the graduation date. The oral presentation involves a 45-minute presentation by the candidate, open to the public, followed by an unspecified period during which the committee will ask questions. The question and answer period is not open to the public.

After the question and answer period, the candidate will be asked to leave the room and the committee will determine if the candidate has passed or failed the examination. The candidate will be granted one more chance to pass the final defense if he or she fails it the first time. Paperwork selecting the thesis committee and indicating the results of the thesis defense must be filed with the Department of Civil, Architectural and Environmental Engineering and the Office of Graduate Studies.

The PhD degree is awarded for original research on a significant Architectural Engineering problem. Graduate students who have an MS degree or have completed work equivalent to that required for an MS degree will continue to work closely with individual faculty members to pursue the PhD degree (see Faculty Research Interests on the department website). PhD dissertation research is usually supported by a research grant from a government agency or an industrial contract.

Many doctoral students take three to five years of full-time graduate study to complete their degrees.

**Sample Plan of Study (MSAE)**

**Indoor Air Quality - Sample Plan of Study**

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits Winter</th>
<th>Credits Spring</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>Fall AE 544</td>
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<td>3.0</td>
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<tr>
<td>AE 550</td>
<td>3.0 AE 551</td>
<td>3.0 Free Electives</td>
<td>6.0</td>
</tr>
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<td>MEM 591</td>
<td>3.0 MEM 592</td>
<td>3.0 Free Electives</td>
<td>3.0</td>
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<td>MEM 621</td>
<td>3.0 ENVE 560</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Free Elective</td>
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<tr>
<td>Total Credits</td>
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**Second Year**

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<td>ENVS 501</td>
<td>3.0 CHE 525</td>
</tr>
<tr>
<td>MEM 621</td>
<td>3.0 ENVE 560</td>
</tr>
<tr>
<td>Free Elective</td>
<td>3.0 ENVE 660</td>
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</table>

**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

**Building Energy - Sample Plan of Study**

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<thead>
<tr>
<th>First Year</th>
<th>Credits Winter</th>
<th>Credits Spring</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>Fall AE 550</td>
<td>3.0 AE 510</td>
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<tr>
<td>MEM 591</td>
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<td>3.0 Free Electives</td>
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<tr>
<td>MEM 611</td>
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**Second Year**

<table>
<thead>
<tr>
<th>Credits Winter</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CHE 513</td>
<td>3.0 ENVE 727</td>
</tr>
<tr>
<td>MEM 621</td>
<td>3.0 AE 552</td>
</tr>
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</tbody>
</table>

**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
- MEM 345 - Heat Transfer
- ENGR 210 - Thermodynamics

**Plan of Study (PhD)**

Upon entering the PhD program, each student will be assigned an academic advisor, and with the help of the advisor will develop and file a plan of study (which can be brought up to date when necessary). The plan of study should be filed with the graduate coordinator no later than the end of the first term.

**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). Associate Professor. Non-destructive evaluation and structural health monitoring; dynamic identification, stress wave propagation modeling.

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

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

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

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

Yaghoob (Amir) Farnam, PhD (Purdue University). Assistant 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) L. D. Betz Chair Professor of Environmental Engineering and Department Head, Civil, Architectural and Environmental Engineering. Water treatment; risk assessment; bioterrorism; environmental modeling and statistics; microbiology; environmental health.

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

Simi Hoque, PhD (University of California - Berkeley). Associate 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). Assistant 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.

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

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

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

Nariman Mostafavi, PhD (University of Massachusetts - Amherst). Assistant Teaching Professor. Simulation tools for analyzing urban metabolism; environmentally responsive design; urban resilience; engineering economics; industrial ecology.

Joseph V. Mullin, PhD (Pennsylvania State University) Associate Department Head. Teaching Professor. Structural engineering; failure analysis; experimental stress analysis; construction materials; marine structures.

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). Assistant Professor. Laboratory testing of geomaterials; geotechnical aspects of natural hazards; soil-structure-interaction; geotechnical engineering.

Michael Ryan, PhD (Drexel University) Associate Department Head of Graduate Studies. Assistant 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 waste water 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.

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

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

Sabrina Spatari, PhD (University of Toronto). Associate Professor. Industrial ecology; development and application of life cycle assessment (LCA) and material flow analysis (MFA) methods for guiding engineering and policy decisions; specific interest in biomass and bioenergy, biofuels, and urban infrastructure.
Robert Swan Associate Teaching Professor. Geotechnical and Geosynthetic Engineering; soil/geosynthetic interaction and performance; laboratory and field geotechnical/geosynthetic testing.

Michael Waring, PhD (University of Texas-Austin) Associate Department Head for Undergraduate Programs; Director of Architectural Engineering Program. Associate Professor. Indoor air quality and building sustainability; indoor particulate matter fate and transport; indoor chemistry and particle formation; secondary impacts of control technologies and strategies.

Jin Wen, PhD (University of Iowa). Associate Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Net-zero Building; and Indoor Air Quality.

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

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

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


Chemical Engineering
Major: Chemical Engineering
Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)
Calendar Type: Quarter
Total Credit Hours: 45.0 (MS); 90.0 (PhD)
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 biological engineering, energy and the environment, multiscale modeling and process systems engineering, and polymer science and engineering.

Programs are arranged to meet the needs and interests of individual students. The plan of study is initially formulated in consultation with the departmental graduate advisor and subsequently guided by the thesis advisor.

A graduate co-op is available for the Master of Science program. For more information, visit the 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 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.

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

Degree Requirements (MS)
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; area of concentration, at least 15.0 credits; free electives, at most 6.0 credits; research, at most 21.0 credits. Core courses in the chemical engineering master's program are listed below. A master's thesis is optional.

Thesis option: The thesis may be based on either a theoretical or an experimental investigation or both of limited scope but involving a significant degree of originality. The nature of the research may involve multidisciplinary areas such as biological engineering, materials processing and engineering, energy and the environment, and other topics. The scope and content of the thesis is guided by the thesis advisor. All students pursuing a master's with thesis must complete 9.0
credits of thesis research (CHE 898) and, at the discretion of the research advisor, up to 12.0 credits of independent study (CHE 799).

**Coursework-only (non-thesis) option**: Students not pursuing master's with thesis may take up to 21.0 credits of independent study (CHE 799) 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 concentration electives. Concentration electives may be chosen from course offerings in chemical engineering, mathematics, science, and other engineering disciplines, and are subject to approval by the departmental graduate advisor. Sample concentration series courses are listed below; there are many other possibilities. 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 3.0
- For No-Thesis Option:
  - Technical Electives 6.0

**Free Electives** 6.0

**Total Credits** 45.0

* 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 1799) CHEM, CIVE, CMGT, CS, DSCI, ECE, ECEC, ECET, ECEE, EGES, EET, EGMT, ENSS, ENTP, ENVP, ENVSC, FDS, GEO, MATE, MEM, PRMT, PROJ, REAL, SYSE, PENG, MATH, PHYS, SE

### Degree Requirements (PhD)

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
- 18.0 core credits
- 15.0 credit hours of specialized plan of study
- 57.0 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 seven problems, each covering a separate core topic from the undergraduate curriculum, including thermodynamics, heat transfer, mass transfer, fluid mechanics, kinetics, control, and separations. Students must display mastery of five out of the seven topics to pass the qualifying exam. 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.

### Plan of Study

All students must meet with their research advisor in their second term to work out a plan of study.

### 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.

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)

**Computational resources:**

- Proteus, Drexel's high-performance cluster (www.drexel.edu/research/urcf/services/cluster (https://drexel.edu/research/resources/urcf/services/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 Plates
- 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 terahertz 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
- Electodeposition 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 spinoater, 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 crimer /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
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. Photonic 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). Associate Professor. Effects of microstructure on transport and properties of polymers; moisture transport and degradation on biodegradation on biodegradable polymers; production of biofuel.

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

Vibha Kalra, PhD (Cornell University). Associate Professor. Electrodes for energy storage and conversion; supercapacitors; Li-S batteries; fuel cells; flow batteries; electrospinning for nanofibers; molecular dynamics simulations; Nanotechnology, polymer nanocomposites.

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

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

Giuseppe R. Palmese, PhD (University of Delaware). George B Francis Professor. Reacting polymer systems; nanostructured polymers; radiation processing of materials; composites and interfaces.

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

Masoud Sorouch, 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). Assistant Professor. Batteries and fuel cells; nonaqueous electrochemistry; charge transport at interfaces.

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

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

Emeritus Faculty


Civil Engineering

Major: Civil Engineering

Degree Awarded: Master of Science in Civil Engineering (MSCE) or Doctor of Philosophy (PhD)

Calendar Type: Quarter

Total Credit Hours: 45.0 (MSCE); 90.0 (PhD)

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.

The goal of the Master’s program is to develop technical depth of expertise for a professional career in the planning, design, construction, and operation of large-scale infrastructure systems, built facilities, and water resources management. The goal of the PhD program is to develop the abilities to discover, pursue, and apply basic knowledge. PhD recipients are prepared to engage in teaching and research or in an industrial career in the development of new concepts and innovative systems.

General Information

The civil engineering programs comprise the following areas of specialization: building systems, geotechnical engineering, hydraulic and coastal engineering, structural engineering, and water resources.

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

Admission Requirements

MS admission is based on an academic record demonstrating adequate preparation and potential for successful graduate study. This typically includes a BS from an engineering curriculum accredited by the Accrediting Board for Engineering and Technology (ABET) or the equivalent from a non-U.S. institution. Submission of results from the Graduate Record Exam (GRE) is required. A grade point average (GPA) of 3.0 is usually required. Graduates who do not have a bachelor’s degree in either Civil, Architectural or Environmental Engineering may be required to take preparatory undergraduate courses.
For additional information on how to apply, visit Drexel’s Admissions page for Civil Engineering (http://www.drexel.edu/grad/programs/coe/civil-engineering/).

**Master of Science in Civil Engineering**

The programs of study at the master’s level continue the specialization developed at the senior level of the undergraduate program or newly developed interests. The Master of Science in Civil Engineering program may be elected by graduates of ABET-accredited undergraduate programs in civil engineering and related fields. Admission and prerequisites are determined on the basis of a student’s undergraduate transcript.

Most MSCE graduates work as professional engineers in consulting firms, industry, or governmental agencies. A number of our graduates have started consulting and construction firms in the Philadelphia area and have been very successful. Other former students hold prominent positions in public utilities, local government agencies, and industry.

The full-time graduate academic program is closely associated with the research efforts of the faculty. Full-time master’s degree candidates are encouraged to base their master’s thesis on some aspect of faculty research. The one-to-one relationship between student and faculty member provides an invaluable learning experience. The General (Aptitude) Test of the Graduate Record Examination (GRE) is required for applicants pursuing full-time study.

The master’s degree requires a total of 45.0 credits, of which 24.0 credits must be in the major field of interest and 6.0 credits are to fulfill math requirements. The remaining credits are taken as electives in related areas. The choice of core and elective courses is made in consultation with the student’s graduate advisor.

Areas of concentration include:

- Structural
- Geotechnical/geoenvironmental/geosynthetics
- Water resources
- Building systems/energy

**Degree Requirements**

**Geotechnical/Geosynthetic Engineering Requirements**

- **Required Cross-Cutting Courses**
  - CIVE 605 Advanced Mechanics Of Material 3.0
  - ENVE 555 Geographic Information Systems 3.0
  - or CIVE 615 Infrastructure Condition Evaluation 3.0
  - ENVE 571 Environmental Life Cycle Assessment 3.0
  - ENVE 750 Data-based Engineering Modeling 3.0
  - or ENVE 727 Risk Assessment 3.0
  - or ENVE 865 Benefit-Cost Analysis for Infrastructure 3.0

- **Required Theme Courses**
  - CIVE 632 Advanced Soil Mechanics 3.0
  - CIVE 635 Slope Stability and Landslides 3.0
  - or CIVE 638 Soil Behavior 3.0
  - CIVE 640 Environmental Geotechnics 3.0
  - or CIVE 650 Geosynthetics I 3.0
  - CIVE 730 Experimental Soil Mechanics I 3.0
  - or CIVE 731 Experimental Soil Mechanics II 3.0
  - or CIVE 651 Geosynthetics II 3.0

- **Technical Elective Courses**

  These courses must be approved by the student’s advisor and the graduate advisor. Select from any of the following that were not already counted for credit.

  - CIVE 530 Geotechnical Engineering for Highways
  - CIVE 531 Advanced Foundation Engineering
  - CIVE 542 Incorporating Sustainability Principles in Design
  - CIVE 562 Introduction to Groundwater Hydrology
  - CIVE 615 Infrastructure Condition Evaluation
  - CIVE 635 Slope Stability and Landslides
  - CIVE 636 Ground Modification
  - CIVE 640 Environmental Geotechnics
  - CIVE 650 Geosynthetics I
  - CIVE 651 Geosynthetics II
  - CIVE 730 Experimental Soil Mechanics I
  - CIVE 731 Experimental Soil Mechanics II
  - CIVE 833 Earth Retaining Structures
  - CIVE 838 Soil Behavior
  - ENVE 555 Geographic Information Systems
  - ENVE 727 Risk Assessment
  - ENVE 750 Data-based Engineering Modeling
  - MATH 520 Numerical Analysis I
  - MATH 521 Numerical Analysis II
  - MEM 591 Applied Engr Analy Methods I
  - 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
  - MEM 682 Finite Element Methods II

  **Electives or Thesis** 9.0

  Total Credits 45.0

  * Must achieve grade of B or better.
  ** For students writing an M.S. thesis, these nine credits should consist of six research credits (CIVE 997) and three thesis credits (CIVE 898). Full time Masters students are encouraged to do a thesis. Students opting not to do a thesis will be required to complete an additional 9.0 elective credits from the list above, therefore, the total elective credits required will be 21.

**Structural Engineering Requirements**

- **Required Cross-Cutting Courses**
  - CIVE 605 Advanced Mechanics Of Material 3.0
  - ENVE 555 Geographic Information Systems 3.0
  - or CIVE 615 Infrastructure Condition Evaluation 3.0
  - ENVE 571 Environmental Life Cycle Assessment 3.0
  - ENVE 750 Data-based Engineering Modeling 3.0
  - or ENVE 727 Risk Assessment 3.0
  - or ENVE 865 Benefit-Cost Analysis for Infrastructure 3.0

- **Required Theme Courses**
  - CIVE 701 Structural Analysis I 3.0
  - CIVE 702 Structural Analysis II 3.0
  - CIVE 703 Structural Analysis III 3.0
  - CIVE 801 Dynamics of Structures I 3.0

- **Technical Elective Courses** 12.0

  These courses must be approved by the student’s advisor and the graduate advisor. Select from any of the following that were not already counted for credit.

  - AE 510 Intelligent Buildings
  - AE 561 Airflow Simulation in Built Environment
  - CIVE 510 Prestressed Concrete
  - CIVE 520 Advanced Concrete Technology
  - CIVE 531 Advanced Foundation Engineering
Electives or Thesis ** 9.0

Total Credits 45.0

* Must achieve grade of B or better.

** For students writing an M.S. thesis, these nine credits should consist of six research credits (CIVE 997) and three thesis credits (CIVE 989). Full time Masters students are encouraged to do a thesis. Students opting not to do a thesis will be required to complete an additional 9.0 elective credits from the list above, therefore, the total elective credits required will be 21.

### PhD in Civil Engineering

The PhD degree is awarded for original research on a significant civil engineering problem. Graduate students who have completed their MS degrees work closely with individual faculty members (see Faculty Research Interests below). PhD dissertation research is usually supported by a research grant from a government agency or an industrial contract.

The full-time graduate academic program is closely associated with the research efforts of the faculty. The General (Aptitude) Test of the Graduate Record Examination (GRE) is required for applicants pursuing full-time study.

Doctoral students normally take at least 45.0 credits, including research credits, beyond the master’s degree requirements. Full-time residency for one continuous academic year is required for the PhD degree to ensure students the opportunity for intellectual association with other scholars. Many doctoral students take two, three, or four years of full-time graduate study to complete their degrees. Involvement in the teaching activity of the Civil, Architectural and Environmental Engineering Department is required of all PhD applicants.

After approximately one year of study beyond the master’s degree, doctoral students take a candidacy examination, consisting of written and oral parts. Each PhD candidate is supervised by a major professor and a doctoral committee chaired by the major professor.

PhD candidates submit a detailed proposal for dissertation research to the doctoral committee. The students then take a proposal examination; successful completion of this examination is required to become a PhD candidate. After approval of the proposal, the committee meets from time to time to review the progress of the research. The dissertation must be submitted to the doctoral committee at least 90 days before the graduation date. The committee schedules and conducts a final oral examination before approval of the dissertation.

Areas of research include:

- Structural
- Geotechnical/geoenvironmental/geosynthetics
- Water resources
- Sustainable engineering
- Building systems/energy
Sample Plan of Study

Geotechnical/Geosynthetic Engineering

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Dual Degree Programs

Civil Engineering students may find it useful to pursue dual MS degrees. Such programs have been pursued in concert with Environmental Engineering/Science, Mechanical Engineering, Information Studies and Engineering Management. A dual degree student must complete the required coursework for each degree. Depending upon the concentration, up to 15.0 credits from another program may count as electives for the MSCE with the advisor's approval. The student is responsible for obtaining approval of MSCE courses that apply to the second degree.

Bachelor's/Master's Dual Degree Program

Exceptional undergraduate students can also pursue a master of science degree in the same period as the bachelor of science. Many students deepen their knowledge with a Master's degree in Civil Engineering, while others have broadened their knowledge with a Master's degree in related areas such as Environmental Science, Engineering Management, Software Engineering and Information Technology.

For more information about this program, visit the Department's website (https://drexel.edu/engineering/academics/departments/civil-architectural-environmental-engineering/academic-programs/undergraduate/accelerated-and-dual-degree-programs/) web page.

Facilities

Construction Materials Laboratory
This laboratory contains facilities for the study of concrete, asphalt, mortar, soil-cement, and timber materials, and moist cure facilities.

Geosynthetics Laboratory
This laboratory contains a complete suite of physical, mechanical, hydraulic, endurance, and environmental test devices for assessing behavior of geotextiles, geogrids, geonets, geomembranes, and geocomposites.

HVAC and Refrigeration Laboratory
This laboratory contains complete models of heating, ventilation, air conditioning, refrigeration, and pumping system models.

Hydromechanics Laboratory
This laboratory contains a wave channel tilting flume, pipe friction equipment, bench demonstration equipment, and a beach erosion model.

Soil Mechanics and Geoenvironmental Laboratory
This laboratory contains triaxial and direct shear equipment, controlled environmental chambers, consolidation tests, flexwall permeameters, and a test bed.

Structural Testing Laboratory
This laboratory contains universal testing machines with 150,000- and 300,000-pound capacity and test beds with MTS dynamic load equipment.

Civil, Architectural and Environmental Engineering Faculty

Ableywa 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). Associate Professor. Non-destructive evaluation and structural health monitoring; dynamic identification, stress wave propagation modeling.

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

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

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

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

Yaghoob (Amir) Farnam, PhD (Purdue University). Assistant 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) L. D. Betz Chair Professor of Environmental Engineering and Department Head, Civil, Architectural and Environmental Engineering. Water treatment; risk assessment; bioterrorism; environmental modeling and statistics; microbiology; environmental health.

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

Simi Hoque, PhD (University of California - Berkeley). Associate 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). Assistant 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.

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

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

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

Nariman Mostafavi, PhD (University of Massachusetts - Amherst). Assistant Teaching Professor. Simulation tools for analyzing urban metabolism; environmentally responsive design; urban resilience; engineering economics; industrial ecology.

Joseph V. Mullin, PhD (Pennsylvania State University) Associate Department Head. Teaching Professor. Structural engineering; failure analysis; experimental stress analysis; construction materials; marine structures.

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). Assistant Professor. Laboratory testing of geomaterials; geotechnical aspects of natural hazards; soil-structure-interaction; geotechnical engineering.

Michael Ryan, PhD (Drexel University) Associate Department Head of Graduate Studies. Assistant 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 waste water 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.

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

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

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

Robert Swan Associate Teaching Professor. Geotechnical and Geosynthetic Engineering; soil/geosynthetic interaction and performance; laboratory and field geotechnical/geosynthetic testing.

Michael Waring, PhD (University of Texas-Austin) Associate Department Head for Undergraduate Programs; Director of Architectural Engineering Program. Associate Professor. Indoor air quality and building sustainability; indoor particulate matter fate and transport; indoor chemistry and particle formation; secondary impacts of control technologies and strategies.

Jin Wen, PhD (University of Iowa). Associate Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Net-zero Building; and Indoor Air Quality.

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

Emeritus Faculty

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

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


Computer Engineering

Major: Computer Engineering

Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)

Calendar Type: Quarter

Total Credit Hours: 45.0 (MS); 90.0 (PhD)

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).

Students within the Master of Science in Computer Engineering are eligible to take part in the Graduate Coop 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/).

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

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).

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

Degree Requirements (MS)

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.

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 (http://drexel.edu/ece/). For more information on the Co-op program visit the Office of Cooperative Education (http://coe.drexel.edu/) web site.

PhD in Electrical Engineering

General Requirements

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

- 90.0 credit hours total
- candidacy examination
- research proposal
- dissertation defense

Students entering with a master’s degree in electrical or computer engineering or a related field will be considered a post-masters PhD student and will only be required to complete a total of 45.0 credit hours, in accordance with University policy.

Curriculum

Appropriate coursework is chosen in consultation with the student’s research advisor. A plan of study must be developed by the student to encompass the total number of required credit hours. Both the departmental graduate advisor and the student’s research advisor must approve this plan.

Candidacy Examination

The candidacy examination explores the depth of understanding of the student in his/her specialty area. The student is expected to be familiar with, and be able to use, the contemporary tools and techniques of the field and to demonstrate familiarity with the principal results and key findings.

The student, in consultation with his/her research advisor, will declare a principal technical area for the examination. The examination includes the following three parts:

- A self-study of three papers from the archival literature in the student’s stated technical area, chosen by the committee in consultation with the student.
- A written report (15 pages or less) on the papers, describing their objectives, key questions and hypotheses, methodology, main results and conclusions. Moreover, the student must show in an appendix independent work he/she has done on at least one of the papers – such as providing a full derivation of a result or showing meaningful examples, simulations or applications.
- An oral examination which takes the following format:
  - A short description of the student’s principal area of interest (5 minutes, by student).
  - A review of the self-study papers and report appendix (25-30 minutes, by students).
  - Questions and answers on the report, the appendix and directly related background (40-100 minutes, student and committee).

In most cases, the work produced during the candidacy examination will be a principal reference for the student’s PhD dissertation; however, this is not a requirement.

Research Proposal

Each student, after having attained the status of PhD Candidate, must present a research proposal to a committee of faculty and industry members, chosen with his/her research advisor, who are knowledgeable in the specific area of research. This proposal should outline the specific intended subject of study; i.e., it should present a problem statement, pertinent background, methods of study to be employed, expected difficulties and uncertainties and the anticipated form, substance and significance of the results.

The purpose of this presentation is to verify suitability of the dissertation topic and the candidate’s approach, and to obtain the advice and guidance of oversight of mature, experienced investigators. It is not to be construed as an examination, though approval by the committee is required before extensive work is undertaken. The thesis proposal presentation must be open to all; announcements regarding the proposal presentation must be made in advance.

The thesis advisory committee will have the sole responsibility of making any recommendations regarding the research proposal. It is strongly recommended that the proposal presentation be given as soon as possible after the successful completion of the candidacy examination.
Dissertation Defense

Dissertation Defense procedures are described 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.

Dual Degree

The ECE Department offers outstanding students the opportunity to receive two diplomas (BS and MS) at the same time. The program requires five (5) years to complete. BSMS applicants, who represent some of the best undergraduates students in the department, can work with faculty members on research projects and also have the option to pursue MS Thesis. This program prepares individuals for careers in research and development; many of its past graduates continued their studies toward a PhD.

For more information on eligibility and academic requirements, visit the Engineering Combined BS/MS (http://drexel.edu/ece/academics/undergrad/bs-ms/) page.

Facilities

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

Research Laboratories at the ECE Department

Adaptive Signal Processing and Information Theory Research Group

The Adaptive Signal Processing and Information Theory Research Group 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:
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 integrated 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:
Drexel University - (GR) College of Engineering

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 electromagnetic 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 (University 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; fiber optic 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-scalar 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.


Construction Management

Major: Construction Management
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Total Credit Hours: 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.

Three concentrations are available: construction project management, real estate, and sustainability and green construction.

Program Goals

The program is designed to increase the students' breadth and depth of knowledge in the principles and practices of construction management. The program serves as an excellent platform to develop senior management for the nation's construction industry.

Graduates of the Master of Science in Construction Management program will:

• exhibit strong technical and managerial skills
• apply scientific methodologies to problem solving
• think critically
• exercise creativity and inject innovation into the process
• operate at the highest level of ethical practice
• employ principles of transformational leadership

Concentrations

Three concentrations are available:

Construction Project Management
This concentration provides the knowledge and skills required to successfully manage complex construction projects. Topics include 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**
In this concentration students explore the knowledge and skills required to create, maintain, and build environments for living, working and entertainment purposes. Relevant issues include project finance, real estate as investments, design and construction, operations, development law, environmental remediation, public policy, market analysis, and architecture.

**Sustainability and Green Construction**
Sustainable development means integrating the decision-making process across the project team, so that every decision is made with an eye to the greatest long-term benefits. Currently, in the Leadership in Energy and Environmental Design (LEED) green building rating system, the construction process represents a significant portion of the effort required to achieve high performance building programs. This concentration is intended to explore these concepts in detail.

For additional information, view the College of Engineering's Construction Management [web page](http://drexel.edu/engineering/academics/departments/construction-engineering-project-management-systems-engineering/) or the program academic adviser:

Ms. Jessica Cruz, jc635@drexel.edu, 215-895-5943

**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 [page](http://drexel.edu/grad/resources/international/) or the program academic adviser.

Visit the Graduate Admissions [web page](http://www.drexel.edu/grad/programs/coe/construction-management/) for more information about requirements and deadlines, as well as instructions for applying online.

**Degree Requirements**

The Master of Science in Construction Management curriculum includes a core of 5 required courses (15.0 credits), a concentration (24.0 credits), and 6.0 credits of culminating experience. The culminating experience includes a capstone project in construction management.

**Core Foundation Courses**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMGT 501</td>
<td>Leadership in Construction</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 505</td>
<td>Construction Accounting and Financial Management</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 510</td>
<td>Construction Control Techniques</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 512</td>
<td>Cost Estimating and Bidding Strategies</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 515</td>
<td>Risk Management in Construction</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Concentrations**

Students pursue a concentration in one of the following areas:

**Construction Management Project Management Concentration**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMGT 525</td>
<td>Applied Construction Project Management</td>
<td></td>
</tr>
<tr>
<td>CMGT 528</td>
<td>Construction Contract Administration</td>
<td></td>
</tr>
<tr>
<td>CMGT 530</td>
<td>Equipment Applications and Economy</td>
<td></td>
</tr>
<tr>
<td>CMGT 532</td>
<td>International Construction Practices</td>
<td></td>
</tr>
<tr>
<td>CMGT 538</td>
<td>Strategic Management in Construction</td>
<td></td>
</tr>
<tr>
<td>CMGT 540</td>
<td>Schedule Impact Analysis</td>
<td></td>
</tr>
<tr>
<td>CMGT 548</td>
<td>Quality Management and Construction Performance</td>
<td></td>
</tr>
<tr>
<td>CMGT 550</td>
<td>Productivity Analysis and Improvement</td>
<td></td>
</tr>
</tbody>
</table>

**Real Estate Concentration**

Select eight of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMGT 535</td>
<td>Community Impact Analysis</td>
<td></td>
</tr>
<tr>
<td>REAL 568</td>
<td>Real Estate Development</td>
<td></td>
</tr>
<tr>
<td>REAL 571</td>
<td>Advanced Real Estate Investment &amp; Analysis</td>
<td></td>
</tr>
<tr>
<td>REAL 572</td>
<td>Advanced Market Research &amp; Analysis</td>
<td></td>
</tr>
<tr>
<td>REAL 573</td>
<td>Sales &amp; Marketing of Real Estate</td>
<td></td>
</tr>
<tr>
<td>REAL 574</td>
<td>Real Estate Economics in Urban Markets</td>
<td></td>
</tr>
<tr>
<td>REAL 575</td>
<td>Real Estate Finance</td>
<td></td>
</tr>
<tr>
<td>REAL 576</td>
<td>Real Estate Valuation &amp; Analysis</td>
<td></td>
</tr>
<tr>
<td>REAL 577</td>
<td>Legal Issues in Real Estate Development</td>
<td></td>
</tr>
</tbody>
</table>

**Sustainability and Green Construction Concentration**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMGT 535</td>
<td>Community Impact Analysis</td>
<td></td>
</tr>
<tr>
<td>CMGT 545</td>
<td>Sustainable Principles &amp; Practices</td>
<td></td>
</tr>
<tr>
<td>CMGT 546</td>
<td>Sustainable Technologies</td>
<td></td>
</tr>
<tr>
<td>CMGT 547</td>
<td>LEED Concepts</td>
<td></td>
</tr>
<tr>
<td>CMGT 558</td>
<td>Community Sustainability</td>
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**Culminating Experience**

6.0

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMGT 696</td>
<td>Capstone Project in Construction Management I</td>
<td></td>
</tr>
<tr>
<td>CMGT 697</td>
<td>Capstone Project in Construction Management II</td>
<td></td>
</tr>
</tbody>
</table>

**Total Credits**

45.0

**Sample Plan of Study**

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits Winter</th>
<th>Credits Spring</th>
<th>Credits Summer</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMGT 501</td>
<td>3.0 CMGT 528</td>
<td>3.0 CMGT 510</td>
<td>3.0 CMGT 515</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 505</td>
<td>3.0 CMGT 538</td>
<td>3.0 CMGT 512</td>
<td>3.0 CMGT 540</td>
<td>3.0</td>
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</table>

6 6 6 3

<table>
<thead>
<tr>
<th>Second Year</th>
<th>Credits Winter</th>
<th>Credits Spring</th>
<th>Credits Summer</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMGT 525</td>
<td>3.0 CMGT 548</td>
<td>3.0 CMGT 530</td>
<td>3.0 CMGT 697</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 532</td>
<td>3.0 CMGT 550</td>
<td>3.0 CMGT 696</td>
<td></td>
<td>3.0</td>
</tr>
</tbody>
</table>

6 6 3

**Total Credits**

45
Construction Management Faculty

Jeffrey Beard, PhD (Georgia Institute of Technology). Associate Clinical Professor. Project and Program Management; Entrepreneurship in design and construction; Integrated project delivery systems; History of engineering and construction; Sustainable design and construction.

Douglas Carney, MBA, AIA (Eastern University). Clinical Professor. Architecture; Contract management; Master planning; Site analysis; Feasibility and zoning issues; Space needs and program development; Code analysis and compliance studies; project scheduling.

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). Assistant Teaching Professor. Workforce development and women in construction; transformative safety leadership; construction education.

Cybersecurity

Major: Cybersecurity
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Total Credit Hours: 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 & (http://www.drexel.edu/ece/) Computer Engineering Department 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 Coop Program. For more information relating to Graduate Coop, please see the Steinbright Career Development Center’s website (https://drexel.edu/scdc/co-op/graduate/).

Additional Information

For additional information about this program, please visit the ECE Department's Cybersecurity degree page (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/academic-programs/graduate/ms/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.

For additional information on how to apply, visit Drexel’s Admissions page for 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.

<table>
<thead>
<tr>
<th>Core Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFO 517</td>
<td>3.0</td>
</tr>
<tr>
<td>INFO 725</td>
<td>3.0</td>
</tr>
<tr>
<td>SE 578</td>
<td>3.0</td>
</tr>
<tr>
<td>Cybersecurity Track-Specific Technical Electives *</td>
<td>27.0</td>
</tr>
<tr>
<td>Cybersecurity Non-Track Technical Electives **</td>
<td>9.0</td>
</tr>
<tr>
<td><strong>Total Credits</strong></td>
<td><strong>45.0</strong></td>
</tr>
</tbody>
</table>

* 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 **

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>INFO 517</td>
<td>3.0</td>
<td>SE 578</td>
<td>3.0 INFO 725</td>
<td>3.0 VACATION</td>
</tr>
<tr>
<td>Track</td>
<td>3.0 Track</td>
<td>3.0 Electives</td>
<td>Track</td>
<td>6.0 Track</td>
<td>3.0</td>
</tr>
<tr>
<td>Elective</td>
<td>3.0 Non-Track Electives</td>
<td>3.0 Elective</td>
<td>3.0</td>
<td></td>
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</tr>
<tr>
<td>Fall</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
</tbody>
</table>

** 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/](https://drexel.edu/scdc/co-op/graduate/)) is available at the Drexel Steinbright Career Development Center. ([http://www.drexel.edu/scdc/](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/asptigroup/home.html](https://research.coe.drexel.edu/ece/asptigroup/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 SNIR 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 (https://tech.coe.drexel.edu/hosting/web/#inactive-site-policy) 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 integrated 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.

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Privacy, Security and Automation Lab

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RE Touch Lab

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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/mobie 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.

Constantine Katsinis, PhD (University of Rhode Island). Teaching Professor. High-performance computer networks, parallel computer architectures with sustained teraflops performance, computer security, image processing.

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, Tucson). 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
Major: Electrical Engineering
Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)
Calendar Type: Quarter
Total Credit Hours: 45.0 (MS) or 90.0 (PhD)
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/).

For more information about the MS or PhD in Electrical Engineering, please visit the Electrical and Computer Engineering (https://drexel.edu/engineering/academics/departments/electrical-computer-engineering/) Department (http://drexel.edu/ece/) web site.

Admission Requirements
Applicants must satisfy general requirements for graduate admission, including a minimum 3.0 GPA (on a 4.0 scale) for the last two years of undergraduate studies, as well as for any subsequent graduate work, and hold a bachelor's degree in electrical engineering, computer engineering, or the equivalent from an accredited college or university. A degree in science (physics, mathematics, computer science, etc.) is also acceptable. Applicants with degrees in sciences may be required to take a number of undergraduate engineering courses. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's.

Applicants for full-time MS and PhD programs must take the GRE general test. Students whose native language is not English and who do not hold a degree from a US institution must take the TOEFL within two years before application.

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

Degree Requirements (MS)
The Master of Science in Electrical Engineering curriculum encompasses 45.0 or 48.0 (with the Graduate Co-op option) approved credit hours, chosen in accordance with the following requirements and a plan of study arranged with the departmental graduate advisor in consultation with the student’s research advisor, if applicable. Before the end of the first quarter in the Department of Electrical and Computer Engineering, for a full-time student, or by the end of the first year for a part-time student, said plan of study must be filed and approved with the departmental graduate advisor.

A total of at least 30.0 credit hours must be taken from among the graduate course offerings of the Department of Electrical and Computer Engineering. These credits must be taken at Drexel University. No transfer credit may be used to fulfill these requirements, regardless of content equivalency.

The remaining courses needed to reach the minimum credit hour requirement for the degree program are considered elective courses. Elective courses can be chosen from among the graduate course offerings of the Department of Electrical and Computer Engineering; other departments within the College of Engineering; the School of Biomedical Science, Engineering and Health Systems; the Department of Mathematics; the Department of Physics; the Department of Chemistry and the Department of Biology. In order to have courses outside of these departments and schools count towards degree completion, they must be approved by the departmental graduate advisors prior to registration for said courses.

Please note that ECEC 500 Fundamentals of Computer Hardware and ECEC 600 Fundamentals of Computer Networks do not count toward the credit requirements to complete the MS in Electrical Engineering degree program.

Required Courses
Electrical Engineering (ECEE, ECEP, ECES, ECET) Courses

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>14.1001</td>
<td>Electrical Engineering</td>
<td>17.0</td>
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(continued)
Options for Degree Fulfillment
Although not required, students are encouraged to complete a Master’s Thesis as part of the MS studies. Those students who choose the thesis option may count up to 9.0 research/thesis credits as part of their required credit hour requirements.

Students may choose to participate in the Graduate Co-op Program, where 6.0 credit hours can be earned for a six month cooperative education experience in industry, working on curriculum related projects. The total number of required credit hours is increased to 48.0 for those students who choose to pursue the Graduate Co-op option. This change represents an increase in non-departmental required credit hours to a total of 18.0 credit hours, 6.0 of which are earned from the cooperative education experience.

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

PhD in Electrical Engineering
General Requirements
The following general requirements must be satisfied in order to complete the PhD in Electrical Engineering:

- 90.0 credit hours total
- candidacy examination
- research proposal
- dissertation defense

Students entering with a master’s degree in electrical or computer engineering or a related field will be considered a post-masters PhD student and will only be required to complete a total of 45.0 credit hours, in accordance with University policy.

Curriculum
Appropriate coursework is chosen in consultation with the student’s research advisor. A plan of study must be developed by the student to encompass the total number of required credit hours. Both the departmental graduate advisor and the student’s research advisor must approve this plan.

Candidacy Examination
The candidacy examination explores the depth of understanding of the student in his/her specialty area. The student is expected to be familiar with, and be able to use, the contemporary tools and techniques of the field and to demonstrate familiarity with the principal results and key findings.

The student, in consultation with his/her research advisor, will declare a principal technical area for the examination. The examination includes the following three parts:

- A self-study of three papers from the archival literature in the student’s stated technical area, chosen by the committee in consultation with the student.
- 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.

Dual Degree
The Department of Electrical and Computer Engineering offers outstanding students the opportunity to receive two diplomas (BS and MS) at the same time. The program requires five (5) years to complete. Participants, who are chosen from the best undergraduates students, work with a faculty member on a research project and follow a study plan that includes selected graduate classes. This program prepares individuals for careers in research and development; many of its past graduates continued their studies toward a PhD.
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-Schwarz, 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.

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**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 *(Universtit 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 ultrasounds; 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.


Electrical Engineering/
Telecommunications Engineering

Major: Electrical/Telecommunications Engineering
Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)
Calendar Type: Quarter
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Co-op Option: Available for full-time on-campus master's-level students
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Standard Occupational Classification (SOC) code: 15-1143; 17-2071

About the Program

Drexel University's Electrical and Computer Engineering Department prepares students to contribute to advances in the rapidly changing field of telecommunications by providing advanced studies as part of the Master of Science (MS) in Electrical and Telecommunications Engineering degree program. The MS in Electrical and Telecommunications Engineering combines the expertise of its faculty in electrical and computer engineering, business, information systems, and humanities. Through its interdisciplinary approach, Drexel's Telecommunications Engineering program trains and nurtures the complete telecommunications engineer.

The MS in Electrical Engineering/Telecommunications Engineering degree is awarded to students who demonstrate in-depth knowledge of the field. The average time required to complete the master's degree is two years of full-time study or three years of part-time study.
Admission Requirements

Applicants must meet the general requirements for graduate admission, which include at least a 3.0 GPA for the last two years of undergraduate study and for any graduate level study undertaken, and are required to hold a bachelor of science degree in electrical engineering or a related field. Applicants whose undergraduate degrees are not in the field of electrical engineering may be required to take a number of undergraduate courses. The GRE General Test is required of applicants for full-time MS and PhD programs. Applicants whose native language is not English and who do not have a previous degree from a US institution are required to take the Test of English as a Foreign Language (TOEFL).

For additional information on how to apply, visit Drexel’s Admissions page for Electrical-Telecommunications Engineering (http://www.drexel.edu/grad/programs/coe/electrical-telecommunications/).

MS in Electrical and Telecommunications Engineering

The Master of Science in Electrical and Telecommunications Engineering curriculum encompasses 45.0 or 48.0 (with the Graduate Co-Op) approved credit hours, chosen in accordance with the following requirements and a plan of study arranged with the departmental graduate advisor in consultation with the student’s research advisor (if applicable). This plan of study must be filed in the Department of Electrical and Computer Engineering and approved with the departmental graduate advisor before the end of the first quarter for a full-time student, or by the end of the first year for a part-time student.

Degree Requirements

A total of at least 30.0 credit hours must be taken from among the graduate course offerings of the Department of Electrical and Computer Engineering. These credits must be taken at Drexel University. No transfer credit may be used to fulfill these requirements, regardless of content equivalency.

- Telecommunications Engineering (ECET) Courses: 6.0
- Telecommunications Engineering Elective (ECEC, ECEE, ECES, ECET) Courses: 15.0
- General Electrical and Computer Engineering (ECEC, ECEE, ECEP, ECES, ECET) Courses: 9.0
- Elective Courses: 15.0
- Total Credits: 45.0

With the remaining required 15.0 credit hours, students may take graduate coursework, subject to the approval of the departmental graduate advisor, in electrical and computer engineering, mathematics, physics or other engineering disciplines.

In addition, students pursuing an MS in Electrical and Telecommunications Engineering are allowed and strongly encouraged to take the following course as part of their required 15.0 credit hours:

- COM 650 Telecommunications Policy in the Information Age

Although not required, students are encouraged to complete a master’s thesis as part of the MS studies. Those students who choose the thesis option may count up to 9.0 research/thesis credits as part of their required credit hour requirements.

Graduate Co-op Program

Students may choose to participate in the Graduate Co-op Program, where 6.0 credit hours can be earned for a six month cooperative education experience in industry, working on curriculum related projects. The total number of required credit hours is increased to 48.0 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.

Please note that ECEC 500 Fundamentals of Computer Hardware and ECEC 600 Fundamentals of Computer Networks do not count toward the credit requirements to complete the MS in Electrical Engineering degree program.

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

PhD in Electrical Engineering

General Requirements

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

- 90.0 credit hours total
- candidacy examination
- research proposal
- dissertation defense

Students entering with a master’s degree in electrical or computer engineering or a related field will be considered a post-masters PhD student and will only be required to complete a total of 45.0 credit hours, in accordance with University policy.

Curriculum

Appropriate coursework is chosen in consultation with the student’s research advisor. A plan of study must be developed by the student to encompass the total number of required credit hours. Both the departmental graduate advisor and the student’s research advisor must approve this plan.

Candidacy Examination

The candidacy examination explores the depth of understanding of the student in his/her specialty area. The student is expected to be familiar with, and be able to use, the contemporary tools and techniques of the field to demonstrate familiarity with the principal results and key findings.

The student, in consultation with his/her research advisor, will declare a principal technical area for the examination. The examination includes the following three parts:

- A self-study of three papers from the archival literature in the student’s stated technical area, chosen by the committee in consultation with the student.
• A written report (15 pages or less) on the papers, describing their objectives, key questions and hypotheses, methodology, main results and conclusions. Moreover, the student must show in an appendix independent work he/she has done on at least one of the papers – such as providing a full derivation of a result or showing meaningful examples, simulations or applications.
• An oral examination which takes the following format:
  • A short description of the student’s principal area of interest (5 minutes, by student).
  • A review of the self-study papers and report appendix (25-30 minutes, by student).
  • Questions and answers on the report, the appendix and directly related background (40-100 minutes, student and committee).
In most cases, the work produced during the candidacy examination will be a principal reference for the student’s PhD dissertation; however, this is not a requirement.

Research Proposal
After having attained the status of PhD Candidate, each student must present a research proposal to a committee of faculty and industry members, chosen with his/her research advisor, who are knowledgeable in the specific area of research. This proposal should outline the specific intended subject of study, i.e., it should present a problem statement, pertinent background, methods of study to be employed, expected difficulties and uncertainties and the anticipated form, substance and significance of the results.

The purpose of this presentation is to verify suitability of the dissertation topic and the candidate’s approach, and to obtain the advice and guidance of oversight of mature, experienced investigators. It is not to be construed as an examination, though approval by the committee is required before extensive work is undertaken. The thesis proposal presentation must be open to all; announcements regarding the proposal presentation must be made in advance.

The thesis advisory committee will have the sole responsibility of making any recommendations regarding the research proposal. It is strongly recommended that the proposal presentation be given as soon as possible after the successful completion of the candidacy examination. The student must be a PhD candidate for at least one year before he/she can defend his/her doctoral thesis.

Dissertation Defense
Dissertation Defense procedures are described in the 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.

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

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

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

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

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

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

Drexel University Nuclear Engineering Education Laboratory

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

Drexel VLSI Laboratory

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

Drexel Wireless Systems Laboratory

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

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

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

DWSL personnel also collaborate to create wearable, fabric based transceivers through collaboration with the Shima Seiki Haute Laboratory in the Drexel ExCITE Center. The knitting equipment at Drexel includes sixteen SDS-ONE APEX3 workstations and four state-of-the-art knitting machines. The workstations accurately simulate fabric construction and provide researchers and designers the opportunity to program, create and simulate textile prototypes, import CAD specifications of final products, and produce made-to-measure or mass-produced pieces on Shima Seiki knitting machines. For testing smart textiles for biomedical, DWSL personnel also have collaborators in the Center for Interdisciplinary Cloning, and controlling other organisms.

Ecological and Evolutionary Signal-processing and Informatics Laboratory

The Ecological and Evolutionary Signal-processing and Informatics Laboratory (EEIS) seeks to solve problems in high-throughput genomics and engineering 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 organization 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 integrated 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 SGB/s; optical spectrum analyzer from Anritsu and power meters from HP; single and multimode fiber optic based optical transmitter and receiver boards covering ITU channels at data rates up to 10Gb/s; passive optical components such as isolator, filter, couplers, optical connectors and fusion splicer; LPKF milling machine for fabrication of printed circuit boards; wire-bonding and Cascade probe stations; Intercontinental test fixtures for testing of MMIC circuits and solid-state transistors; state-of-the-art microwave and
electromagnetic CAD packages such as Agilent ADS, ANSYS HFSS, and COMSOL multi-physics module.

Music and Entertainment Technology Laboratory

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

NanoPhotonics+ Lab

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; 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 (University of Singapore). Assistant Professor. Design of
algorithms for neuromorphic computing, particularly using spiking neural
networks, datalow-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,
ariches 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
Total Credit Hours: 48.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0101
Standard Classification of Instructional Programs (SOC) code: 17.2199

About the Program

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.

Degree Requirements

The degree requires a total of 48.0 credits, including at least 18.0 credits from an engineering discipline core. This core may be from any engineering department: Civil and Architectural, Chemical, Electrical and Computer, Materials, or Mechanical Engineering and Mechanics. (Please refer to the appropriate departmental description in this catalog for more information about each department.) The department Advisor will work closely with the student to develop an plan of study that meets the program requirements.

Engineering Management

Major: Engineering Management
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Total Credit Hours: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 15.1501
Standard Classification of Instructional Programs (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.

The Engineering Management Program (http://www.drexel.edu/egmt/) is designed to provide the background in management science necessary to advance from purely technical positions to supervisory responsibilities in such areas as research and development, production, engineering, design, and technical marketing. Study can be on a part-time or full-time basis, and courses are available both online and face to face.

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 Opportunity

The Engineering Management Program offers a five-course Graduate Certificate in Engineering Management (p. 59).

Students can pursue the Graduate Certificate in Engineering Management, earn the credential, and subsequently apply those credits toward completion of a master’s in engineering management. However, current students in pursuit of the master’s in engineering management may not simultaneously pursue the graduate certificate.

Non-engineering management graduate students in the College of Engineering are welcome to apply for the certificate with Advisor approval, and they can do so while simultaneously 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.

**Degree Requirements**

The master's in engineering management degree requires 45.0 credits: 30.0 credits in required core courses and 15.0 graduate elective credits.

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.*

<table>
<thead>
<tr>
<th>Engineering Management</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EGMT 501 Leading and Managing Technical Workers</td>
<td>3.0</td>
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<tr>
<td>EGMT 502 Analysis and Decision Methods for Technical Managers</td>
<td>3.0</td>
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<tr>
<td>EGMT 504 Design Thinking for Engineering Communications</td>
<td>3.0</td>
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<tr>
<td>EGMT 581 Meeting Engineering Leadership Challenges</td>
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<table>
<thead>
<tr>
<th>Quantitative Analysis</th>
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<tbody>
<tr>
<td>EGMT 571 Engineering Statistics</td>
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<tr>
<td>EGMT 572 Statistical Data Analysis</td>
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<tr>
<td>EGMT 573 Operations Research</td>
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<thead>
<tr>
<th>Economics and Financial Management</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EGMT 531 Engineering Economic Evaluation &amp; Analysis</td>
<td>3.0</td>
</tr>
<tr>
<td>EGMT 535 Financial Management</td>
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<table>
<thead>
<tr>
<th>Engineering Management Capstone</th>
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<tbody>
<tr>
<td>EGMT 692 Engineering Management Capstone</td>
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<thead>
<tr>
<th>Electives</th>
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<td>Select five of the following electives:</td>
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<tr>
<td>EGMT 536 Advanced Financial Management for Engineers</td>
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<tr>
<td>EGMT 650 Systems Thinking for Leaders</td>
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<table>
<thead>
<tr>
<th>Marketing &amp; Business Development</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EGMT 614 Marketing: Identifying Customer Needs</td>
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<table>
<thead>
<tr>
<th>Systems Engineering &amp; Systems Thinking</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EGMT 635 Visual System Mapping</td>
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<tr>
<td>SYSE 685 Systems Engineering Management</td>
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<tr>
<td>SYSE 688 Systems Engineering Analysis</td>
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<tr>
<td>SYSE 690 Modeling and Simulation</td>
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<thead>
<tr>
<th>Engineering Law &amp; Ethics</th>
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<tr>
<td>EGMT 610 Ethics &amp; Business Practices for Engineers</td>
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<tr>
<td>EGMT 652 Engineering Law</td>
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<th>Other Approved Electives</th>
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<tr>
<td>SYSE 510 Systems Engineering Process</td>
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<tr>
<td>SYSE 511 Systems Engineering Tools</td>
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</tr>
<tr>
<td>SYSE 520 Global Sustainment and Integrated Logistics</td>
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<tr>
<td>SYSE 521 Integrated Risk Management</td>
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</tr>
<tr>
<td>SYSE 522 Engineering Supply Chain Systems</td>
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<tr>
<td>SYSE 523 Systems Reliability Engineering</td>
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</tr>
<tr>
<td>SYSE 524 Systems Reliability, Availability &amp; Maintainability Analysis</td>
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<tr>
<td>SYSE 525 Statistical Modeling &amp; Experimental Design</td>
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<tr>
<td>SYSE 530 Systems Engineering Design</td>
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<td>SYSE 531 Systems Architecture Development</td>
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<tr>
<td>SYSE 532 Software Systems Engineering</td>
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<tr>
<td>SYSE 533 Systems Integration and Test</td>
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</table>

**Total Credits 45.0**

*EGMT 572 Statistical Data Analysis requires as a prerequisite EGMT 571 Managerial Statistics or approval from the program administration to complete a waiver and request to take then pass the STAT Placement Exam in place of EGMT 571. If approved for the waiver of EGMT 571, students will be eligible to complete an upper level course substitution to satisfy the degree requirements.**

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

**Sample Plan of Study**

**First Year**

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Credits Winter</th>
<th>Credits Spring</th>
<th>Credits Summer</th>
<th>Credits</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>EGMT 501</td>
<td>EGMT 502</td>
<td>EGMT 572</td>
<td>EGMT 573</td>
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<tr>
<td></td>
<td></td>
<td>EGMT 504</td>
<td>EGMT 571</td>
<td>EGMT 531</td>
<td>EGMT 535</td>
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**Second Year**

<table>
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<th>Credits Spring</th>
<th>Credits Summer</th>
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<tr>
<td></td>
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<td>EGMT 652</td>
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**Total Credits 45**

**First Year**

<table>
<thead>
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<th>Credits Winter</th>
<th>Credits Spring</th>
<th>Credits Summer</th>
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<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>EGMT 504</td>
<td>EGMT 571</td>
<td>EGMT 572</td>
<td>EGMT 573</td>
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Second Year

<table>
<thead>
<tr>
<th>Fall</th>
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<tbody>
<tr>
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<td>EGMT 692</td>
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</tr>
<tr>
<td>Elective</td>
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</tr>
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</table>

Total Credits 45

Engineering Management Faculty

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

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

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, DEng (Southern Methodist University). Teaching Professor. Pharmaceutical, Bio-pharmaceutical, and Medical Device development and manufacturing

Engineering Technology

Major: Engineering Technology
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Total Credit Hours: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 15.0000
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.

The Master of Science in Engineering Technology offers courses focused on the technologies used in today's modern emerging industries. The program is designed for individuals who want marketable, applicable skills and currently hold an accredited baccalaureate degree in engineering technology or have relevant work or class experience in science, technology, engineering, or mathematics (STEM) fields. The primary goal of the Master of Science in Engineering Technology is to develop advanced-level practitioners who are capable in resolving technical problems through the application of engineering principles and technology.

The program can be pursued on a part-time or full-time basis. Courses will be delivered in several modes—face-to-face and/or online—and will allow practicing professionals the opportunity to update knowledge and skills based on the latest technological developments in the industrial environment and, therefore, advance in their chosen careers. The flexibility of the program curriculum permits students to select a combination of courses relevant to their individual career goals or to provide the foundation for further advanced study.

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 (https://drexel.edu/engineering/academics/departments/engineering-technology/) webpage 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:
Environmental Engineering

- 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

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

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGMT 571</td>
<td>Engineering Statistics</td>
<td>3.0</td>
</tr>
<tr>
<td>EGMT 610</td>
<td>Ethics &amp; Business Practices for Engineers</td>
<td>3.0</td>
</tr>
<tr>
<td>ET 610</td>
<td>Networks for Industrial Environments</td>
<td>3.0</td>
</tr>
<tr>
<td>ET 615</td>
<td>Rapid Prototyping and Product Design</td>
<td>3.0</td>
</tr>
<tr>
<td>ET 619</td>
<td>Programmable Devices and Systems</td>
<td>3.0</td>
</tr>
<tr>
<td>ET 620</td>
<td>Microsystems and Microlabication</td>
<td>3.0</td>
</tr>
<tr>
<td>ET 681</td>
<td>Nanomaterials and Nanoengineering</td>
<td>3.0</td>
</tr>
<tr>
<td>ET 725</td>
<td>Sensors and Measurement Systems</td>
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<tr>
<td>ET 732</td>
<td>Modern Energy Conversion Technologies</td>
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</table>

Electives 9.0

Select three of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>EGMT 572</td>
<td>Statistical Data Analysis</td>
</tr>
<tr>
<td>ET 605</td>
<td>Materials for Emerging Technologies</td>
</tr>
<tr>
<td>ET 635</td>
<td>Engineering Quality Methods</td>
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<tr>
<td>ET 675</td>
<td>Reliability Engineering</td>
</tr>
<tr>
<td>ET 685</td>
<td>Precision Manufacturing</td>
</tr>
<tr>
<td>ET 730</td>
<td>Lean Manufacturing Principles</td>
</tr>
<tr>
<td>ET 733</td>
<td>Renewable Energy Technology</td>
</tr>
<tr>
<td>ET 755</td>
<td>Sustainable and Green Manufacturing</td>
</tr>
<tr>
<td>PROJ 501</td>
<td>Introduction to Project Management</td>
</tr>
<tr>
<td>SYSE 685</td>
<td>Systems Engineering Management</td>
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</tbody>
</table>

Capstone Course 9.0

- ET 775 Master's Project and Thesis in Engineering Technology

Total Credits 45.0

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

Engineering Technology Faculty


Richard Chiou, PhD (Georgia Institute of Technology). Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Yalcin Ertekin, PhD (University of Missouri-Rolla). Associate Clinical Professor. High speed machining with micromachining applications, machining process optimization and condition monitoring using multiple sensors, FEA simulation with 3D solid modeling applications, rapid prototyping and reverse engineering, quality and reliability improvement through statistically designed experiments, neural networks and data mining and Taguchi methods, CNC machine tool calibration characterization of cold fastening, clinching and self-pierced riveting processes, non-invasive surgical tool design, student learning enhancement using online simulation tools.

Vladimir Genis, PhD (Kiev State University, Ukraine) Department Head, Engineering Technology, Professor. Ultrasonic wave propagation and scattering, ultrasound imaging, electronic instrumentation, piezoelectric transducers, and engineering education. Designed and developed diagnostic and therapeutic equipment for medical applications and electronic systems and techniques for defense-related and industrial applications.

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

Lunal Khuon, PhD (Massachusetts Institute of Technology). Clinical Associate Professor. Radio frequency, analog, and biomedical integrated circuits, biomedical instrumentation, neural interfaces, wireless systems, and engineering education. Research topics include area-efficient and power-efficient integrated circuits, plasmonics, adiabatic circuits, rotary clocks, and medical cyber-physical systems.

Michael Mauk, PhD, PE (University of Delaware). Assistant Clinical Professor. Rapid prototyping, microfluidics, alternative energy including solar energy and photovoltaics, semiconductor materials science, nanotechnology.

Environmental Engineering

Major: Environmental Engineering

Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)

Calendar Type: Quarter

Total Credit Hours: 45.0 (MS); 90.0 (PhD)

Co-op Option: None

Classification of Instructional Programs (CIP) code: 14.1401

Standard Occupational Classification (SOC) code: 17-2081

About the Program

Programs in environmental engineering are available with specializations in air pollution, hazardous and solid waste, subsurface contaminant hydrology, water resources, water and wastewater, and sustainability treatment.

Environmental engineering is concerned with protecting human, animal, and plant populations from the effects of adverse environmental factors, including toxic chemicals and wastes, pathogenic bacteria, and global warming.

Environmental engineers also try to minimize the effect of human activities on the physical and living environment so that we can all live more healthy
and sustainable lives. This field builds on other branches of engineering, especially civil, chemical, and mechanical engineering. It also builds on information from many of the sciences, such as chemistry, physics, hydrology, geology, atmospheric science, and several specializations of biology (ecology, microbiology) and public health. Students who elect to study environmental engineering will become familiar with many of these areas because maintaining and improving the environment requires that problems be evaluated and solutions found using a multidisciplinary approach.

For more information about this program, visit the MS in Environmental Engineering (http://www.drexel.edu/grad/programs/coe/environmental-engineering/).

**Admission Requirements**

In addition to the general entrance requirements for all environmental engineering applicants, entrance to the MS in Environmental Engineering program requires an undergraduate engineering degree from an ABET-approved institution. Students lacking this credential will be required to complete additional undergraduate courses to incorporate related elements of the functional equivalent of the ABET engineering BS degree. Typically, courses must be taken in computer programming, differential equations, linear algebra and fluid mechanics.

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

**Degree Requirements (MS)**

The MS in Environmental Engineering program requires 45.0 credits of coursework. Both a thesis and a non-thesis option are available. It is possible to finish the MS degree on either a part-time or full-time 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 credits)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ENVE 660</td>
<td>Chemical Kinetics in Environmental Engineering</td>
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</tr>
<tr>
<td>ENVS 501</td>
<td>Chemistry of the Environment</td>
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<tr>
<td>Approved Statistics course (as above)</td>
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<tr>
<td>BIO 640</td>
<td>Biometry</td>
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<tr>
<td>BMES 510</td>
<td>Biomedical Statistics</td>
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<tr>
<td>ENVE 750</td>
<td>Data-based Engineering Modeling</td>
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<tr>
<td>ENVS 506</td>
<td>Biostatistics</td>
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<tr>
<td>Approved Policy course (as above)</td>
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<tr>
<td>CIVE 564</td>
<td>Sustainable Water Resource Engineering</td>
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<tr>
<td>ECON 616</td>
<td>Public Finance and Cost Benefit Analysis</td>
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<tr>
<td>EOH 560</td>
<td>Overview of Issues in Global Health</td>
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<tr>
<td>PLCY 503</td>
<td>Theory and Practice of Policy Analysis</td>
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<tr>
<td>PLCY 504</td>
<td>Methods of Policy Analysis</td>
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<tr>
<td>Approved Life Sciences course (as above)</td>
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<tr>
<td>ENVE 516</td>
<td>Fundamentals of Environmental Biotechnology</td>
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<td>ENVS 511</td>
<td>Evolutionary Ecology</td>
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**Specialization Courses (9-12 credits) - select one are to complete**

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<thead>
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<tr>
<td>ENVE 546</td>
<td>Solid Waste Systems</td>
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<tr>
<td>ENVE 661</td>
<td>Envr Engr Op-Chem &amp; Phys</td>
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<tr>
<td>ENVE 662</td>
<td>Envr Engr Unit Oper-Bio</td>
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<tr>
<td>ENVE 665</td>
<td>Hazardous Waste &amp; Groundwater Treatment</td>
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**Human Risks**

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<tbody>
<tr>
<td>AE 550</td>
<td>Comfort Analysis and Indoor Air Quality</td>
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<tr>
<td>ENVE 727</td>
<td>Risk Assessment</td>
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<tr>
<td>EOH 510</td>
<td>Principles and Practice of Environmental and Occupational Health</td>
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<td>EOH 612</td>
<td>Environmental Exposure Science</td>
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**Water Resources**

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<tr>
<td>CIVE 564</td>
<td>Sustainable Water Resource Engineering</td>
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<tr>
<td>CIVE 565</td>
<td>Urban Hydraulics</td>
<td></td>
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<tr>
<td>CIVE 664</td>
<td>Open Channel Hydraulics</td>
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<tr>
<td>ENVE 571</td>
<td>Environmental Life Cycle Assessment</td>
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</tr>
<tr>
<td>ENVE 681</td>
<td>Analytical and Numerical Techniques in Hydrology</td>
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**Environmental Modeling**

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<td>ENVE 551</td>
<td>Geographic Information Systems</td>
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<tr>
<td>ENVE 571</td>
<td>Environmental Life Cycle Assessment</td>
<td></td>
</tr>
<tr>
<td>ENVE 681</td>
<td>Analytical and Numerical Techniques in Hydrology</td>
<td></td>
</tr>
<tr>
<td>ENVE 750</td>
<td>Data-based Engineering Modeling</td>
<td></td>
</tr>
<tr>
<td>Approved Advanced Math course:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEM 591</td>
<td>Applied Engr Analy Methods I</td>
<td></td>
</tr>
<tr>
<td>or CHE 502</td>
<td>Mathematical Methods in Chemical Engineering</td>
<td></td>
</tr>
<tr>
<td>or MATE 535</td>
<td>Numerical Engineering Methods</td>
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</table>

**Air Quality**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
</tr>
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<tbody>
<tr>
<td>AE 550</td>
<td>Comfort Analysis and Indoor Air Quality</td>
<td></td>
</tr>
<tr>
<td>EOH 510</td>
<td>Principles and Practice of Environmental and Occupational Health</td>
<td></td>
</tr>
<tr>
<td>ENVE 560</td>
<td>Fundamentals of Air Pollution Control</td>
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</table>

**Cognate Discipline Track (12 credits)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
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<tbody>
<tr>
<td>Statistics course</td>
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<tr>
<td>Statistics course</td>
<td>3.0 Life Science course</td>
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**Electives or Thesis (6 - 9 credits) (45 credits total for degree)**

<table>
<thead>
<tr>
<th>Credits</th>
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<tbody>
<tr>
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</table>

**Total Credits**

<table>
<thead>
<tr>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>42.0-48.0</td>
</tr>
</tbody>
</table>

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

** Students must complete a course sequence aside from their specialization. This might include a second specialization or a sequence within engineering, an applicable science, public health, or other as approved by the graduate advisor.

*** One of these is required.

**Sample Plan of Study (MS)**

**First Year**

**Fall**

<table>
<thead>
<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>ENVS 501</td>
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<table>
<thead>
<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>ENVE 660</td>
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<tr>
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<tr>
<td>ENVE 662</td>
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<tr>
<td>ENVE 665</td>
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<tr>
<td>ENVE 546</td>
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<tr>
<td>ENVE 661</td>
<td>3.0</td>
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<tr>
<td>ENVE 662</td>
<td>3.0</td>
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<tr>
<td>ENVE 665</td>
<td>3.0</td>
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<tr>
<td>ENVE 546</td>
<td>3.0</td>
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<td>3.0</td>
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<td>3.0</td>
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<tr>
<td>ENVE 665</td>
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</table>

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>ENVE 546 Solid Waste Systems</td>
<td></td>
</tr>
<tr>
<td>ENVE 661 Env Engr Op-Chem &amp; Phys</td>
<td></td>
</tr>
<tr>
<td>ENVE 662 Envr Engr Unit Oper-Bio</td>
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<tr>
<td>ENVE 665 Hazardous Waste &amp; Groundwater Treatment</td>
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<tr>
<td>Human Risks</td>
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<tr>
<td>AE 550 Comfort Analysis and Indoor Air Quality</td>
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</tr>
<tr>
<td>ENVE 727 Risk Assessment</td>
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</tr>
<tr>
<td>EOH 510 Principles and Practice of Environmental and Occupational Health</td>
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<tr>
<td>EOH 612 Environmental Exposure Science</td>
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<tr>
<td>Water Resources</td>
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<tr>
<td>CIVE 564 Sustainable Water Resource Engineering</td>
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</tr>
<tr>
<td>CIVE 565 Urban Hydraulics</td>
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</tr>
<tr>
<td>CIVE 664 Open Channel Hydraulics</td>
<td></td>
</tr>
<tr>
<td>ENVE 571 Environmental Life Cycle Assessment</td>
<td></td>
</tr>
<tr>
<td>ENVE 681 Analytical and Numerical Techniques in Hydrology</td>
<td></td>
</tr>
<tr>
<td>Environmental Modeling</td>
<td></td>
</tr>
<tr>
<td>ENVE 551 Geographic Information Systems</td>
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<tr>
<td>ENVE 571 Environmental Life Cycle Assessment</td>
<td></td>
</tr>
<tr>
<td>ENVE 681 Analytical and Numerical Techniques in Hydrology</td>
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<tr>
<td>ENVE 560 Fundamentals of Air Pollution Control</td>
<td></td>
</tr>
<tr>
<td>Cognate Discipline Track (12 credits)</td>
<td>12.0</td>
</tr>
</tbody>
</table>

Each student must complete a coherent four course sequence aside from the specialization. This may be either within the environmental engineering/ environmental science area, or in another related field (e.g. engineering, science, etc.).

<table>
<thead>
<tr>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0-9.0</td>
</tr>
</tbody>
</table>

| Total Credits
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>42.0-48.0</td>
</tr>
</tbody>
</table>

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

** Students must complete a course sequence aside from their specialization. This might include a second specialization or a sequence within engineering, an applicable science, public health, or other as approved by the graduate advisor.

*** One of these is required.
## Degree Requirements (PhD)

Applicants to the doctoral program are judged on the basis of academic excellence and the alignment of their research interests with those of the faculty in the School. To be awarded the PhD, students must complete a major research project publishable in peer-reviewed journals. The degree requires a total of 90.0 credits; credits earned toward a master’s degree may apply toward the 90.0 credits. There is no prescribed coursework—students must take courses needed to complete their research under guidance of an academic advisor. There is a one-year residency requirement. Students must successfully pass the candidacy examination, the proposal defense, and a PhD dissertation and oral defense.

Prospective PhD student are welcome to contact the Department (http://www.drexel.edu/cae/) to discuss their research interests.

## Dual MS Degrees

The university encourages students with broad interest to consider a dual-master’s option. Students can simultaneously work on two master’s degrees, applying to both programs a limited number of credits (a maximum of 15.0 to each). Applicants interested in a dual degree should apply for just one program; once enrolled at Drexel, the student may then request admission to the second program. The graduate advisors from both degree programs must approve the student’s enrollment, and they must approve the transfer of credits from one program to another. Applicants considering two degrees are encouraged to contact the appropriate academic departments.

## Facilities

The Department of Civil, Architectural, and Environmental Engineering is well equipped with state-of-the-art facilities:

- Analytical instrumentation for measuring biological and chemical contaminants in air, water and land
- Field sampling equipment for water and air measurements
- Molecular biology capability
- Computational facilities including access to multi-processor clusters, and advanced simulation and data analysis software

## Civil, Architectural and Environmental Engineering Faculty

Abieyuwa Aghayere, PhD (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). Associate Professor. Non-destructive evaluation and structural health monitoring; dynamic identification, stress wave propagation modeling.

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

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

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

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

Yaghoob (Amir) Farnam, PhD (Purdue University). Assistant 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) L. D. Betz Chair Professor of Environmental Engineering and Department Head, Civil, Architectural and Environmental Engineering. Water treatment; risk assessment; bioterrorism; environmental modeling and statistics; microbiology; environmental health.

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

Simi Hoque, PhD (University of California - Berkeley). Associate 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). Assistant 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.
Joseph P. Martin, PhD (Colorado State University). Professor. Geotechnical and geoenvironmental engineering; hydrology; transportation; waste management.

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

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

Nariman Mostafavi, PhD (University of Massachusetts - Amherst). Assistant Teaching Professor. Simulation tools for analyzing urban metabolism; environmentally responsive design; urban resilience; engineering economics; industrial ecology.

Joseph V. Mullin, PhD (Pennsylvania State University) Associate Department Head, Teaching Professor. Structural engineering; failure analysis; experimental stress analysis; construction materials; marine structures.

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). Assistant Professor. Laboratory testing of geomaterials; geotechnical aspects of natural hazards; soil-structure-interaction; geotechnical engineering.

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

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

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

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

Robert Swan Associate Teaching Professor. Geotechnical and Geosynthetic Engineering; soil/geosynthetic interaction and performance; laboratory and field geotechnical/geosynthetic testing.

Michael Waring, PhD (University of Texas-Austin) Associate Department Head for Undergraduate Programs; Director of Architectural Engineering Program. Associate Professor. Indoor air quality and building sustainability; indoor particulate matter fate and transport; indoor chemistry and particle formation; secondary impacts of control technologies and strategies.

Jin Wen, PhD (University of Iowa). Associate Professor. Architectural engineering; Building Energy Efficiency; Intelligent Building; Net-zero Building; and Indoor Air Quality.

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

Emeritus Faculty

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

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


Machine Learning Engineering

Major: Machine Learning Engineering
Degree Awarded: Master of Science in Machine Learning Engineering (MSMLE)
Calendar Type: Quarter
Total Credit Hours: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 54.0903
Standard Occupational Classification (SOC) code: 15-1132

About the Program

The MS in Machine Learning is designed to provide students with a strong academic background in machine learning and prepare them for a career as a machine learning 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.

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**

<table>
<thead>
<tr>
<th>Core Courses</th>
<th>12.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECE 610</td>
<td>Machine Learning &amp; Artificial Intelligence</td>
</tr>
<tr>
<td>ECE 612</td>
<td>Applied Machine Learning Engineering</td>
</tr>
<tr>
<td>ECE 687</td>
<td>Pattern Recognition</td>
</tr>
<tr>
<td>ECES 521</td>
<td>Probability &amp; Random Variables</td>
</tr>
</tbody>
</table>

**Aligned Mathematical Theory** | 6.0 |

Choose 2 courses

- ECES 522 Random Process & Spectral Analysis
- ECES 523 Detection & Estimation Theory
- ECES 611 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 510 Technical Writing
- COM 610 Theories of Communication and Persuasion
- EDGI 510 Culture, Society & Education in Comparative Perspective
- EDGI 512 Globalization and Educational Change

**Mastery (Thesis and Non-Thesis Option)** | 6.0 |

Choose 1 course

- ECE 898 Master's Thesis

**Sample Plan of Study**

**Thesis Option**

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits Winter</th>
<th>Credits Spring</th>
<th>Credits Summer</th>
<th>Credits</th>
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<tr>
<td>Fall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECE 687</td>
<td>3.0 ECE 612</td>
<td>3.0 ECE 610</td>
<td>3.0 VACATION</td>
<td></td>
</tr>
<tr>
<td>ECES 521</td>
<td>3.0 Aligned Mathematical Theory courses</td>
<td>6.0 Applications course</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Signal Processing course

|                   |         |         |         |         |
|                   | 9       | 9       | 9       | 0       |

**Second Year**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits Winter</th>
<th>Credits</th>
<th>Credits</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>ECE 898</td>
<td>3.0 ECE 898</td>
<td>3.0</td>
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<tr>
<td>Engineering elective</td>
<td>Engineering elective</td>
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<tr>
<td>Transformational elective</td>
<td>Transformational elective</td>
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</tbody>
</table>

|                   |         |         |         |         |
|                   | 9       | 9       |         | 0       |

**Non-Thesis Option**

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits Winter</th>
<th>Credits Spring</th>
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<tbody>
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<tr>
<td>ECE 687</td>
<td>3.0 ECE 612</td>
<td>3.0 ECE 610</td>
<td>3.0 VACATION</td>
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<tr>
<td>ECES 521</td>
<td>3.0 Aligned Mathematical Theory courses</td>
<td>6.0 Applications course</td>
<td>3.0</td>
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</table>

Signal Processing course

|                   |         |         |         |         |
|                   | 9       | 9       |         | 0       |

|                   |         |         |         |         |
|                   | 9       | 9       |         |         |

**Second Year**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits Winter</th>
<th>Credits</th>
<th>Credits</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>Aligned Mathematical Theory</td>
<td>Aligned Mathematical Theory</td>
<td>3.0</td>
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</tr>
<tr>
<td>Theory, Applications, or Signal Processing</td>
<td>Theory, Applications, or Signal Processing</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering elective</td>
<td>Engineering elective</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transformational elective</td>
<td>Transformational elective</td>
<td>3.0</td>
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</tbody>
</table>

|                   | 9       | 9       |         |         |

**Materials Science and Engineering**

Major: Materials Science and Engineering

Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)

Calendar Type: Quarter

Total Credit Hours: 45.0 (MS); 90.0 (PhD)

Co-op Option: None

Classification of Instructional Programs (CIP) code: 14.1801

Standard Occupational Classification (SOC) code: 17-2131
About the Program

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

In addition, the program provides students with research training through their courses and thesis research at the MS and PhD levels.

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

Graduate programs in Materials Science and Engineering are offered both on a regular full-time and on a part-time (MS only) 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, Intel, IBM, 3M, DuPont, Lockheed-Martin, Johnson and Johnson, Merck, AstraZeneca, Arkema, Army Research Laboratory, Los Alamos National Laboratory, Air Products, Micron, Xerox, Motorola, Monsanto, Corning, and Eastman Kodak.

Additional Information

For more information about Materials Science and Engineering, visit 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 (MS)

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 in 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 *

<table>
<thead>
<tr>
<th>Required core courses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 510 Thermodynamics of Solids 3.0</td>
</tr>
<tr>
<td>MATE 512 Introduction to Solid State Materials 3.0</td>
</tr>
<tr>
<td>Select four additional core courses from the following:</td>
</tr>
<tr>
<td>MATE 501 Structure and Properties of Polymers</td>
</tr>
<tr>
<td>MATE 507 Kinetics</td>
</tr>
<tr>
<td>MATE 515 Experimental Technique in Materials</td>
</tr>
<tr>
<td>MATE 535 Numerical Engineering Methods</td>
</tr>
<tr>
<td>MATE 610 Mechanical Behavior of Solids</td>
</tr>
<tr>
<td>MATE 661 Biomedical Materials I</td>
</tr>
<tr>
<td>Any additional related courses if approved by the graduate advisor (such as MATE 514 and MATE 573)</td>
</tr>
</tbody>
</table>

Optional Core Courses **

| 18.0 |
| Thesis and Alternatives |
| 9.0 |
| 9.0 credits MS thesis OR 6.0 credits of thesis proposal (literature review) + 3.0 credit course OR 9.0 credits of electives |

Total Credits 45.0

* PhD candidates must achieve a minimum B- grade in each of the core courses. Waiver of any of the 6 core courses must be approved by the MSE Department Graduate Advisor and the student's Thesis Advisor in Advance.

** Of the 18 technical elective credits, at least 9 credits must be taken as Materials Science and Engineering (MATE) courses, while the rest may be taken within the College of Engineering, College of Arts and Sciences, or at other colleges if consistent with the student's plan of study (and given advance written approval by his/her advisor). At least 9 of these 18 technical electives must be exclusive of independent study courses or research credits.

Degree Requirements (PhD)

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

<table>
<thead>
<tr>
<th>Required Core Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 510 Thermodynamics of Solids</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 512 Introduction to Solid State Materials</td>
<td>3.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional Required Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 504 The Art of Being a Scientist</td>
<td>2.0</td>
</tr>
<tr>
<td>MATE 536 Materials Seminar Series</td>
<td>6.0</td>
</tr>
<tr>
<td>MATE 998 Ph.D. Dissertation</td>
<td>9.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selected Core Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 501 Structure and Properties of Polymers</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 507 Kinetics</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 514 Structure, Symmetry, and Properties of Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 515 Experimental Technique in Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 535 Numerical Engineering Methods</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 610 Mechanical Behavior of Solids</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 661 Biomedical Materials</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Related courses as approved by the Graduate Advisor/Thesis Advisor

<table>
<thead>
<tr>
<th>Optional Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 541 Introduction to Transmission Electron Microscopy and Related Techniques</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 542 Nuclear Fuel Cycle &amp; Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 543 Thermal Spray Technology</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 544 Nanostructured Polymeric Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 563 Ceramics</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 572 Materials for High Temperature and Energy</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 573 Electronic, Magnetic and Optical Characterization of Energy Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 576 Recycling of Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 580 Special Topics in MATE</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 582 Materials for Energy Storage</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 583 Environmental Effects on Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 585 Nanostructured Carbon Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 602 Soft Materials</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 702 Natural Polymers</td>
<td>3.0</td>
</tr>
<tr>
<td>MATE 897 Research</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Other MSE courses that may be available

Total: 90.0 credits

PhD students must achieve a minimum "B-" grade in each of the 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.

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

Facilities

Biomaterials and Biosurfaces Laboratory
This laboratory contains 10 kN biaxial and 5 kN uniaxial servo-hydraulic mechanical testing machines, a Fluoroscan X-ray system, a microscopic imaging system, a spectra fluorometer, a table autoclave, centrifuge, vacuum oven, CO2 incubators, biological safety cabinet, thermostatic water baths, precision balance, and ultrasonic sterilizer.

Nanobiomaterials and Cell Engineering Laboratory
This laboratory contains a photo-resist spinner, impedance analyzer, Zeta potential meter, spectrophotometer, piezoelectric d33 meter, wire-bonder, and laser displacement meter.

MAX Phase Ceramics Processing Laboratory
This laboratory contains fume hood with vacuum/gas dual manifold, vacuum pump and rotary evaporator for general organic/polymer synthesis; gel electrophoresis and electroblotting for protein characterization; bath sonicator, glass homogenizer and mini-extruder for nanoparticle preparation; centrifuge, ultrapure water conditioning system; precision balance; and pH meter and shaker.

Ceramics Processing Laboratory
This laboratory contains a vacuum hot-press; cold isostatic press (CIP) and hot isostatic press (HIP) for materials consolidation and synthesis; precision dilatometer; laser scattering particle size analyzer; impedance analyzer, creep testers, and assorted high temperature furnaces.

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

Mesoscale Materials Laboratory
This laboratory contains instrumentation for growth, characterization, device fabrication, and design and simulation of electronic, dielectric, ferroelectric, and photonic materials. Resources include physical and chemical vapor deposition and thermal and plasma processing of thin films, including oxides and metals, and semiconductor nanowire growth. Facilities include pulsed laser deposition, atomic layer deposition, chemical vapor deposition, sublimation growth, and resistive thermal evaporation. Variable-temperature high-vacuum probe station and optical cryostats including high magnetic field, fixed and tunable-wavelength laser sources, several monochromators for luminescence and Raman scattering spectroscopies, scanning electron microscopy with electron beam lithography, and a scanning probe microscope.

Nanomaterials Laboratory
This laboratory contains instrumentation for testing and manipulation of materials under microscope, high-temperature autoclaves, Sievert's apparatus; glove-box; high-temperature vacuum and other furnaces.
for the synthesis of nano-carbon coatings and nanotubes; and electrophoretic deposition system for producing nano-fibers.

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

**Powder Processing Laboratory**
This laboratory contains vee blenders, ball-mills, sieve shaker and sieves for powder classification, several furnaces (including one with controlled atmosphere capability); and a 60-ton Baldwin press for powder compaction.

**Soft Matter Research and Polymer Processing Laboratories**
These laboratories contain computerized thermal analysis facilities including differential scanning calorimeters (DSC), dynamic mechanical analyzer (DMA), and thermo-gravimetric analyzer (TGA); single-fiber tensile tester; strip biaxial tensile tester; vacuum evaporator; spincoater; centrifuge; optical microscope with hot stage; liquid crystal tester; microbalance; ultrasonic cleaner; laser holographic fabrication system; polymer injection molder and single screw extruder.

**Natural Polymers and Photonics Laboratory**
This laboratory contains a spectroscopic ellipsometer for film characterization; high purity liquid chromatography (HPLC) system; lyophilizer; centrifuge; refractometer; and electro-spinning system for producing nano-fibers.

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

**Materials Characterization Core Facility**
The Department of Materials Science & Engineering relies on Materials Characterization Core facility within the University for materials characterization and micro- and nano-fabrication. These facilities contain state-of-the-art materials characterization instruments, including environmental and variable pressure field-emission scanning electron microscopes with Energy Dispersive Spectroscopy (EDS) for elemental analysis and Orientation Image Microscopy (OIM) for texture analysis; a Transmission Electron Microscope (TEM) with STEM capability and TEM sample preparation equipment; a dual beam focused ion beam (FIB) system for nano-characterization and nano-fabrication; a femtosecond/terahertz laser Raman spectrometer; visible and ultraviolet Raman micro spectrometers with a total of 7 excitation wavelengths for non-destructive chemical and structural analysis and Surface Enhanced Raman (SERS); a Nanoindenter; an X-ray Photoelectron Spectrometer (XPS)/Electron Spectroscopy for Chemical Analysis (ESCA) system; and X-Ray Diffractometers (XRD), including small angle/wide angle X-Ray scattering (SAX/WAX).

More details of these instruments, information how to access them, and instrument usage rates can be found on the Core Facilities webpage (http://crf.coe.drexel.edu/).

**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, PhD (Kiev Polytechnic Institute) Director, A. J. Drexel Nanotechnology Institute. Distinguished University & Charles T. and Ruth M. Bach Professor. Nanomaterials; carbon nanotubes; nanodiamond; graphene; MXene; materials for energy storage, supercapacitors, and batteries.

Richard Knight, PhD (Loughborough University) Associate Department Head and Undergraduate Advisor. Teaching Professor. Thermal plasma technology; thermal spray coatings and education; plasma chemistry and synthesis.

Christopher Y. Li, PhD (University of Akron). Professor. Soft and hybrid materials for optical, energy, and bio applications; polymeric materials, nanocomposites, structure and properties.

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.

Michele Marcolongo, PhD, PE (University of Pennsylvania) Department Head, Materials Science and Engineering. Professor. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

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

Ekaterina Pomerantseva, PhD (Moscow State University, Russia). 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 nanofilbers.

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.

Mitra Taheri, PhD (Carnegie Mellon University) Hoeganes Professor of Metallurgy. Professor. Development of the ultrafast Dynamic Transmission Electron Microscope (DETM) for the study of laser-induced microstructural evolution/phase transformations in nanostructured...
materials; use of various in-situ Transmission Electron Microscopy techniques.

Jörn Vanderbos, 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

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. Corneliussen, PhD (University of Chicago). Professor Emeritus. Fracture, blends and alloys, as well as compounding.


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.

Mechanical Engineering and Mechanics

Major: Mechanical Engineering and Mechanics
Degree Awarded: Master of Science (MS) or Doctor of Philosophy (PhD)
Calendar Type: Quarter
Total Credit Hours: 45.0 (MS) or 90.0 (PhD)
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 and Mechanics (MEM) Department (https://drexel.edu/engineering/academics/departments/mechanical-engineering/) offers MS and PhD degrees. The courses often associate with one or more areas of specialization: design and manufacturing, mechanics, systems and control, and thermal and fluid sciences. The mechanical engineering field is rapidly changing due to ongoing advances in modern science and technology. Effective mechanical engineers must possess expertise in mechanical engineering core subjects, interdisciplinary skills, teamwork skills, as well as entrepreneurial and managerial abilities. The degree programs are designed so students can learn the state-of-the-art knowledge now, and have the foundation to acquire new knowledge as they develop in future.

The MS degree program is offered on both a full-time and a part-time basis. The General (Aptitude) Test of the Graduate Record Examination (GRE) is required for applicants pursuing full-time study. Graduate courses are often scheduled in the late afternoon and evening, so full-time students and part-time students can take the same courses. The department has recently adopted the Graduate Co-op program at the master’s level as an option.

The PhD degree program is offered for full-time students only and is a research intensive program. The research areas include, but are not limited to, bio-engineering, energy systems, high performance materials, nanotechnology, plasma science and engineering, and robotics.

Admission Requirements

Applicants must meet the graduate requirements for admission to Drexel University. Students holding a bachelor’s degree in a science or engineering discipline other than mechanical engineering are advised to take several undergraduate courses as preparation for graduate studies. Though these courses are not counted toward the required credits for the degree, they also must be listed in the student’s plan of study. Outstanding students with a GPA of at least 3.5 in their master’s program will be considered for admission to the program leading to the doctor of philosophy degree in mechanical engineering.

Degree Requirements (MS)

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.

Typical MS Program

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Core-Course Sequences (required)</td>
<td>12.0</td>
</tr>
<tr>
<td>Three Mathematics Courses (required)</td>
<td>9.0</td>
</tr>
<tr>
<td>Eight Technical Electives (including 9 credits for thesis option)</td>
<td>24.0</td>
</tr>
<tr>
<td><strong>Total Credits</strong></td>
<td><strong>45.0</strong></td>
</tr>
</tbody>
</table>

* Mathematics courses: MEM 591, MEM 592, MEM 593.

Core Areas

All students take core courses in the department’s areas of specialization as part of a comprehensive and flexible program. Further details can be obtained from the department’s Graduate Programs Manual (http://www.drexel.edu/mem/academics/graduate/grad-manual/).

The core courses in each area are listed below:

<table>
<thead>
<tr>
<th>Area</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>MEM 660</td>
<td>Theory of Elasticity I</td>
<td>3.0</td>
</tr>
</tbody>
</table>
A student who enters the PhD program with a prior MS degree must take the Candidacy Examination within the first year after entry to the PhD program. A student who enters the PhD program without a prior MS degree must take the Candidacy Examination within 2 years after entry to the PhD program.

The Candidacy Examination consists of two components: A course-component examination and a research-component examination. The student must demonstrate excellence in both components. The research-component examination consists of a written report and an oral presentation. The Candidacy Committee selects three or more research papers in the student’s declared research area for student to conduct a critical review. In three weeks the student submits a written report. One week after the written report is submitted the student makes an oral presentation. The presentation is followed by questions by the Committee. The goals of the questions: To evaluate the student’s knowledge in the scientific fields related to the research area, including related background and fundamental material, and the student’s ability to integrate information germane to success in research. Additional details are given in the Mechanical Engineering and Mechanics Graduate Program Manual.

**Thesis Proposal**

At least one year prior to graduation, the PhD candidate must give a thesis proposal to the dissertation advisory committee. The student must submit a written proposal and make a presentation. The written proposal normally includes: abstract, introduction, detailed literature review, preliminary results, proposed research tasks and timetable. The committee will approve/reject the thesis topic, the scope of work and the general method of attack.

**Thesis Defense**

A final examination consisting of a presentation and defense of the research dissertation is required, before the PhD degree is granted. Further details can be obtained from the department's Graduate Programs Manual.

**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, ABOUS, and more. The machines include two Sanders Model Maker rapid prototyping machines, a BridgePort CNC Machining Center, a BOY 220 injection molding machine, an Electro 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, microorgan, 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 the Dynamic Multifunctional 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
Jennifer Atchison, PhD (Drexel University). Assistant 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.

Nicholas P. Cernansky, PhD (University of California-Berkeley) Hess Chair Professor of Combustion. Professor. Combustion chemistry and kinetics; combustion generated pollution; utilization of alternative and synthetic fuels.

Bor-Chin Chang, PhD (Rice University). Professor. Computer-aided design of multivariable control systems; robust and optimal control systems.

Richard Chiou, PhD (Georgia Institute of Technology). Associate Professor. Green manufacturing, mechatronics, Internet-based robotics and automation, and remote sensors and monitoring.

Young I. Cho, PhD (University of Illinois-Chicago). Professor. Heat transfer; fluid mechanics; non-Newtonian flows; biofluid mechanics; rheology.

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

Alexander Fridman, DSc (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.

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.

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

Andrei Jabloukov, PhD (University of Wisconsin, Madison) Associate Department Head for Undergraduate Affairs, Mechanical Engineering and Mechanics. Associate Teaching Professor. Engineering education; kinematics; geometric modeling.

Antonios Kontsos, PhD (Rice University). Associate Professor. Applied mechanics; probabilistic engineering mechanics; modeling of smart multifunctional materials.

E. Caglan Kumbur, PhD (Pennsylvania State University). Associate Professor. Next generation energy technologies; fuel cell design and development.

Harry G. Kwatny, PhD (University of Pennsylvania) S. Herbert Raynes Professor of Mechanical Engineering. Professor. Dynamic systems analysis; stochastic optimal control; control of electric power plants and systems.

Alan Lau, PhD (Massachusetts Institute of Technology). Professor. Deformation and fracture of nano-devices and macroscopic structures; damage-tolerant structures and microstructures.

Michele Marcolongo, PhD, PE (University of Pennsylvania) Department Head, Materials Science and Engineering. Professor. Orthopedic biomaterials; acellular regenerative medicine, biomimetic proteoglycans; hydrogels.

Roger Marino, PhD (Drexel University). Associate Teaching Professor. Engineering education; land development; product Development.

Matthew McCarthy, PhD (Columbia University) Associate Department Head for Graduate Affairs, Mechanical Engineering and Mechanics. 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.
Nanomaterials

Major: Nanomaterials
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Total Credit Hours: 45.0
Co-op Option: None

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.

Sorin Siegler, PhD (Drexel University). Professor. Orthopedic biomechanics; robotics; dynamics and control of human motion; applied mechanics.

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.

Ying Sun, PhD (University of Iowa). Associate Professor. Transport processes in multi-component systems with fluid flow; heat and mass transfer; phase change; pattern formation.

Tein-Min Tan, PhD (Purdue University). Associate Professor. Mechanics of composites; computational mechanics and finite-elements methods; structural dynamics.

James Tangorra, PhD (Massachusetts Institute of Technology) Department Head, Engineering Technology. Associate Professor. Analysis of human and (other) animal physiological systems; head-neck dynamics and control; balance, vision, and the vestibular system; animal swimming and flight; robotics; system identification; bio-inspired design.

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.


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.

Classification of Instructional Programs (CIP) code: 15.1601
Standard Occupational Classification (SOC) code: 17-2199

About the Program

The Department of Materials Science and Engineering provides an excellent opportunity for students to gain an advanced understanding of nanomaterials in this Master of Science degree program. Students will attend lectures and work in laboratories alongside faculty and other students to solve problems in energy and health using novel approaches in the area of nanomaterials. The program is designed to expand knowledge and integrate critical thinking and research in everyday life. The Department of Materials Science and Engineering will work in conjunction with the A.J. Drexel Nanomaterials Institute to deliver this academic program.

Additional Information

For more information, contact:
Danielle Kopicko, M.S.Ed.
Associate Director, A.J. Drexel Nanomaterials Institute
dt372@drexel.edu

Admission Requirements

Application Deadlines

- • US Students
  - • Aug. 1 (Fall Term)
  - • Nov. 1 (Winter Term)
  - • Feb. 1 (Spring Term)
- • International Students:
  - • June 13 (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. Funding options are decided on an individual basis.

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 US 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.

- • Standardized Test Scores
• GRE test scores are required.
• Minimum score varies.

Degree Requirements

Core Courses
Select 15.0 credits from the list below:

- ECSE 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 Nanomaterials
- PHYS 553 Nanoscience

Academic Track: Choose one*

Nanobiomaterials
- BIO 500 Biochemistry I
- BMES 631 Tissue Engineering I
- BMES 632 Tissue Engineering II
- BMES 541 Nano and Molecular Mechanics of Biological Materials
- 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

Nanomaterials for Energy
- CHEM 555 Quantum Chemistry Of Molecules I
- CHEM 774 Electrochemistry for Chemists
- CHEM 868 Topics in Analytical Chemistry
- ECSE 821 Nanoelectronics
- ET 681 Nanomaterials and Nanoeengineering
- 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

Thesis or Non-Thesis option**

- Master's Thesis
- MATE 898 Master's Thesis

Chose 9.0 credits from courses listed in the academic track above

Total Credits 45.0-47.0

* Students selecting the Nanobiomaterials track will complete 47.0 credits.
** Master’s Thesis students take MATE 898 [WI] for 9.0 credits while Non-Master's Thesis students select 9.0 credits from courses listed within each concentration. Additionally, Non-Master’s Thesis students may request approval from the Grad Advisor to take Special Topics courses.

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 (/http://drexel.edu/coas/academics/departments-centers/english-philosophy/university-writing-program/writing-intensive-courses/) 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/)

Sample Plan of Study

Nanomaterials for Energy Track (Thesis Option)

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Total Credits 45

* Students enrolled in the Master's Thesis program make take up to 9.0 additional credits of MATE 898 [WI] with the approval of their Graduate Advisor making their program 54.0 credits. Students enrolled in the Non-Master's Thesis program take electives in place of MATE 898 [WI].

Nanobiomaterials Track (Thesis Option)

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Total Credits 47

* Students enrolled in the Master's Thesis program make take up to 9.0 additional credits of MATE 898 [WI] with the approval of their Graduate Advisor making their program 56.0 credits. Students enrolled in the Non-Master's Thesis program take electives in place of MATE 898 [WI].
Major: Peace Engineering
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Total Credit Hours: 48.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.0401
Standard Occupational Classification (SOC) code: 17-2081

About the Program
Peace Engineering will educate a new 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 that aims to transform conflict management using education and research efforts that integrate innovative technologies, approaches, and policies with the studies and practices of peacebuilders.

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 resolve conflict non-violently, emerge from the dynamics and interactions of social, technical, and environmental systems. A one-year and a two-year M.S. are offered and combine online and classroom courses with experiential learning at partners such as the PeaceTech Lab, the U.S. Institute of Peace, and Drexel’s Dornsife Center.

Peace Engineering will be educating students to serve in fields that are growing rapidly due to the confluence of the increased awareness of conflicts and its causes (e.g., climate change), the widespread availability of technology that connects communities and economies, and the strong desire in current generations to have a 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.

Degree Requirements

<table>
<thead>
<tr>
<th>Core Peacebuilding Requirements</th>
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<tr>
<td>PENG 501 Peace Engineering Seminar - Fall</td>
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<td>PENG 502 Peace Engineering Seminar - Winter</td>
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<td>PENG 545 Introduction to Peacebuilding for Engineers</td>
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<td>PENG 550 Conflict Management for Engineers</td>
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<td>PENG 560 Peacebuilding Skills</td>
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<th>Core Engineering Requirements</th>
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<tr>
<td>ENVE 727 Risk Assessment</td>
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<td>PROJ 501 Introduction to Project Management</td>
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<td>SYSE 540 Systems Engineering for Peacebuilding</td>
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<tr>
<td>SYSE 540</td>
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<td>ENVE 750</td>
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<td>ENVE 727</td>
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<td>CAEE 501</td>
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<td>EMTS 500</td>
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<td>PENG 600</td>
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<tr>
<th>Technical Focus Sequences **</th>
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<tr>
<td>Database Management</td>
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<tr>
<td>Machine Learning and AI</td>
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<tr>
<td>Information Security</td>
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<td>Software Development</td>
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<td>Systems Analysis</td>
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<td>Water and Sanitation Systems</td>
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<td>Renewable Energy Systems</td>
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<td>Infrastructure Systems</td>
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<td>Urban Climbing Systems</td>
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Sample Plan of Study
One Year M.S.

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<th>Credits Summer</th>
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<td>SYSE 540</td>
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Two Year M.S.

<table>
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<td>EMTS 545</td>
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<td>ENVE 750</td>
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<td>ENVE 727</td>
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* 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 570, SCTS 571, SCTS 615, SCTS 620, SCTS 641, SCTS 645
- Politics electives: PSCI 510, PSCI 553, ENVP 552
- Education electives: EDGI 530, EDGI 533, EDGI 536

** Technical Focus Sequences
Students must complete one sequence of at least 2 courses (6 credits) from the following approved sequences.
- Software Development: CS 520, CS 570, CS 571 (optional)
- Machine Learning and AI: CS 510, CS 613, CS 610 (optional)
- Information Security: INFO 517, INFO 712, INFO 710 (optional)
- Database Management: INFO 605, INFO 606, INFO 607 (optional)
- Information Retrieval: INFO 605, INFO 624, INFO 633 (optional)
- Data Mining: INFO 605, INFO 634, INFO 633 (optional)
- Web and Mobile Development: INFO 552, INFO 655
- Game Design: DIGM 505, DIGM 506
- Serious gaming: DIGM 530, DIGM 531
- Interaction: DIGM 520, DIGM 521
- WASH: CIVE 564, CIVE 567 (optional), CIVE 561 (optional)
- Power systems and Distribution: ECEP 501, ECEP 502, ECEP 601 (optional)
**Robotics and Autonomy**

**Major: Robotics and Autonomy**

**Degree Awarded: Master of Science (MS)**

**Calendar Type: Quarter**

**Total Credit Hours: 45.0**

**Co-op Option: None**

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.

**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**

<table>
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**Systems Courses**

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**Choose 2 courses in mathematics and/or signal processing**

**Mathematics**

- ECES 521: Probability & Random Variables
- MATH 504: Linear Algebra & Matrix Analysis
- MATH 510: Applied Probability and Statistics I
- 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

**Choose 2 courses in mathematics and/or signal processing**

**Signal Processing**

- ECES 522: Random Process & Spectral Analysis
- ECES 523: Detection & Estimation Theory
- ECES 604: Optimal Estimation & Stochastic Control

**Choose 2 courses in robotics and autonomy from the perspective of full systems or use**

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<td>MEM 573</td>
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**Core Components**

Take 1 course in each of the four disciplines critical to robotics

**Perception**

- ECES 681: Fundamentals of Computer Vision
- ECES 682: Fundamentals of Image Processing
- ECET 512: Wireless Systems
- ECET 580: Special Topics in ECET

**Cognition and Behavior**

- CS 510: Introduction to Artificial Intelligence
- CS 583: Introduction to Computer Vision
- CS 613: Machine Learning
- CS 630: Cognitive Systems

**Action**

- 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
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

Transformational Electives 6.0
Choose 2 elective courses that promote the development of leadership, communication, and ethics

COM 510 Technical Writing
COM 610 Theories of Communication and Persuasion
EDGI 510 Culture, Society & Education in Comparative Perspective
EDGI 512 Globalization and Educational Change

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 six credits of additional coursework in a Technical Focus Area. Graduate Co-op is encouraged for non-thesis students, but is not required.

Experiential Learning (optional)

Total Credits 45.0

Sample Plan of Study

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits Winter</th>
<th>Credits Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
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<tr>
<td>ECES 511</td>
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<td>3.0 CS 613</td>
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</tr>
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<tr>
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<td>CS 510</td>
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</table>

Total Credits 45

Vince and Judy Vidas Program in Systems Engineering

Major: Systems Engineering
Degree Awarded: Master of Science (MS)
Calendar Type: Quarter
Total Credit Hours: 45.0
Co-op Option: None
Classification of Instructional Programs (CIP) code: 14.2701
Standard Occupational Classification (SOC) code: 17-2199

About the Program

The Master of Science in Systems Engineering is an interdisciplinary curriculum which integrates systems thinking with financial management and planning. The degree enables engineering leaders to perform, lead, and manage systems development throughout the entire life-cycle, from conceptual development and engineering design through the operation and sustainment phases. Study can be on a part-time or full-time basis, and the program is available both online and on-campus.

Drexel's MS Systems Engineering is certified by the International Council on Systems Engineering (INCOSE), and it is one of only six programs 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.

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 using SysML and DODAF, also covering major aspects of the systems domain.
- Teach systems engineering processes and skills to integrate user needs, manage requirements, conduct technological evaluation, and build elaborate system architectures, assess risk and establish financial and schedule constraints.
- Prepare students to intelligently manage and contribute to any engineering challenge, 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;
- develop and manage processes relevant to complex systems development;
- architect, design, implement, integrate, verify, validate, support and decommission complex systems;
- use systems engineering tools and practices to identify and execute effective technical solutions;
- manage system-intensive projects within cost and schedule constraints;
- consider financial elements in all complex systems solutions.

Certificate Opportunity

Students may complete a Graduate Certificate as a standalone pursuit or as a gateway to the full Master of Science in Systems Engineering. Students may apply for admission to the Masters of Science in Systems Engineering degree program at any point in a certificate series. Upon admission, graduate courses successfully completed in the certificate series may be applied toward the Master’s degree as applicable. Certificate opportunities include:

- Certificate in Systems Design and Development (p. 63)
- Certificate in Systems Engineering (p. 63)
- Certificate in Systems Engineering Analysis (p. 64)
• Certificate in Systems Engineering Integrated Logistics (p. 64)
• Certificate in Systems Reliability Engineering (p. 65)

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 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

Degree Requirements

The master of science in systems engineering degree requires a minimum of 45.0 credits, including 30.0 credits in required core courses and 15.0 elective credits.

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.

Required Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EGMF 572</td>
<td>Statistical Data Analysis</td>
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</tr>
<tr>
<td>EGMF 573</td>
<td>Operations Research</td>
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<td>SYSE 520</td>
<td>Global Sustainment and Integrated Logistics</td>
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<td>SYSE 533</td>
<td>Systems Integration and Test</td>
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<td>SYSE 598</td>
<td>Capstone in Systems Engineering</td>
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<td>SYSE 640</td>
<td>Model Based Systems Engineering</td>
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<td>SYSE 682</td>
<td>Introduction to Systems Science</td>
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<td>SYSE 685</td>
<td>Systems Engineering Management</td>
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<td>Systems Engineering Analysis</td>
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<tr>
<td>SYSE 690</td>
<td>Modeling and Simulation</td>
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</table>

Electives

Complete five of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>ECEP 501</td>
<td>Power System Analysis</td>
</tr>
<tr>
<td>ECEP 502</td>
<td>Computer Analysis of Power Systems</td>
</tr>
<tr>
<td>ECEP 503</td>
<td>Synchronous Machine Modeling</td>
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<table>
<thead>
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<tr>
<td>EGMF 611</td>
<td>Power System Security</td>
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<tr>
<td>EGMF 612</td>
<td>Economic Operation of Power Systems</td>
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<td>EGMF 511</td>
<td>Fundamentals of Systems I</td>
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<td>EGMF 512</td>
<td>Fundamentals of Systems II</td>
</tr>
<tr>
<td>EGMF 513</td>
<td>Fundamentals of Systems III</td>
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<tr>
<td>EGMF 521</td>
<td>Probability &amp; Random Variables</td>
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<tr>
<td>EGMF 522</td>
<td>Random Process &amp; Spectral Analysis</td>
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<tr>
<td>EGMF 523</td>
<td>Detection &amp; Estimation Theory</td>
</tr>
<tr>
<td>EGMF 811</td>
<td>Optimization Methods for Engineering Design</td>
</tr>
<tr>
<td>EGMF 501</td>
<td>Leading and Managing Technical Workers</td>
</tr>
<tr>
<td>EGMF 502</td>
<td>Analysis and Decision Methods for Technical Managers</td>
</tr>
<tr>
<td>EGMF 531</td>
<td>Engineering Economic Evaluation &amp; Analysis</td>
</tr>
<tr>
<td>EGMF 535</td>
<td>Financial Management</td>
</tr>
<tr>
<td>EGMF 615</td>
<td>New Product Conceptualization, Justification, and Implementation</td>
</tr>
<tr>
<td>EGMF 616</td>
<td>Value Creation through New Product Development</td>
</tr>
<tr>
<td>EGMF 620</td>
<td>Engineering Project Management</td>
</tr>
<tr>
<td>EGMF 625</td>
<td>Project Planning, Scheduling and Control</td>
</tr>
<tr>
<td>EGMF 630</td>
<td>Global Engineering Project Management</td>
</tr>
<tr>
<td>EGMF 635</td>
<td>Visual System Mapping</td>
</tr>
<tr>
<td>EGMF 645</td>
<td>Managing Engineering Disasters</td>
</tr>
<tr>
<td>SYSE 521</td>
<td>Integrated Risk Management</td>
</tr>
<tr>
<td>SYSE 522</td>
<td>Engineering Supply Chain Systems</td>
</tr>
<tr>
<td>SYSE 523</td>
<td>Systems Reliability Engineering</td>
</tr>
<tr>
<td>SYSE 524</td>
<td>Systems Reliability, Availability &amp; Maintainability Analysis</td>
</tr>
<tr>
<td>SYSE 525</td>
<td>Statistical Modeling &amp; Experimental Design</td>
</tr>
<tr>
<td>SYSE 530</td>
<td>Systems Engineering Design</td>
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<tr>
<td>SYSE 531</td>
<td>Systems Architecture Development</td>
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<tr>
<td>SYSE 532</td>
<td>Software Systems Engineering</td>
</tr>
<tr>
<td>SYSE 688</td>
<td>Master’s Thesis in Systems Engineering **</td>
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</table>

Total Credits 45.0

Sample Plan of Study

First Year

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<td>Summer</td>
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Total Credits 45

Second Year

<table>
<thead>
<tr>
<th>Term</th>
<th>Credits</th>
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<tbody>
<tr>
<td>Fall</td>
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<tr>
<td>Spring</td>
<td>6</td>
</tr>
<tr>
<td>Summer</td>
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</table>

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>EGMF 531</td>
<td>Engineering Economic Evaluation &amp; Analysis</td>
</tr>
<tr>
<td>EGMF 501</td>
<td>Leading and Managing Technical Workers</td>
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<td>New Product Conceptualization, Justification, and Implementation</td>
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<tr>
<td>SYSE 688</td>
<td>Master’s Thesis in Systems Engineering **</td>
</tr>
</tbody>
</table>

* Electives from other engineering disciplines and/or Drexel colleges may be considered with review and approval by the advisor.

** If a student decides to pursue the Master’s Thesis option, the student will complete the 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.
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 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 Systems Engineering prepares students to become effective systems engineers, leaders, managers, and future executives. With a systems engineering background, students are able to tackle a wide array of engineering challenges from the entire systems life cycle, including concept development, technology assessment, architecture selection, and proposal development.

Systems engineers are highly valued in industry because their skills complement those in traditional engineering fields. Whereas other engineering disciplines usually focus deeply in only one area, systems engineers must integrate all of those areas into a comprehensive and effective system. This is a versatile skill-set that allows for a flexible career path, as systems engineering expertise is sought by a wide range of industries such as healthcare, defense, communications, aerospace, government, transportation, finance, and more. Drexel University’s MS Systems Engineering will prepare students from any of these fields to lead large, complex projects in their organizations.

Systems Engineering Faculty

Richard Grandrino, MBA (Drexel University). Teaching Faculty. Manager for advanced logistics operations at Lockheed Martin

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.

Program Requirements

Programming, Data Structures, Algorithms Requirement
Complete 1 of the following courses: 3.0
- BMES 550 Advanced Biocomputational Languages
- CS 520 Computer Science Foundations
- CS 521 Data Structures and Algorithms I
- CS 540 High Performance Computing
- CS 550 Programming Languages
- CS 571 Advanced Programming Techniques
- CS 575 Software Design
- CS 576 Dependable Software Systems

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
- MATH 554 Advanced Engineering Mathematics I
- 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
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/departments/construction-engineering-project-management-systems-engineering/academic-programs/graduate/construction-management/).

Admission Requirements

The admissions process for this program is the same as for the MS in Construction Management (http://www.drexel.edu/grad/apply/overview/).

Program Requirements

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Requirements</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CMGT 510</td>
<td>Construction Control Techniques</td>
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<tr>
<td>CMGT 512</td>
<td>Cost Estimating and Bidding Strategies</td>
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</tr>
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<td>CMGT 515</td>
<td>Risk Management in Construction</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 525</td>
<td>Applied Construction Project Management</td>
<td>3.0</td>
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<td>CMGT 528</td>
<td>Construction Contract Administration</td>
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</tr>
<tr>
<td>CMGT 538</td>
<td>Strategic Management in Construction</td>
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<td><strong>Total Credits</strong></td>
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Additional Information

For more information, view the College of Engineering’s Construction Management (https://drexel.edu/engineering/academics/areas-of-study-programs/construction-management/) webpage or contact the program academic adviser:

Ms. Jessica Cruz
Emails: jc635@drexel.edu
Phone: 215-895-5943
About the Program

This program is a superb training ground for engineers and scientists who want to obtain a solid foundation in critical areas in management, communications, economics, and finance without having to commit to the entire graduate program. After completing the program, students have the option of applying the earned credits toward a master’s degree in engineering management.

Admission 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.

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

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EGMT 501</td>
<td>Leading and Managing Technical Workers</td>
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<tr>
<td>EGMT 504</td>
<td>Design Thinking for Engineering Communications</td>
<td>3.0</td>
</tr>
<tr>
<td>EGMT 531</td>
<td>Engineering Economic Evaluation &amp; Analysis</td>
<td>3.0</td>
</tr>
<tr>
<td>EGMT 535</td>
<td>Financial Management</td>
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Electives (Choose One)

<table>
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<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGMT 502</td>
<td>Analysis and Decision Methods for Technical Managers</td>
<td>3.0</td>
</tr>
<tr>
<td>EGMT 536</td>
<td>Advanced Financial Management for Engineers</td>
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<tr>
<td>EGMT 614</td>
<td>Marketing: Identifying Customer Needs</td>
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<td>PROJ 501</td>
<td>Introduction to Project Management</td>
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</tr>
<tr>
<td>SYSE 685</td>
<td>Systems Engineering Management</td>
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Total Credits 15.0

Sample Plan of Study

First Year

<table>
<thead>
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<th>Fall</th>
<th>Credits</th>
<th>Winter</th>
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<td>EGMT 504</td>
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Second Year

<table>
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Total Credits 15

Additional Information

To learn more about the certificate or to apply for admission, please visit the Engineering Management (https://drexel.edu/engineering/academics/departments/construction-engineering-project-management-systems-engineering/academic-programs/graduate/engineering-management/certificate/) program page.

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 principals 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.

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.

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 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

Program Requirements

<table>
<thead>
<tr>
<th>Required Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSE 605 Naval Systems Engineering</td>
<td>3.0</td>
</tr>
<tr>
<td>SYSE 610 Naval Engineering for the 21st Century</td>
<td>3.0</td>
</tr>
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<table>
<thead>
<tr>
<th>Elective Courses (Choose 2)</th>
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</thead>
<tbody>
<tr>
<td>SYSE 524 Systems Reliability, Availability &amp; Maintainability Analysis</td>
<td></td>
</tr>
<tr>
<td>SYSE 533 Systems Integration and Test</td>
<td></td>
</tr>
<tr>
<td>SYSE 611 Advanced Naval Engineering</td>
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<td>SYSE 688 Systems Engineering Analysis</td>
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</table>

Total Credits 12.0

Sample Plan of Study

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits</th>
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<tbody>
<tr>
<td>SYSE 605 Fall</td>
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<tr>
<td>SYSE 610 Winter</td>
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<td>SYSE 611 Spring</td>
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<tr>
<td>SYSE 533 Summer</td>
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Total Credits 12

Certificate in Pharmaceutical and Medical Device Manufacturing

Certificate Level: Graduate

Admission Requirements: Bachelor of Science degree

Certificate Type: Post-Baccalaureate

Number of Credits to Completion: 18.0

Instructional Delivery: Online; Face-to-Face

Calendar Type: Quarter

Expected Time to Completion: 1 year

Financial Aid Eligibility: Not aid eligible

Classification of Instructional Program (CIP) Code: 51.2009

Standard Occupational Classification (SOC) Code: 29-1051

About the Program

Many chemical engineering graduates are working in the pharmaceutical industry. The Chemical and Biological Engineering Department offers a certificate in Pharmaceutical Engineering that addresses many topics that are relevant to the design and manufacture of pharmaceutical products and medical devices while maintaining regulatory compliance. The certificate can be taken as a standalone certificate or be used to fulfill elective requirements for MS or PhD degrees in engineering disciplines.

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 including official transcripts from all universities or colleges attended.
- Resume
- Personal essay

Master's students pursuing other technical disciplines may also complete the certificate courses as electives with approval from their advisor.
Program Requirements

Core Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHE 571</td>
<td>Pharmaceutical &amp; Medical Device Manufacturing I</td>
<td>3.0</td>
</tr>
<tr>
<td>CHE 572</td>
<td>Pharmaceutical &amp; Medical Device Manufacturing II</td>
<td>3.0</td>
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</table>

Foundation Courses (Choose Two)

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<thead>
<tr>
<th>Course</th>
<th>Title</th>
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<tr>
<td>CHE 560</td>
<td>Transport Phenomena in Biological Systems</td>
<td></td>
</tr>
<tr>
<td>CHE 562</td>
<td>Bioreactor Engineering</td>
<td></td>
</tr>
<tr>
<td>CHE 564</td>
<td>Unit Operations in Bioprocess Systems</td>
<td></td>
</tr>
<tr>
<td>PROJ 501</td>
<td>Introduction to Project Management</td>
<td></td>
</tr>
<tr>
<td>or EGMT 620</td>
<td>Engineering Project Management</td>
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</table>

Electives (Choose Two - including unused from Foundation Courses)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>BMES 501</td>
<td>Medical Sciences I</td>
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</tr>
<tr>
<td>BMES 509</td>
<td>Entrepreneurship for Biomedical Engineering and Science</td>
<td></td>
</tr>
<tr>
<td>BMES 510</td>
<td>Biomedical Statistics</td>
<td></td>
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<tr>
<td>BMES 538</td>
<td>Biomedical Ethics and Law</td>
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<tr>
<td>BMES 568</td>
<td>Medical Device Development</td>
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<tr>
<td>BMES 604</td>
<td>Pharmacogenomics</td>
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<td>BMES 660</td>
<td>Biomaterials I</td>
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<td>BMES 661</td>
<td>Biomaterials II</td>
<td></td>
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<td>BMES 821</td>
<td>Medical Instrumentation</td>
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<tr>
<td>BMES 822</td>
<td>Medical Instrumentation</td>
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<tr>
<td>BIO 500</td>
<td>Biochemistry I</td>
<td></td>
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<tr>
<td>BIO 615</td>
<td>Proteins</td>
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<td>BIO 640</td>
<td>Biometry</td>
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<td>BIO 641</td>
<td>Data Analysis in Biosciences</td>
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<tr>
<td>EGMT 531</td>
<td>Engineering Economic Evaluation &amp; Analysis</td>
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</tr>
<tr>
<td>EGMT 571</td>
<td>Engineering Statistics</td>
<td></td>
</tr>
<tr>
<td>EGMT 610</td>
<td>Ethics &amp; Business Practices for Engineers</td>
<td></td>
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<tr>
<td>EGMT 614</td>
<td>Marketing: Identifying Customer Needs</td>
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<tr>
<td>EGMT 615</td>
<td>New Product Conceptualization, Justification, and Implementation</td>
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<tr>
<td>EGMT 616</td>
<td>Value Creation through New Product Development</td>
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Total Credits 18.0

Sample Plan of Study

<table>
<thead>
<tr>
<th>First Year</th>
<th>Credits</th>
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<tbody>
<tr>
<td>Fall</td>
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</tr>
<tr>
<td>CHE 571</td>
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<tr>
<td>Foundation Course I</td>
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<tr>
<td>Winter</td>
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<tr>
<td>CHE 572</td>
<td>3.0</td>
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<tr>
<td>Elective</td>
<td>3.0</td>
</tr>
<tr>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>3.0 Foundation Course</td>
<td></td>
</tr>
<tr>
<td>3.0 Elective</td>
<td></td>
</tr>
<tr>
<td>Total Credits</td>
<td>18.0</td>
</tr>
</tbody>
</table>

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 wishing to complete this certificate in the context of a master's degree should consider the MS in Construction Management (p. 20) with a concentration in Real Estate.

Program Requirements

Requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>REAL 568</td>
<td>Real Estate Development</td>
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<tr>
<td>REAL 571</td>
<td>Advanced Real Estate Investment &amp; Analysis</td>
<td>3.0</td>
</tr>
<tr>
<td>REAL 572</td>
<td>Advanced Market Research &amp; Analysis</td>
<td>3.0</td>
</tr>
<tr>
<td>REAL 575</td>
<td>Real Estate Finance</td>
<td>3.0</td>
</tr>
<tr>
<td>REAL 577</td>
<td>Legal Issues in Real Estate Development</td>
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</tr>
<tr>
<td>or select one of the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REAL 573</td>
<td>Sales &amp; Marketing of Real Estate</td>
<td>3.0</td>
</tr>
<tr>
<td>REAL 574</td>
<td>Real Estate Economics in Urban Markets</td>
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</tr>
<tr>
<td>REAL 576</td>
<td>Real Estate Valuation &amp; Analysis</td>
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</table>

Total Credits 18.0

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/) webpage or contact the program academic advisor:

Ms. Jessica Cruz
jc635@drexel.edu
215-895-5943

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

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMGT 535 Community Impact Analysis</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 545 Sustainable Principles &amp; Practices</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 546 Sustainable Technologies</td>
<td>3.0</td>
</tr>
<tr>
<td>CMGT 547 LEED Concepts</td>
<td>3.0</td>
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<tr>
<td>CMGT 558 Community Sustainability</td>
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<tr>
<td><strong>Total Credits</strong></td>
<td><strong>15.0</strong></td>
</tr>
</tbody>
</table>

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 the program academic advisor:

Ms. Jessica Cruz
jc635@drexel.edu
215-895-5943

Certificate in Systems Design and Development

Certificate Level: Graduate
Admission Requirements: Bachelor's degree in engineering or other science
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: 14.2701
Standard Occupational Classification (SOC) Code: 17-2199

About the Program

The courses in this certificate focus on teaching students engineering design and management of large complex systems, including software intensive systems. By exposing the students to the systems engineering design body of knowledge and allowing them to develop systems skills in stimulating and challenging environments, they will be prepared to become industry leaders who can make a significant difference. Upon completion of this certificate, the students will be able to design, lead, and manage any systems engineering effort regardless of size, complexity, technologies, or engineering emphasis.

Admission Requirements

Degree and GPA Requirement

A bachelor's degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor’s degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. Applicants with degrees in the sciences may be required to take a number of undergraduate or post-baccalaureate courses. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required.

TOEFL Requirement

For students whose native language is not English and who do not hold a degree from a US institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum 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

Requirements

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Credits</th>
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<tbody>
<tr>
<td>SYSE 685 Systems Engineering Management</td>
<td>3.0</td>
</tr>
<tr>
<td>SYSE 688 Systems Engineering Analysis</td>
<td>3.0</td>
</tr>
<tr>
<td>SYSE 530 Systems Engineering Design</td>
<td>3.0</td>
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<td>SYSE 531 Systems Architecture Development</td>
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<td>SYSE 532 Software Systems Engineering</td>
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</tbody>
</table>

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: 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: 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 six 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.

Any students working or interested in the field of systems engineering should consider pursuing and completing this certificate.

**Admission Requirements**

**Degree and GPA Requirement**

A bachelor's degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor's degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. 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.

**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

**Program Requirements**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>SYSE 682</td>
<td>Introduction to Systems Science</td>
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<tr>
<td>SYSE 685</td>
<td>Systems Engineering Management</td>
<td>3.0</td>
</tr>
<tr>
<td>SYSE 688</td>
<td>Systems Engineering Analysis</td>
<td>3.0</td>
</tr>
<tr>
<td>SYSE 520</td>
<td>Global Sustainment and Integrated Logistics</td>
<td>3.0</td>
</tr>
<tr>
<td>SYSE 640</td>
<td>Model Based Systems Engineering</td>
<td>3.0</td>
</tr>
<tr>
<td>SYSE 690</td>
<td>Modeling and Simulation</td>
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</tr>
<tr>
<td><strong>Total Credits</strong></td>
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<td><strong>18.0</strong></td>
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**Sample Plan of Study**

**First Year**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Winter</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
<th>Summer</th>
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<tbody>
<tr>
<td>SYSE 685</td>
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<td>SYSE 520</td>
<td>3.0</td>
<td>SYSE 690</td>
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<tr>
<td>Fall</td>
<td>Credits</td>
<td>Winter</td>
<td>Credits</td>
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<tr>
<td>SYSE 682</td>
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<td><strong>18</strong></td>
</tr>
</tbody>
</table>

**Certificate in Systems Engineering Analysis**

Certificate Level: Graduate

Admission Requirements: Bachelor's degree in engineering or other science

Certificate Type: Post-Baccalaureate

Number of Credits to Completion: 15.0

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: 11-9041

**About the Program**

The courses in this certificate focus on teaching students statistical analysis and the use of mathematical models to solve a variety of problems. The courses are structured to discuss theory, process, and application. The primary emphasis is application, as the objectives of the courses are to provide students with skills to model problems, determine a quantitative solution, and perform sensitivity analysis. Theory and process are also studied so students learn how the models work by understanding the underlying theory associated with a particular model. Understanding of theory also enforces skills to conduct sensitivity analyses and helps answer “what if?” type questions. Upon successful completion of this certificate, students will be able to formulate mathematical models and solve quantitative problems.

Any students interested in decision sciences or advanced mathematical modeling and analysis should consider pursuing this certification.

**Admission Requirements**

**Degree and GPA Requirement**

A bachelor's degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor's degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor's degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor's degree as well as for any subsequent graduate-level work is required.

**TOEFL Requirement**

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**Other Requirements**

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- Official, sealed college transcripts
- An essay
- Two or more letters of recommendation

**Requirements**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EGMT 571</td>
<td>Engineering Statistics</td>
<td>3.0</td>
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<tr>
<td>EGMT 572</td>
<td>Statistical Data Analysis</td>
<td>3.0</td>
</tr>
<tr>
<td>EGMT 573</td>
<td>Operations Research</td>
<td>3.0</td>
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<tr>
<td>SYSE 525</td>
<td>Statistical Modeling &amp; Experimental Design</td>
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<td><strong>Total Credits</strong></td>
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**Certificate in Systems Engineering Integrated Logistics**

Certificate Level: Graduate
Admission Requirements: Bachelor’s degree in engineering or other science
Certificate Type: Graduate Certificate
Number of Credits to Completion: 18.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 1.5 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 courses in this certificate focus on teaching students to understand, analyze, and enhance the performance of complex and dynamic global supply chains. The certificate is structured with three quantitative courses: EGMT 571, EGMT 572, and EGMT 573 that will provide students with mathematical and statistical tools to analyze and evaluate the supply chain.

The remaining three courses (SYSE 520, SYSE 522, and SYSE 690) allow students to understand the dynamic and complex nature of global supply chains from a systems engineering perspective. They also teach students to implement the quantitative tools learned during the first three courses to efficiently manage the supply chain. Students will evaluate and analyze diverse types of supply chains through case studies, and they will analyze and discuss the best practices in supply chains across the world.

All affiliated courses may be applied to the Master of Science in Systems Engineering (p. 56) and the Master of Science in Engineering Management (p. 37).

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. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor’s degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor’s degree as well as for any subsequent graduate-level work is required.

TOEFL Requirement
For students whose native language is not English and who do not hold a degree from a US institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum 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

Requirements
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<td>EGMT 571</td>
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<tr>
<td>EGMT 572</td>
<td>Statistical Data Analysis</td>
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</tr>
<tr>
<td>EGMT 573</td>
<td>Operations Research</td>
<td>3.0</td>
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Certificate in Systems Reliability Engineering
Certificate Level: Graduate
Admission Requirements: Bachelor’s degree in engineering or other science
Certificate Type: Graduate Certificate
Number of Credits to Completion: 18.0
Instructional Delivery: Online
Calendar Type: Quarter
Expected Time to Completion: 1.5 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
This certificate teaches students to design for sustainability and reliability of systems during the life-cycle of an operation. The first three courses teach students the analytical tools required to perform reliability and maintainability modeling and analysis. The final three courses will focus on systems reliability, maintainability, and availability analysis (RM&A) for systems. The courses have an application to all phases of the systems engineering process, including requirements definition through systems design and development. The students will learn the process that starts with RM&A in the initial phases of development, conducting trade-off analysis during the system development phase to optimize reliability and availability of the system. The students will also learn to improve the reliability and availability of a product or a system by modeling and analysis of systems reliability using probability models.

Upon completion of the courses, students will be able to understand RM&A and modeling and apply reliability models for a product or system during its life-cycle: design, production, and warranty. Additionally, students will learn to conduct trade-off analysis to enhance availability and reliability of the system and to develop maintenance concepts that are cost effective and support sustainment of the system.

Admission Requirements
Degree and GPA Requirement
A bachelor’s degree in an engineering discipline from an ABET-accredited college or university is required. A bachelor’s degree in the sciences (physics, mathematics, computer science, etc.) may also be acceptable. An undergraduate degree earned abroad must be deemed equivalent to a US bachelor’s degree. A minimum 3.0 GPA (on a 4.0 scale) for a bachelor’s degree as well as for any subsequent graduate-level work is required.

TOEFL Requirement
For students whose native language is not English and who do not hold a degree from a US institution, the Test of English as a Foreign Language (TOEFL) is required. TOEFL scores must be less than two years old to be considered. Minimum 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

Program Requirements

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<tr>
<td>SYSE 688</td>
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<tr>
<td>SYSE 523</td>
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