



# COLLEGE OF ENGINEERING

## GRADUATE PROGRAMS

- **Biomechanics and Movement Science (MS, PhD)**  
(Interdisciplinary Program, see page 269)
- **Bioengineering**
- **Chemical Engineering (MCHE, PhD)**
- **Civil and Environmental Engineering (MAS, MCE, PhD)**
- **Electrical and Computer Engineering (MS, PhD)**
- **Materials Science and Engineering (MMSE, PhD)**
- **Mechanical Engineering (MEM, MSME, PhD)**
- **Ocean Engineering (MS, PhD)**

The College of Engineering has a strong commitment to graduate education through teaching and research. Programs leading to both the master's and PhD degrees are offered through the departments of Chemical, Civil and Environmental, Electrical and Computer, Materials Science and Engineering, and Mechanical Engineering. There is also a graduate program in Biomechanics and Movement Science. Many faculty are engaged in research in the bioengineering field, and there are numerous opportunities for graduate student participation.

Engineering graduate students at the University have the opportunity to participate in the College's eight research centers: the Center for Applied Coastal Research, the Center for Biomedical Engineering Research, the Center for Catalytic Science and Technology, the Center for Composite Materials, the Center for Innovative Bridge Engineering, the Center for Molecular and Engineering Thermodynamics, the Center for the Study of Metals in the Environment, and the Delaware Center for Transportation. Detailed information on specific research programs may be obtained from the appropriate center office or the relevant engineering department, or see:

<http://www.udel.edu/engg>

The College also meets the needs of practicing engineers who wish to further their education. The Engineering Outreach Program is designed to facilitate professionally convenient graduate education by working with the academic departments to schedule classes in the late day, evening, or in distance format. Part-time non-degree graduate students can take courses through Engineering Outreach, and these courses may be applied to a traditional or non-thesis graduate engineering degree upon regular admission to the graduate program. Detailed information about the Engineering Outreach Program may be obtained by calling (302) 831-2401. For more information, please visit the program web site at:

<http://www.udel.edu/engg/outreach>

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### BIOENGINEERING

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#### PROGRAM OVERVIEW

Although there are no programs in the College of Engineering which lead to a degree in biomedical engineering, considerable research and instruction in the application of engineering to problems related to the human body are being conducted in the Chemical,

Electrical and Computer, and Mechanical Engineering Departments. Many College faculty are actively involved in the Center for Biomedical Engineering Research and the Biomechanics and Movement Science Program. These efforts are also supported by programs in the Departments of Biological Sciences, Physical Therapy and Health and Exercise Sciences. In addition, education and research projects in biomedical engineering often involve extensive interaction with local medical centers and industrial laboratories.

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### CHEMICAL ENGINEERING

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Telephone: (302) 831-2543

<http://www.che.udel.edu>

Faculty Listing: <http://www.che.udel.edu/directory/faculty.html>

#### PROGRAM OVERVIEW

The Department of Chemical Engineering offers graduate programs leading to the Master of Chemical Engineering (MCHE) degree and the Doctor of Philosophy (PhD) in Chemical Engineering.

The purpose of the department's graduate programs is to provide the guidance and opportunity for students to develop the quantitative skills of engineering and science, and the acumen to apply these skills for the welfare of modern society. Students in the program naturally have a broad range of interests and career objectives, and it is the philosophy of the department to expose them to a variety of fundamental and applied research problems that will hone those engineering skills necessary in any career, whether in industry, academia or government.

This involves a combination of graduate core courses in chemical engineering and applied mathematics, advanced science and engineering electives, and independent (thesis) research conducted with the guidance and mentorship of a chemical engineering faculty member. (A non-thesis option is also available for the MCHE degree).

The Chemical Engineering Department is housed in Allan P. Colburn Laboratory, a memorial to one of the pioneers in chemical engineering who established the department. The laboratory houses the Center for Catalytic Science and Technology, which is equipped with the modern tools of catalysis and surface science, and the Center for Molecular and Engineering Thermodynamics, whose personnel study a range of thermodynamic problems. Other laboratory facilities

are for research in alternative energy, polymer engineering, rheology, process control, fluid mechanics, biochemical and biomedical engineering, materials science, photovoltaic systems, mass transfer, and separation processes. The department's growing emphasis on Bioengineering is enhanced by the participation of a number of faculty and students in the Delaware Biotechnology Institute. The department also benefits from close contacts with industrial colleagues in the Delaware Valley–New Jersey heartland of the chemical process industries. An extensive program of visiting scholars brings distinguished engineering scientists from around the world to the campus for periods ranging from a few days to a year.

Close contact, formal as well as informal, with colleagues in a wide range of industries is one of the distinguishing characteristics of the department. Such contact, with corporate leaders as well as practicing engineers and scientists, helps to provide students with an understanding of the milieu in which the engineer works. Lectures given by these visitors describe the unique opportunities that engineers have to contribute to the quality of life and also the restrictions that society, acting through industry and government, places on technology.

Extensive facilities for research and graduate study are available within the department. Laboratories specifically devoted to **catalysis, electrocatalysis and reaction engineering** house gas chromatographs interfaced with a computer-controlled mass spectrometer, infrared spectrophotometers for surface studies of working catalysts, electron spectrometers for analysis of catalyst surfaces, x-ray diffractometers, transmission and scanning electron microscopes, a laser-Raman spectrometer, an x-ray spectrometer, gas chemisorption equipment, many catalytic flow microreactors, and hardware/software for computational studies. Many of these studies are carried out in the University's pioneering Center for Catalytic Science and Technology, supported by governmental funds and grants from a group of industrial sponsors.

Laboratories specifically devoted to **polymer engineering** are equipped with multiple rheogoniometers and mechanical spectrometers, Instron test equipment, x-ray diffractometers, and equipment for spinning and extruding polymers. The polymer engineering group is involved in the research of Delaware's Center for Composite Materials and in interdisciplinary activity supported by several industrial organizations of the U.S., France, Germany, Italy, Japan, and the United Kingdom.

**Biochemical and biomedical engineering** laboratories contain a range of equipment for cell culture and fermentation, and for protein purification, analysis, and characterization. The latter includes 2-D gel electrophoresis, high performance liquid chromatography, membrane ultrafiltration, atomic force microscopy, and capillary electrophoresis. Research in the biological area is also conducted in collaboration with colleagues in the life sciences, the Department of Chemistry and Biochemistry, the College of Agriculture and Natural Resources, the Delaware Biotechnology Institute, and laboratories in the pharmaceutical and biotechnology industries.

The **process control and monitoring** laboratories contain a number of real-time instrumented experiments for online model-based control and fault diagnosis. The specific experiments include emulsion polymerization, complex quadruple-tank level control and other systems. All of these units are equipped with state-of-the-art control hardware and software systems.

The J.A. Gerster Memorial **Thermodynamics** Laboratories contain equipment for high-pressure and low-pressure vapor-liquid equilibrium, for high-temperature and multiphase equilibrium and other physical property measurements, and for separations processes. Molecular dynamics and quantum mechanical calculations and modeling of simple and complex fluids are performed on the Facility for Computational Chemistry's parallel computer and at other computational resources at the University as well as at national centers. These and other facilities are part of the Center for Molecular

and Engineering Thermodynamics.

Laboratories focused on the study of **colloids and interfaces** contain a variety of spectrometers for quasi-elastic light scattering, fluorescence measurements, and small-angle x-ray scattering. State-of-the-art instruments are available for the measurement of electrophoretic mobilities of colloids, surface tensions, ion activities, and conductivities, as well as for the determination of liquid phase compositions. Small angle neutron scattering investigations are also performed at national facilities.

Several faculty and students are involved in chemical engineering research in **photovoltaics** in which information needed for the design of large-scale processing units is obtained from laboratory-scale experimentation, in collaboration with the Institute for Energy Conversion. Experimental and theoretical studies in photovoltaic unit operations are conducted in a cooperative activity between the department and the Institute of Energy Conversion.

One of the most rapidly growing aspects of research within the department is **process modeling**. Research efforts include computer control and modeling of biochemical reactors, development and modeling of novel separations processes, modeling of transport in living systems, modeling and simulation of polymer processes, and elucidation and modeling of reaction pathways. To support the research in chemical engineering analysis, the department maintains its own computer laboratory. Numerous microcomputers are in use in our research laboratories both for data acquisition and modeling; most recently several BEOWULF clusters of high performance PC computers have been built; the department also makes extensive use of the University and national computing facilities described elsewhere in this catalog.

#### REQUIREMENTS FOR ADMISSION

The minimum requirements for admission to degree programs in the Department of Chemical Engineering are listed below:

1. A baccalaureate degree in the field or in a closely allied field of science or mathematics.
2. An undergraduate grade-point average in engineering, science, and mathematics courses of at least 3.0 on a 4.0 scale.
3. A minimum of three letters of strong support from former teachers or supervisors.
4. A minimum combined score of 1150 on the Graduate Record Examination Aptitude Test is required of all applicants to the Chemical Engineering PhD program. For the master's program, the GRE test is optional provided the applicant has a B.S. degree in chemical engineering from an ABET approved U.S. institution.
5. The Test of English as a Foreign Language is required for students whose first language is not English and who have not received a degree from a college or university in which English is the sole language of instruction. (Minimum score: 600 paper based TOEFL; 250 computer based TOEFL; 1010 IBET TOEFL.)

For chemical engineering applicants the scholastic index of 3.0 in the major field is computed from the previous undergraduate work and from graduate work done in mathematics, chemistry, physics, and engineering courses. In exceptional circumstances, it may be possible to obtain provisional admission if one or more of the above criteria has not been satisfied. Admission to the graduate program in Chemical Engineering at the University of Delaware is selective and competitive based on the number of well-qualified applicants and the limits of available faculty and facilities. Those who meet stated minimum academic requirements are not guaranteed admission. On the other hand, on rare occasions, those who fail to meet those requirements can be granted admission if they offer other exceptional strengths.

Undergraduate preparation consisting of a bachelor's program in chemical engineering leads most directly into the graduate program.

However, students and practicing industrialists with a background in chemistry will also profit from this graduate program, since chemical engineering provides for the application of their scientific skills to solutions of technological problems in industry and society. Graduates of other disciplines are also encouraged to apply; some remedial work may be required and is discussed on an individual basis.

#### FINANCIAL AID

Please refer to the chapter "Graduate Fellowships and Assistantships" in this catalog.

#### REQUIREMENTS FOR THE MASTER'S DEGREE

To develop the skills that recipients of master's degrees are expected to possess and use effectively, students enroll in courses that sharpen their analytic tools and provide practice in the application of these to engineering problems. Students may also select studies that develop an appreciation for society's constraints on, and opportunities for, science and technology. The MCHE program is typically elected by students wishing to carry out industrial design analysis or process and product development, and by some students who continue their studies toward the PhD. The formal requirements of 24 credit hours of course work and a 6-credit-hour thesis for the MCHE degree are substantial and are recognized as such by industrial organizations. A non-thesis MCHE degree of 30 credit hours of appropriate course work is also a degree option in the department.

#### REQUIREMENTS FOR THE PHD DEGREE

Students may elect to study directly toward a PhD upon enrollment or may obtain the MCHE degree first. Admission to the PhD program in chemical engineering formally requires passing an oral qualifying examination prepared by the department as well as achieving a minimum 3.0 GPA in a set of required graduate courses. The oral examination includes presentation of a research proposition by the candidate to demonstrate the ability to devise and develop a research idea. Current requirements also include a minimum of 3 elective CHEG 600 and 800 level courses (a total of 8 credits) with at least 3 credits at the advanced (800) level. Students may also substitute courses offered by other departments upon approval.

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### CIVIL AND ENVIRONMENTAL ENGINEERING

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Telephone: (302) 831-2442

<http://www.ce.udel.edu>

Faculty Listing: <http://www.ce.udel.edu/directories/faculty.html>

#### PROGRAM OVERVIEW

The Department of Civil and Environmental Engineering offers graduate programs of study and research leading to three degrees: Master of Civil Engineering, Master of Applied Sciences, and Doctor of Philosophy in Civil Engineering. The Master of Civil Engineering degree emphasizes Civil Engineering, while the Master of Applied Sciences degree is for students not having engineering as first degrees. The PhD is aimed at training the graduate student in research within a chosen topic. All three degrees are based on the student completing an individually designed program of courses and writing a thesis. A non-thesis Master's degree option is available, typically for students with professional experience. Students selecting the non-thesis option are not eligible for financial support from the University. Areas of concentration are:

- Environmental Engineering
- Structural Engineering
- Geotechnical Engineering
- Transportation Engineering

- Coastal Engineering
- Water Resource Engineering

In cooperation with the College of Marine and Earth Studies, the department also offers multidisciplinary degrees for the Master of Science and Doctor of Philosophy in Ocean Engineering.

In each area, mathematics, fundamental sciences and engineering sciences are combined to provide a personalized program of study and research.

All graduate students work in close cooperation with the faculty, and the department has extensive facilities for research and graduate study in all the areas of concentration. Laboratories specifically devoted to research in environmental engineering include facilities for study of chemical and physical aspects of water and wastewater purification with specialized equipment for analysis of fluid particle suspensions and particle technology, heavy metal and toxic waste removal and biological engineering aspects of water pollution control.

The ocean engineering laboratory is one of the largest and best equipped in the country. A unique wavemaker capable of generating realistic three-dimensional seas has been installed in one of the wave basins. Narrow and wide wave tanks are also available including a high precision 108 ft. long wave flume. Equipment available for field research includes tide gages, current meters, fathometers, surveying equipment, remote-sensing apparatus, and small research vessels.

The structures laboratories include an excellent range of equipment for static, dynamic, and fatigue testing, and a modern concrete testing facility. The geotechnical laboratory has state-of-the-art equipment for testing soils and geotextiles.

The department's research is extensively funded through many contracts from federal agencies, the state, and private engineering sponsors. The department houses the Center for Applied Coastal Research, the Center for Innovative Bridge Engineering, the Center for the Study of Metals in the Environment, and the Delaware Center for Transportation.

#### REQUIREMENTS FOR ADMISSION

Candidates for admission are invited to correspond with the department chair and/or members of the faculty. A personal visit to the department is recommended wherever possible. Students who are interested in admission may request current department information on curriculum, core courses, and degree programs.

Courses are offered annually or in alternate years, but always as organized programs orchestrated to ensure that the necessary courses are always available to our students.

Applicants are expected to have:

1. A baccalaureate degree in the field or in a closely allied field of science or mathematics,
2. An undergraduate grade-point average in engineering, science, and mathematics courses of 3.0 on a 4.0 scale,
3. A minimum of three letters of strong support from former teachers or supervisors,
4. A minimum combined score of 1050 on the Graduate Record Examination Aptitude Test,
5. The Test of English as a Foreign Language (TOEFL) is required for students whose first language is not English and who have not received a degree from a college or university in which English is the sole language of instruction. (Minimum score: 550 paper based TOEFL; 213 computer based TOEFL; 79 IBET TOEFL.)

Admission to the graduate program in Civil Engineering at the University of Delaware is selective and competitive based on the number of well qualified applicants and the limits of available faculty and facilities. Those who meet stated minimum academic requirements are not guaranteed admission.

## FINANCIAL AID

Please refer to the chapter "Graduate Fellowships and Assistantships" in this catalog.

## REQUIREMENTS FOR THE MASTER'S DEGREES

The master's degree requires that the student obtains skills in a range of modern analytical and computational tools and in their application to engineering problems. Formally, the student must perform 24 credit hours of course work and 6 credit hours of thesis. For students with professional experience, a non-thesis option is available. The MCE program is often chosen by students planning to pursue a career as professional engineers. The program, however, is also well suited as an introduction to a PhD in Civil Engineering or other engineering or science-oriented areas.

The specific requirements for the different degrees are available upon request to the department.

## REQUIREMENTS FOR THE PHD DEGREE

Although it is possible for students to study toward a PhD directly upon entering graduate school, most students choose to obtain the MCE or MAS first.

A student's doctoral program, including the doctoral thesis, is centered on a research objective in applied or engineering science. The degree requires sufficient course work within, or in direct support of, the chosen area of concentration to form an adequate basis for original work. In addition, the student's knowledge must be extended within other fundamental sub-areas such as applied mathematics, physical, chemical, biological and engineering sciences. In the thesis the student reports the findings of his or her independent research. Further information about details may be obtained from the current Departmental Graduate Program brochures.

The PhD is particularly useful for students who plan to pursue a career in research and teaching at the university level but also provides a superlative education for a career as a professional engineer.

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## ELECTRICAL AND COMPUTER ENGINEERING

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Telephone: (302) 831-2406

<http://www.ece.udel.edu>

Faculty Listing: <http://www.ece.udel.edu/people/faculty/>

## PROGRAM OVERVIEW

The Electrical and Computer Engineering Department offers programs leading to the degrees of Master of Science in Electrical and Computer Engineering and Doctor of Philosophy in Electrical and Computer Engineering.

Active areas of research in electrical and computer engineering include bioengineering, clean energy, communications, signal processing and controls, computer and sensor networks, computer systems, electromagnetics and photonics, and materials devices nanoelectronics.

The Department of Electrical and Computer Engineering is housed in Evans Hall and DuPont Hall. The Department maintains excellent facilities for teaching and research, including supercomputing and distributed computing systems, and class 10 and class 1000 clean rooms equipped for epitaxial crystal growth, semiconductor device fabrication, and nanofabrication. Additional laboratories are well-equipped for electronic, microwave, and optical measurements, signal and image capture and processing, antenna, electromagnetics, and communications studies, and biomedical signal capture and investigations. Complementing these facilities are Government funded major Research Centers supporting the focus areas, including the Solar Power Center, Nanotechnology Center, and the Delaware Biotechnology Institute.

General computing facilities include state-of-the-art servers from Sun Microsystems, with a variety of workstations from Sun, SGI, HP, IBM and others. The Department maintains a state-of-the-art Intranet connecting all rooms, labs, and offices, as well as connecting the Department with the rest of campus and the Internet. Several computing laboratories are available with workstations, PCs, and a variety of software to support teaching and research with 24x7 access. Many labs contain specialized computing and networking equipment to aid research in specific areas.

Graduate students are expected to actively participate in research, including the development of presentations and publications detailing their research contributions.

## REQUIREMENTS FOR ADMISSION

The requirements for admission to the master's and/or doctoral program in electrical and computer engineering are:

1. Applicants normally will have a B.S. in electrical or computer engineering. However, admission may be granted to applicants with good training in other engineering or related fields, such as math, physics, or computer science. Students without a B.S. in electrical or computer engineering may be admitted with provisional status and may be required to complete prerequisite courses that are deemed necessary for the appropriate preparation for courses in the program.
2. All applicants are required to submit Graduate Record Examination (GRE) scores. The Department requires a combined score of the verbal and math sections in excess of 1050, with a mathematics score in excess of 600. (Foreign student applicants with low verbal scores will be considered if the applicant's TOEFL score is acceptable and if the applicant has a high quantitative GRE score.)
3. The Test of English as a Foreign Language (TOEFL) is required for students whose first language is not English and who have not received a degree from a college or university in which English is the sole language of instruction. The Department requires a minimum TOEFL score of 550/213/79 (papers/computer examination in IBET) for admission and a minimum score of 600/250/100 for consideration as a Teaching Assistant (TA).
4. Applicants are expected to have a "B" or better undergraduate record, which is based on the last two years of undergraduate schooling, plus the applicant's record in advanced engineering, mathematics, and science courses. Admission is selective and meeting the minimum requirements of the Department does not guarantee admission. The number and quality of other applicants as well as the availability of faculty supervision and laboratory space affect the number of students offered admission. The Department may find it appropriate to consider admitting an applicant who does not meet all of the admission requirements as stated if it is clear that other strengths identified in the applicant's admission information outweigh the stated minimum requirements for admission.

## REQUIREMENTS FOR THE DEGREES

### Master's Degree - Thesis Program

The thesis master's degree program is designed for individuals who want to broaden their electrical and computer engineering foundation knowledge while also conducting an in-depth research project. All master's degree students receiving financial aid, at any point in their program, must take the thesis option.

**Credit Requirements:** The master's program requires 30 credit hours including at least 24 graduate course credits and at least 6 credits for master's thesis (ELEG 869). The Graduate Committee must approve each student's program.

The 24-credit course program of each student must include:

1. Six (6) credits of electrical and computer engineering Foundation courses.

2. Eighteen (18) credits of advanced technical courses (level 600 or above) related to the student's area of interest. At most twelve (12) credits of these can bear non-ELEG/CPEG numbers and at least three (3) credits must be of 800 level electrical and computer engineering courses.

**Thesis Requirement:** All students in the thesis master's degree program will carry out original publishable research in collaboration with their advisor and, possibly, other collaborators. Masters's candidates must write a thesis describing their contributions to this research. Theses must follow the University's rules and those accepted in the profession for the presentation of original work. Master's theses will have two faculty readers, the advisor and one additional reader approved by the faculty advisor and Graduate Committee. The Department Chair, upon recommendation of the readers, approves theses.

#### Master's Degree - Non-Thesis Program

This program is intended to satisfy the continuing education needs of working engineers and recent graduates who want to broaden their electrical and computer engineering foundation before starting an industrial career. University financial aid is not available to students taking this program. Students receiving financial aid, at any point in their program, must enroll in the thesis master's degree program.

**Credit Requirements:** The non-thesis master's program requires 30 credit hours of course work. The Graduate Committee must approve each student's program.

The 30-credit course program of each student must include:

1. Six (6) credits of electrical and computer engineering foundation courses.
2. Twenty-four (24) credits of advanced technical courses (level 600 or above) related to the student's area of interest. At least six (6) credits of these must be 800 level electrical and computer engineering courses and at most twelve (12) credits can bear non-ELEG/CPEG numbers.

#### PhD Degree

The PhD degree program is designed for individuals interested in fundamental research on novel aspects of electrical and computer engineering. The degree is intended for individuals planning to pursue academic research and/or industrial research and development careers. All students pursuing the PhD degree are initially entered in pre-candidacy. Formal entry into the PhD program, or candidacy, is granted following the successful completion of the PhD Qualifying Examination and approval by the Graduate Committee of the student's Research and Study Program.

The PhD is a research degree. Each PhD candidate must carry out a program of substantial original publishable research on a topic agreed upon by his/her committee and prepare a written dissertation. Candidates must also satisfy the following general requirements:

1. Candidates are required to complete one continuous academic year of full-time study as a residency requirement.
2. Candidates must complete the course requirements for the thesis master's degree, or have been awarded a master's degree in electrical or computer engineering or closely related field.
3. Candidates must take at least two foundation courses outside their area of concentration.
4. Candidates must take at least 9 credits of Doctoral Dissertation (ELEG 969).

### CONCENTRATIONS

Students in all Electrical and Computer Engineering graduate degree programs may elect to choose a concentration area of study. Concentrations are available in Computer Systems & Networking, Signal Processing, Communications and Controls, Materials and Devices, Electromagnetics and Photonics, and Biomedical

Engineering. Students selecting a concentration must meet the concentration requirements detailed below, in addition to meeting their general degree requirements. Concentrations are voluntary, and students selecting multidisciplinary or other specialized studies need not declare a concentration.

### CONCENTRATION IN COMPUTER SYSTEMS & NETWORKING

Students in the Computer Systems & Networking (CSN) concentration focus on research and coursework in computer architecture and parallel systems, optimizing and parallelizing compilers, design and test of high-performance digital and analog VLSI circuits, wired and mobile wireless networking, computer program optimization, as well as emerging CSN theories and applications.

#### Required Courses:

|          |  |   |
|----------|--|---|
| ELEG 651 | Computer Networking Communications           | 3 |
| ELEG 652 | Principles of Parallel Computer Architecture | 3 |
| ELEG 662 | Digital System Seminar (each semester)       | 0 |

#### A minimum of two courses from the following:

|              |  |   |
|--------------|--|---|
| CPEG 621     | Compiler Design                                    | 3 |
| CPEG 622     | Computer Systems Design II                         | 3 |
| CPEG 660     | Introduction to VLSI Systems                       | 3 |
| ELEG 653     | Computer System Security                           | 3 |
| ELEG 667-011 | Sensor Networks                                    | 3 |
| ELEG 667-012 | High-performance Computing with Commodity Hardware | 3 |
| ELEG 819     | Topics in Networking I                             | 3 |
| ELEG 820     | Topics in Networking II                            | 3 |

### CONCENTRATION IN SIGNAL PROCESSING, COMMUNICATIONS, AND CONTROLS

Students in the Signal Processing, Communications, and Controls (SPCC) concentration focus on research and coursework in multimedia signal processing, statistical and nonlinear signal processing, image processing, time-frequency analysis, wireless communications, information theory, coding, as well as emerging SPCC theories and applications. Students in the SPCC concentration must complete the following:

#### A minimum of two courses from the following:

|          |                               |   |
|----------|-------------------------------|---|
| ELEG 630 | Information Theory            | 3 |
| ELEG 631 | Digital Signal Processing     | 3 |
| ELEG 635 | Digital Communications        | 3 |
| ELEG 636 | Statistical Signal Processing | 3 |

#### A minimum of two courses from the following:

|          |   |   |
|----------|---|---|
| ELEG 611 | Linear Systems Theory                         | 3 |
| ELEG 619 | Multimedia Communications                     | 3 |
| ELEG 633 | Image Processing                              | 3 |
| ELEG 654 | Sensor and Data Wireless Networks             | 3 |
| ELEG 675 | Image Processing with Biomedical Applications | 3 |
| ELEG 677 | Biosignal Processing                          | 3 |
| ELEG 811 | Channel Coding Theory and Practice            | 3 |
| ELEG 812 | Wireless Digital Communications               | 3 |
| ELEG 832 | Wavelets and Filter Banks                     | 3 |
| ELEG 833 | Nonlinear Signal Processing                   | 3 |

#### Required courses:

|          |   |   |
|----------|---|---|
| ELEG 663 | Signal Processing Seminar (each semester) | 0 |
|----------|---|---|

### CONCENTRATION IN MATERIALS AND DEVICES

Students in the Materials and Devices (MD) concentration focus on research and coursework in solid-state physics, semiconductor growth, device fabrication, and electromagnetic measurement and characterization.

#### Required courses:

|          |   |   |
|----------|---|---|
| ELEG 622 | Electronic Materials Processing               | 3 |
| ELEG 646 | Nanoelectronic Device Principles              | 3 |
| ELEG 661 | Materials and Devices Seminar (each semester) | 0 |

**A minimum of two courses from the following:**

|          |  |   |
|----------|--|---|
| ELEG 627 | THz and MMW Light Generation and Detection. . . . .  | 3 |
| ELEG 639 | Magnetism and Spintronics . . . . .                  | 3 |
| ELEG 640 | Opto-Electronics . . . . .                           | 3 |
| ELEG 648 | Advanced Engineering Electromagnetics . . . . .      | 3 |
| ELEG 647 | Optical Properties of Solids . . . . .               | 3 |
| ELEG 650 | Semiconductor Device Design and Fabrication. . . . . | 3 |

**CONCENTRATION IN ELECTROMAGNETICS AND PHOTONICS**

Students in the Electromagnetics and Photonics (EP) concentration focus on research and coursework in optics and electromagnetics, optoelectronic, microwave, millimeter-wave and terahertz devices and systems, device fabrication, and electromagnetic measurement and characterization.

**Required courses:**

|          |   |   |
|----------|---|---|
| ELEG 648 | Advanced Engineering Electromagnetics . . . . .         | 3 |
| ELEG 661 | Materials and Devices Seminar (each semester) . . . . . | 0 |
| ELEG 667 | Optics and Photonics . . . . .                          | 3 |

**A minimum of two courses from the following:**

|          |   |   |
|----------|---|---|
| ELEG 622 | Electronic Materials Processing . . . . .           | 3 |
| ELEG 627 | THz and MMW Light Generation and Detection. . . . . | 3 |
| ELEG 638 | Theory and Design of Diffractive Optics . . . . .   | 3 |
| ELEG 640 | Opto-Electronics . . . . .                          | 3 |
| ELEG 641 | Antenna Theory and Design . . . . .                 | 3 |
| ELEG 646 | Nanoelectronic Device Principles . . . . .          | 3 |
| ELEG 842 | RF and Microwave Technology . . . . .               | 3 |
| ELEG 853 | Integrated Optics . . . . .                         | 3 |
| ELEG 855 | Microwave and Millimeter-wave Technology . . . . .  | 3 |

**CONCENTRATION IN BIOMEDICAL ENGINEERING**

Students in the Biomedical Engineering (BME) concentration focus on research and coursework in biomedical applications of signal and image processing, imaging systems, biophotonics, biochemical detection, cardiovascular and respiratory control, electrophysiology, computational biology, and bioinformatics. The BME concentration is available to students in the MSECE and PhD degree programs.

**Required courses:**

|          |  |   |
|----------|--|---|
| ELEG 664 | Biomedical Engineering Seminar (each semester) . . . . . | 0 |
| ELEG 671 | Introduction to Biomedical Engineering . . . . .         | 3 |
| ELEG 679 | Introduction to Medical Imaging Systems. . . . .         | 3 |

**A minimum of two courses from the following:**

|          |   |   |
|----------|---|---|
| ELEG 670 | Biophysics of Excitable Membranes . . . . .             | 3 |
| ELEG 673 | Signal Processing in Neural Systems. . . . .            | 3 |
| ELEG 675 | Image Processing with Biomedical Applications . . . . . | 3 |
| ELEG 676 | Bioinformatics and Biosystems Analysis I. . . . .       | 3 |
| ELEG 678 | Introduction to Nano and Biophotonics . . . . .         | 3 |
| ELEG 680 | Immunology for Engineers . . . . .                      | 3 |

**MATERIALS SCIENCE AND ENGINEERING**

Telephone: (302) 831-2062  
<http://www.mseg.udel.edu/>  
 Faculty Listing: <http://www.mseg.udel.edu/directories/index.php>

**PROGRAM OVERVIEW**

The Department of Materials Science and Engineering offers programs leading to the degrees of Master of Materials Science and Engineering and Doctor of Philosophy. At the master's level, there are both thesis and non-thesis options.

The goal of materials science is to provide improved materials for society. Current new materials technologies demand materials scientists and engineers who can relate the processing, structure, and properties of a broad range of materials. The master's program offers a foundation in the science of materials and their uses. The PhD program offers a development of the student's ability to conduct original, creative research. Areas of study within the program include:

**Materials chemistry** - design and synthesis of novel materi-

als by combining chemical architectures that have specific properties, e.g., electrical conductivity, rigidity, flexibility, solubility, etc.

**Polymers** - interrelations among processing, microstructure and behavior of polymeric solids and thin films.

**Electronic materials** - electrical, magnetic, optical and thermal behavior of materials, including semiconductors, photovoltaics, superconductors, electroluminescent polymers, and devices.

**Composite materials** - manufacturing, microstructure, and properties of composite materials.

**Biomolecular materials** - synthesis and characterization of novel chemical architectures that incorporate peptide and nucleotide sequences; bio-inspired materials, protein polymers.

**Nanoscale materials** - synthesis, characterization and processing of materials at length scales where bulk "properties" are modified.

**RESEARCH FACILITIES**

Since the primary goal of the Department is to foster the development of Materials Science in general at Delaware, we are committed to acquiring, operating and maintaining a wide range of experimental equipment. To this end, and in addition to the usual laboratory equipment, the Department operates an Electron Microscope Laboratory, a Vibrational (Raman, IR) Spectroscopy Laboratory, and an X-ray Laboratory as facilities which are available to researchers who may need them in the course of their work. A wide range of other analytical, computing, synthesis, and fabrication facilities are also available within the College of Engineering.

**FINANCIAL AID**

Please refer to the chapter "Graduate Fellowships and Assistantships" in this catalog.

**REQUIREMENTS FOR ADMISSION**

Applicants are expected to have:

1. A baccalaureate degree in materials science, in an engineering discipline or in a physical science.
2. An undergraduate grade-point average in engineering, science, and mathematics courses of 3.2 on a 4.0 scale.
3. A minimum of three letters of strong support from former teachers or supervisors.
4. A minimum combined verbal and quantitative score of 1150 on the Graduate Record Examination Aptitude Test.
5. The Test of English as a Foreign Language for students whose first language is not English and who have not received a degree from a college or university in which English is the sole language of instruction. (Minimum score: 550 on paper based TOEFL; 213 on computer based TOEFL 79 on IBET TOEFL.)

Admission is selective and competitive based on the number of well qualified applicants and the limits of available faculty and facilities. Those who meet stated minimum academic requirements are not guaranteed admission.

**REQUIREMENTS FOR THE DEGREES**

For the **MMSE degree with thesis**, 24 credit hours of course work and 6 credits of thesis work on a research topic are required. Of the 24 credits of course work, 9 credits are elective and are chosen in an area of specialization after discussion with the student's advisor.

For the **MMSE degree without thesis**, 30 credit hours of course work are required. Of the 30 credits of course work, 15 credits are elective and are chosen after discussion with the student's advisor and will usually be related to the student's area of interest. The non-thesis MMSE degree is offered specifically for off-campus, part-time students and is not available to full-time graduate students.

For the **PhD degree**, 12 credits of coursework are required beyond those necessary for the master's degree. The candidate must also pass a qualifying examination. Subsequently, the student conducts research on a topic with an adviser of his or her own choosing. The dissertation must be of publishable quality as judged by the senior materials faculty. Finally, the student must pass an oral examination on the dissertation.

Part-time graduate education is available through the Engineering Outreach Program.

All graduate students must maintain a cumulative grade-point index of 3.0.

### FACILITY OF EXPRESSION IN ENGLISH

It is a requirement of the Department that students demonstrate an ability to express themselves orally in a clear and professional manner. Each candidate must present his or her research results in a departmental colloquium.

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## MECHANICAL ENGINEERING

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Telephone: (302) 831-2421

<http://www.me.udel.edu>

Faculty Listing: <http://www.me.udel.edu/People/people.html>

### PROGRAM OVERVIEW

The Department of Mechanical Engineering offers graduate programs leading to the degrees of Master of Science in Mechanical Engineering (MSME), Master of Engineering: Mechanical (MEM) and Doctor of Philosophy (PhD) in mechanical engineering.

The graduate programs are designed to provide a broad based extension of the undergraduate experience in combination with formal course work and research in the student's selected area of specialization. Independent research is required for both the MSME and PhD degrees, while the MEM is a non-thesis degree program designed for part-time students. One may enroll into the PhD program directly after the Bachelor's degree in Mechanical Engineering.

### RESEARCH FACILITIES AND OPPORTUNITIES

The research opportunities in the department cover essentially all fundamental fields of mechanical engineering including solid and fluid mechanics, materials, dynamics, thermodynamics and heat transfer. Applied and interdisciplinary research of the department is focused in five areas: biomedical engineering, clean energy, composites and nanotechnology, robotics and control, and atmospheric and environmental fluid mechanics.

The department faculty participate in cross-disciplinary research programs of the Center for Composite Materials, whose work includes the mechanics and manufacture of multifunctional materials and the study of smart structures.

The Center for Biomedical Engineering Research provides a framework for interdisciplinary research in the general area of biomedical engineering. Topics include the generation of force and motion in the human body, orthopedic and rehabilitation engineering, joint lubrication, tissue engineering, sports medicine, and biofluid mechanics.

The Center for Fuel Cell Research supports research to improve the understanding of fuel cell materials and processes by facilitating coordination amongst the approximately 20 UD faculty members working in this area. The CFCR also encourages interactions and collaborations with industries involved in fuel cells and hydrogen infrastructure activities.

While the major focus of clean energy research is on the improvement of performance and durability of fuel cells, other topics include wind energy, and vehicle-to-grid technology.

Composites and nanotechnology research involves characterization, modeling and processing of heterogeneous and nanostructured materials. Composites research is focused on process modeling and manufacturing, mechanics and multiscale modeling, durability, and temperature dependent behavior. Nanotechnology research encompasses nanotubes, nanofibers, nanoclays and their composites.

Current research areas in robotics and control are design of novel robotic systems, coordination and control of multi-degree-of-freedom robot systems, intelligent small machines, and control of dynamic systems.

Atmospheric and environmental fluid mechanics deal with naturally occurring flow systems and their impact on contaminant transport in air and groundwater at all scales as well as weather, climate, and the water cycle.

The department is housed in the Robert L. Spencer Laboratory, containing modern facilities for a wide range of computational and experimental projects. Among the facilities are particle image velocimeters, scanning and transmission electron microscopes, high-vacuum chambers, mechanical- and ballistic-impact-testing systems, robots, fuel cell test stands, high speed infrared thermographic camera, tension and compression split Hopkinson bars, 3-D printer, fully equipped 6-camera gait analysis laboratory, telemetered and wired EM6 amplifiers, ultrasound, and extensive research-grade electronic instrumentation. A fully staffed and equipped machine shop with a CNC lathe and miller support the research programs.

A wide variety of other research facilities are available throughout the college and university.

### REQUIREMENTS FOR ADMISSION

The following minimum criteria apply. Satisfaction of the minimum requirements will not guarantee financial aid.

1. A baccalaureate degree in mechanical engineering or in a closely allied field of science or mathematics.
2. An undergraduate grade point average in engineering, science and mathematics courses of at least 3.0 on a 4.0 scale.
3. A minimum of at least three letters of strong support from former teachers or supervisors.
4. A minimum combined Quantitative and Verbal score of 1200 in the Graduate Record Examination Aptitude Test.
5. The Test of English as a Foreign Language for students whose first language is not English. (Minimum score: 600 on paper based TOEFL or equivalent.)

Awards of financial assistance are made on the basis of merit and students who complete applications by January 15 are given preference.

### FINANCIAL AID

Please refer to the chapter "Graduate Fellowships and Assistantships" in this catalog.

### REQUIREMENTS FOR THE DEGREES

The **Master of Science in Mechanical Engineering degree** requires a minimum of 24 credit hours of course work beyond the bachelor's degree and a thesis equivalent to 6 credit hours. The Master of Engineering: Mechanical degree requires the completion of 30 credit hours of course work beyond the bachelor's degree and does not require a thesis. Courses for both degrees may be selected from a range of fundamental and applied topics in mechanical engineering.

The **doctoral program** in mechanical engineering allows considerable flexibility in setting up a plan of study that best suits the student's individual needs and interests. It is possible to pursue the PhD degree directly after a bachelor's degree. Students must pass the Qualifying Exam within 1 year of starting the program.

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**OCEAN ENGINEERING**


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Telephone: (302) 831-2442

**PROGRAM OVERVIEW**

The Ocean Engineering program offers Master of Science and Doctor of Philosophy degrees through a cross-disciplinary program operated jointly by the Physical Ocean Science and Engineering (POSE) program in the Graduate College of Marine and Earth Studies (CMES) and the Ocean Engineering program of the Department of Civil and Environmental Engineering. Additional information about the two academic units is available at the web-sites:

<http://www.ocean.udel.edu>

(The Graduate College of Marine and Earth Studies)

<http://www.coastal.udel.edu>

(The Department of Civil and Environmental Engineering, Center for Applied Coastal Research)

Subject to the admission requirements below, students matriculating through CMES have the option of pursuing advanced degrees in Marine Studies through CMES or the cross-disciplinary degree in Ocean Engineering. Students matriculating through the College of Engineering have the option of pursuing advanced degrees in Ocean Engineering or in Civil and Environmental Engineering.

**REQUIREMENTS FOR ADMISSION**

The minimum requirements for admission to a graduate program for a Master of Science or Doctor of Philosophy in Ocean Engineering are as follows: a Bachelor of Science in engineering, an undergraduate grade point average of at least 3.0 (out of a possible 4.0), GRE scores (verbal and quantitative combined) of at least 1200, and a TOEFL score (for international students) of at least 600 on the paper based TOEFL; 250 on computer based TOEFL; 100 on IBET TOEFL. The POSE graduate committee may increase these minimum requirements.

Students with bachelor's degrees and exceptional academic backgrounds may be admitted directly into the PhD program. Students admitted into the MS program may petition to move into the PhD program before completing the MS

Students considering doctoral study must have completed all previous graduate studies with at least a 3.5 grade point average and have clearly demonstrated a capacity for independent work. If a MS thesis or other comprehensive work was written at another institution, a copy of the thesis will be provided to the advisor when the student enrolls at University of Delaware.

Students will be assigned an advisor upon admission to the Ocean Engineering program and will be enrolled in the academic unit that is the home of the advisor (Department of Civil and Environmental Engineering in the College of Engineering or the POSE program in the College of Marine and Earth Studies).

**FINANCIAL AID**

Please refer to the chapter "Graduate Fellowships and Assistantships" in this catalog.

**REQUIREMENTS FOR THE MASTER'S DEGREE**

The Ocean Engineering program is aimed at providing graduate students with advanced technical training in ocean science and engineering for positions in the public and private sectors and for matriculating into PhD programs.

General Requirements: The Ocean Engineering Master of Science requires a minimum of 30 credit hours. This includes a thesis and dependent research. Students shall defend their thesis in an open oral examination chaired by the advisor. Students may earn up to six credits for their thesis.

**\*Required Courses:**

MAST 691/CIEG 639 Ocean Fluid Dynamics  
 MAST 882 Physical Ocean Science and Engineering Seminar  
 or  
 CIEG 865 Civil Engineering Seminar  
 MEEG 690 Intermediate Engineering Mathematics  
 MAST 693 Waves in the Marine Environment  
 or  
 CIEG 672/MAST 648 Wave Water Mechanics

Additional courses typically include at least 9 credits at the graduate level with 6 credits at the 800 level. Approval for the course curriculum is made by the student's advisor. Petitions for required course substitutions may be made via the advisor to the program director. A maximum of 9 graduate course credits from other universities may be applied toward the Master's degree.

**REQUIREMENTS FOR THE PHD DEGREE**

The Ocean Engineering PhD program is aimed at training graduate students to achieve the highest level of proficiency in research. The doctoral program is planned around a central engineering objective. The total program is comprised of 72 credits beyond the bachelor's degree that include a minimum of 36 credits of coursework, 6 credits for the Master's Thesis (if applicable), 9 credits for the PhD Dissertation, and a minimum of 9 credits for research. For students holding a master's degree in an appropriate field of study, the coursework from the master's degree will be taken into account in the design of the doctoral program. All graduate students work in close cooperation with the faculty on their dissertation area.

**GENERAL REQUIREMENTS**

**Residency Requirement:** The student must meet a campus residency requirement of at least one continuous academic year. If a student has earned a master's degree at the University of Delaware, this can be used to fulfill the residency requirement.

**Qualifying Exam:** The qualifying examination is usually taken near the completion of the required credits of coursework beyond the bachelor's degree.

**Required Courses:** All courses in the program are selected with the approval of the student's advisor. The program requires a minimum of 36 credits in graduate courses beyond the Bachelor of Science degree. The purpose of the course work is to provide a solid foundation for original research in the field of study and, within the limits of available time, to extend the student's knowledge outside that field. The required courses beyond the Bachelor of Science are as follows:

CIEG 639/MAST 691 Ocean Fluid Dynamics  
 CIEG 672/MAST 648 Water Wave Mechanics  
 MEEG 690 Intermediate Engineering Mathematics  
 MEEG 691 Advanced Engineering Mathematics  
 MAST 693 Waves in the Marine Environment  
 MAST 882 Physical Ocean Science and Engineering Seminar  
 CIEG 865 Civil Engineering Seminar

Students matriculating from other universities may petition to have these courses waived if their course of study included equivalent courses. At least 6 credits should be taken outside of the Program of Ocean Science and Engineering and may include significant components from other departments.