



# COLLEGE OF ENGINEERING

- **Biomechanics and Movement Science (Interdisciplinary Program)**
- **Bioengineering**
- **Chemical Engineering**
- **Civil and Environmental Engineering**

The College of Engineering has a strong commitment to graduate education through teaching and research. Programs leading to both the master's and Ph.D. 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 nine 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, Center for Innovative Bridge Engineering, the Center for Molecular and Engineering Thermodynamics, the Center for the Study of Metals in the Environment, the Delaware Center for Transportation, and the Innovative Multi-disciplinary Photonic Architectures using Complementary Technologies (IMPACT) Center. 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 on video. 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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## BIOMECHANICS AND MOVEMENT SCIENCE

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Telephone: (302) 831-1321

For more information, please visit the program web site at <http://www.bmsc.udel.edu>

The Biomechanics and Movement Science (BIOMS) program offers programs leading to master's and doctoral degrees. It is an

- **Electrical and Computer Engineering**
- **Materials Science and Engineering**
- **Mechanical Engineering**
- **Ocean Engineering**

interdisciplinary program that combines faculty and physical resources from several different units including the Department of Mechanical Engineering, the Department of Physical Therapy, the Department of Health and Exercise Sciences, the Center for Biomedical Engineering Research, and The A.I. duPont Hospital for Children. By implementing an interdisciplinary approach, the availability of faculty members with backgrounds in sport biomechanics, physical therapy, applied physiology, engineering, and computer science, affords students a much more diverse educational environment. In addition, the collective research laboratories of the participating units provide exposure to outstanding facilities. The laboratories of the Ice Skating Science Development Center, the Department of Physical Therapy, and the A.I. duPont Hospital for Children present an array of equipment for both upper and lower extremity biomechanics and movement studies.

## REQUIREMENTS FOR ADMISSION

Applicants to the BIOMS program should meet the minimum recommended GRE requirements of 1050 on combined quantitative and verbal scores, and an undergraduate grade point index of 3.0. They are expected to have course experience in the areas of math (through calculus), anatomy/physiology, physics (2 semesters), and chemistry (2 semesters). See the Graduate Admissions chapter in this catalog for additional information.

Admission is selective and competitive based on the number of well-qualified applicants and the limits of available faculty and facilities. Those applicants who meet the stated minimum academic requirements for admission are not guaranteed admission, nor are those applicants who fail to meet those minimum requirements necessarily precluded from admission if they offer other appropriate strengths.

Applicants will be directed to faculty with appropriate expertise. Once a faculty advisor has been secured, prospective students must submit a proposed program of study to the BIOMS graduate committee. Applicants will be considered for admission to the BIOMS program provided that they 1) meet all admission requirements of the Office of Graduate Studies and the BIOMS program, and 2) are successful in securing a faculty advisor.

## FINANCIAL AID

Financial assistance for students in the BIOMS program is obtained from a variety of external sources and will therefore vary in form and availability. Assistance will be awarded on a competitive basis to applicants best fitting the needs of the granting agencies and

sponsoring faculty. Students receiving full stipends will be expected to work up to 20 hours per week on faculty projects, and are expected to maintain full-time status. Please refer to the chapter "Graduate Fellowships and Assistantships" in this catalog for more information.

### REQUIREMENTS FOR THE DEGREES

Programs of study are created to serve the interests of both the student and sponsoring faculty member. Core courses for all areas of study include 2 (M.S.) or 3 (Ph.D.) semesters of BIOMS seminar, an experimental design/statistics course, a course in computing, laboratory instrumentation or engineering applications, and two courses outside the principal area of study.

The Master's degree program requires 24 credit hours of coursework (including BMSC 801 and BMSC 868) plus 6 credit hours of thesis. The student's program of study should be created by the student and his/her advisor as part of the admission process. This program of study must be reviewed and approved by the BIOMS Graduate Committee. The thesis committee must consist of at least three BIOMS faculty members, and at least one of the committee members must be from a different department than that of the advisor. Prior to conducting the thesis research, the student must successfully defend the thesis proposal before the BIOMS faculty. The final thesis defense must then be approved by the thesis committee.

The Ph.D. program requires 33 credit hours of coursework (including BMSC 801 and BMSC 868) beyond the Master's degree plus 9 credit hours of dissertation. A student entering the Ph.D. program without a Master's degree must complete a minimum of 63 credit hours of coursework plus 9 credit hours of dissertation. As with the Master's degree, the student's program of study should be created by the student and his/her advisor as part of the admission process. This program of study must then be reviewed and approved by the BIOMS Graduate Committee. The dissertation committee must consist of at least three BIOMS faculty members one of whom must be from a department different than that of the advisor, and one committee member from outside the BIOMS program. Please refer to the program policy statement for more specific details regarding dissertation committee membership. Prior to conducting the dissertation, the student must successfully defend the dissertation proposal. The defense of the dissertation proposal constitutes the qualifying examination for candidacy into the Ph.D. degree program. Candidacy is completed when the student successfully defends the dissertation.

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### BIOENGINEERING

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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

For more information, please visit the department web site at <http://www.che.udel.edu>

The Department of Chemical Engineering offers graduate programs leading to the Master of Chemical Engineering (M.Ch.E.) degree and the Doctor of Philosophy (Ph.D.) 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 M.Ch.E. degree).

The Chemical Engineering Department is housed in the newly renovated and expanded 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 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 the student 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 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, and many catalytic flow microreactors. 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. 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 Ph.D. 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 A minimum score of 600 on 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.

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 M.Ch.E. 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 Ph.D. The formal requirements of 24 credit hours of course work and a 6-credit-hour thesis for the M.Ch.E. degree are substantial and are recognized as such by industrial organizations. A non-thesis M.Ch.E. degree of 30 credit hours of appropriate course work is also a degree option in the department.

## REQUIREMENTS FOR THE PH.D. DEGREE

Students may elect to study directly toward a Ph.D. upon enrollment or may obtain the M.Ch.E. degree first. Admission to the Ph.D. 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

For more information, please visit the department web site at <http://www.ce.udel.edu>

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 Ph.D. 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 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, photoelastic and holographic stress analysis and a modern concrete testing facility. The geotechnical laboratory has state-of-the-art equipment for testing soils and geotextiles.

The Civil and Environmental Engineering computing systems consist of a large number of SUN and SPARC workstations running a network with a central file server, a PC computer lab and access to the University mainframe computers.

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. A minimum score of 550 on the Test of English as a Foreign Language (TOEFL) 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.

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 M.C.E. 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 Ph.D. 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 PH.D. DEGREE**

Although it is possible for students to study toward a Ph.D. directly upon entering graduate school, most students choose to obtain the M.C.E. or M.A.S. 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 Ph.D. 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

For more information, please visit the department web site at <http://www.ece.udel.edu>

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 engineering are signal and image processing and estimation, with emphasis on digital techniques; communications theory; devices and materials, with emphasis on semiconductors, electronic materials, and integrated optics; electrooptical systems, with emphasis on optical communication and holography; and digital systems, with emphasis on distributed software, microprocessor applications, speech characterization, and networking; biomedical engineering, with an emphasis on bioinformation processing, neuroscience, and biotechnology.

Facilities are available for research in each of the areas. Excellent departmental laboratories support the devices, materials and electrooptical systems research in addition to the extensive facilities of the various other components of the interdepartmental materials program in engineering. Solid state and optical communication facilities include class 10 and class 1000 clean rooms equipped for semiconductor device fabrication and crystal growth, and well-equipped labs for electronic and optical measurements.

The Department of Electrical and Computer Engineering is housed in Evans Hall and a section of Pierre S. DuPont Hall. The Department maintains excellent facilities for teaching and research. The computing facilities include state-of-the-art servers from Sun Microsystems, with a variety of workstations from Sun, SGI, HP, Compaq, IBM and PCs. 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 laboratories of computers 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 the research in those areas.

All graduate students must participate in the research programs of the University. Publication of the results of student research is an important goal of the program. Graduate students are required to participate in one of the research seminars conducted in each of the areas of departmental concentration.

**REQUIREMENTS FOR ADMISSION**

Applicants are expected to have:

1. A baccalaureate degree in the field or in a closely allied field of engineering, science or mathematics.
2. 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.
3. A minimum of three letters of strong support from former teachers or supervisors.
4. All applicants are required to submit Graduate Record Examination Scores (GRE). The department requires a combined score of the verbal and math sections in excess of 1050 with a mathematics score in excess of 700. (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.)
5. A minimum score of 550 (600 required for teaching assistantship) on 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.

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 degree program requires 30 credit hours including at least 24 graduate course credits and at least 6 credits of master's thesis. The 24 credit course program of each student must include:

1. Six credits of foundation electrical engineering courses.
2. Eighteen credits of advanced technical courses related to the student's area of interest. At least three credits of these must be of 800 level electrical engineering courses and at most six credits can bear non-ELEG numbers.

All candidates in the thesis M.S. program will carry out original publishable research, most often in collaboration with their advisor and others in the department, and prepare a written thesis.

**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 engineering foundation before starting an industrial career. Financial aid is usually not available to students taking this program. The non-thesis master's program requires 30 credit hours of course work meeting the following requirements:

1. Six credits of foundation electrical engineering courses.
2. Twenty-four credits of advanced technical courses related to the student's area of interest. At least six credits of these must be of 800 level electrical engineering courses and at most six credits can bear non-ELEG numbers.

**Ph.D. Degree**

Candidates for the Ph.D. degree must complete the course requirements for the thesis master's degree as outlined above, or have been awarded a master's degree in electrical engineering. In addition, a Ph.D. candidate must complete a course program in his/her area of specialization. All Ph.D. candidates in residence must participate in the one credit research seminar in their area of concentration and must also be enrolled in at least one advanced technical course, acceptable to their advisor each regular term, regardless of where they are in their program. For the Ph.D., the University requires one continuous academic year of full-time study as a residency requirement. The Ph.D. is a research degree. Each Ph.D. candidate must carry out a program of substantial original publishable research on a topic agreed upon by his/her committee and the departmental Graduate Committee and prepare a written dissertation.

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**MATERIALS SCIENCE AND ENGINEERING**


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Telephone: (302) 831-2062

For more information, please visit the department web site at <http://www.udel.edu/mse>

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 Ph.D. 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 materials 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 fiber-reinforced 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 or cease to exist.

## 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. A minimum score of 550 on 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.
- 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 **M.M.S.E. 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, 6 credits are elective and are chosen in an area of specialization after discussion with the student's advisor.

For the **M.M.S.E. degree without thesis**, 30 credit hours of course work are required. Of the 30 credits of course work, 12 credits are elective and are chosen after discussion with the student's adviser and will usually be related to the student's area of interest. The non-thesis M.M.S.E. degree is offered specifically for off-campus, part-time students and is not available to full-time graduate students.

For the **Ph.D. degree**, 12 credits of coursework are required beyond those necessary for the master's degree, including 9 credits of elective courses. 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

For more information, please visit the department web site at <http://www.me.udel.edu>

The Department of Mechanical Engineering offers graduate programs leading to the degrees of Master of Science in Mechanical Engineering (M.S.M.E.), Master of Engineering: Mechanical (M.E.M.) and Doctor of Philosophy (Ph.D.) 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 M.S.M.E. and Ph.D. degrees, while the M.E.M. is a non-thesis degree program designed for part-time students. One may enroll into the Ph.D. 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 six areas: composites, environmental fluid mechanics, biomedical engineering, manufacturing, robotics and control, engineering materials, and nanostructured materials.

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.

Environmental fluid mechanics is concerned with understanding laminar and turbulent flow in combustion, fuel cell processing and climate.

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 exercise physiology.



Manufacturing research is concerned with the phenomena of spreading of coatings, the behavior of fibers in concentrated suspensions, resin transfer mold filling processes in composites manufacturing, rapid tooling, and lubrication and cooling during machining.

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, smart materials and intelligent structures and control of dynamic systems and manufacturing processes.

Engineering materials research involves the characterization and modeling of advanced materials and structures including polymers, metals, ceramics, and their composites. Current research ranges from low strain rate, as in high temperature creep, to high strain rate, as in impact mechanics. Nanostructured materials research is focused on nanotubes and nanoclays.

The department is housed in the Robert L. Spencer Laboratory, containing modern facilities for a wide range of computational and experimental programs. Among the facilities are a particle image velocimeter, a three-dimensional laser-Doppler velocimeter, scanning and transmission electron microscopes, high-vacuum chambers, mechanical- and ballistic-impact-testing systems, robots, rotating mirror high speed camera, 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 computers and peripherals are available which are networked into the College of Engineering and University computers.

#### Requirements For Admission

The following minimum criteria will normally be applied. Satisfaction of the minimum requirements will not guarantee admission to the program:

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 1050 in the Graduate Record Examination Aptitude Test.
5. A minimum score of 550 in the Test of English as a Foreign Language for students whose first language is not English. This test is not required of students who have received an undergraduate or post-graduate degree from a College or University in which English is the sole language of instruction.

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 include applied mathematics, engineering analysis, solid and fluid mechanics, and materials science.

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 Ph.D. degree directly after a bachelor's degree.

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#### OCEAN ENGINEERING

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Telephone: (302) 831-2442

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 Studies (CMS) 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 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 CMS have the option of pursuing advanced degrees in Marine Studies through CMS 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. The POSE graduate committee may increase these minimum requirements.

Students with bachelor's degrees and exceptional academic backgrounds may be admitted directly into the Ph.D. program. Students admitted into the M.S. program may petition to move into the Ph.D. program before completing the M.S.

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 M.S. 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 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 Ph.D. 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 PH.D. DEGREE**

The Ocean Engineering Ph.D. 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 Ph.D. 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.