

COLLEGE OF ENGINEERING AND SCIENCE

The College of Engineering and Science offers advanced degrees in Automotive Engineering, Bioengineering, Biosystems Engineering, Chemical Engineering, Chemistry, Civil Engineering, Computer Engineering, Computer Science, Digital Production Arts, Electrical Engineering, Environmental Engineering and Science, Environmental Toxicology, Hydrogeology, Industrial Engineering, Materials Science and Engineering, Mathematical Sciences, Mechanical Engineering, Physics, Polymer and Fiber Science.

Courses are offered in astronomy, engineering graphics, and environmental science and policy to provide electives for students in other areas.

Degrees offered are the Master of Engineering, Master of Science, and Doctor of Philosophy. The MS and PhD programs serve primarily full-time graduate students. Industrial residency programs leading to the Master of Science degree are available in certain engineering departments. Financial aid, in the form of full and partial fellowships and teaching and research assistantships, is available. Other financial aid packages are available to outstanding applicants. A broad and vigorous research program provides excellent opportunities for thesis and dissertation research.

The Master of Engineering program is open to individuals who are interested in professionally oriented advanced study. Requirements for the program are a baccalaureate degree from an ABET-accredited engineering program or equivalent, academic and professional records which indicate motivation for and the ability to complete additional professional study, and acceptance by the chair of the department in which the individual plans to major and by the Dean of the College of Engineering and Science.

Graduate engineering education opportunities for practicing engineers are available in two disciplines. The Department of Electrical and Computer Engineering offers off-campus graduate courses leading to the Master of Engineering degree through satellite broadcasts, Internet, and DVD. The Department of Mechanical Engineering offers selected off-campus graduate courses at the University Center of Greenville. Furthermore, graduate courses in both disciplines are offered on-campus during the late afternoon/early evening once a week.

AUTOMOTIVE ENGINEERING

Master of Science

Doctor of Philosophy

The Master of Science and Doctor of Philosophy degrees in Automotive Engineering prepare a new generation of engineers to deal with the complex technological, environmental, and globalization issues facing the automobile industry.

The big challenge facing the industry is the integration of diverse technologies in the automobile and its cost effective and environmentally responsible manufacture, all being done in a global network with people of different backgrounds and cultures. The Automotive Engineering programs equip students with the basis, depth, and domain knowledge needed for master's and doctoral-level expertise in systems integration and vehicle systems engineering and the ability to work globally. Graduates of the program are able to lead teams of culturally diverse individuals to produce an integrated automobile platform or to work in research laboratories involved with the design of new products in the automotive field. While the program is geared toward the automobile industry, it produces strong linkages with the aerospace and other industries within the state, region, and nation as some of the challenges faced by the automotive industry are also faced in other sectors.

Master of Science

Admission to the MS program occurs in the fall semester only. Students are required to hold a BS degree from a recognized relevant engineering or science discipline and the equivalent of two years of postbaccalaureate full-time work experience in industry. Students have the opportunity to tailor the program either in the functional aspects or systems aspects of automotive engineering through appropriate course choices.

The program is divided into four content areas, consisting of 36 credit hours of coursework and six hours of project work, as follows:

Core Courses—AU E 880, 881, 882, 883

Automotive Engineering Track—18 credit hours in two or three track areas with nine hours in automotive engineering courses and nine hours based on the student's interests and specialization.

Business or Related Field—a minimum of six hours in a concentration area or minor approved by the advisory committee

Internship—a six-credit-hour internship of six months duration in an industrial setting

Foreign language proficiency is required as an outcome of the program.

Doctor of Philosophy

Students are admitted into the PhD program in the fall, spring, and summer terms. Minimum admission requirements include a bachelor's or master's degree in a recognized relevant engineering or science discipline. Students entering the program directly with a BS degree must meet the entrance requirements for the MS degree and have a grade-point ratio of 3.5 or higher in their undergraduate pro-

grams. Students with an MS degree in a recognized relevant engineering or science discipline are not subject to the two years of postbaccalaureate full-time industrial experience requirement.

Program requirements are as follows:

Core Courses—AU E 880, 881, 882

Automotive Engineering Track—minimum of six hours (two AU E courses from two track areas)

Discipline-Specific Courses—no minimum requirements, typically five additional courses

Business or Related Field—minimum of three hours in a directed, nontechnical field

Technical Courses—minimum of nine hours in a concentration area outside the discipline or a technical minor

Dissertation—18 credit hours

Foreign Residency Requirement—six-month residency at a foreign research laboratory or university

BIOENGINEERING

Master of Science

Doctor of Philosophy

Bioengineering is the application of engineering and scientific principles to understand and solve medical problems. As medical technology has rapidly developed over the past four decades, the demand for qualified bioengineers has dramatically increased. Career opportunities for bioengineers range from teaching and conducting basic research in academia to research and development work in the growing medical product industry. Employment opportunities are also available in independent research laboratories, hospitals, and federal agencies such as the Food and Drug Administration or the National Institutes of Health.

Clemson University's Bioengineering Program is one of the oldest in the world; its PhD program began in 1963, and its MS program was added in 1966. Historically the department is widely recognized to have pioneered the field of biomaterials. Today the Department of Bioengineering maintains its focus on biomaterials and related areas, including tissue engineering, regenerative medicine, drug delivery, biomechanics, and biosensing. Although Clemson University does not have a medical school, the Bioengineering Department maintains close collaborative ties with several medical centers in the Carolinas. In particular, Clemson has a formal partnership with the Medical University of South Carolina, located in Charleston, and maintains full-time bioengineering faculty and students at both campuses. Interactions between the two institutions are facilitated by state-of-the-art video-conferencing facilities, which enable students to take classes and interact directly with faculty at either location. A joint MD/PhD program is provided for qualified students as part of this partnership.

Applicants to the Bioengineering programs typically hold a Bachelor of Science degree in engineering, science, or life science. Students with nonengineering backgrounds may be required to take remedial courses in engineering (e.g. materials science, statics

and mechanics, and calculus through differential equations) in addition to their regular bioengineering curriculum, which may be taken either before or after enrollment.

The Department offers a Master of Science and a Doctor of Philosophy degree. The curriculum for the MS degree consists of a core of recommended bioengineering courses supplemented by elective courses that provide the student greater depth in a specific area of interest. Two degree options are offered at the master's degree level: a thesis and a nonthesis option. The thesis option requires a total of 30 credit hours (six of which must be research credits) and the submission and defense of a master's thesis. The nonthesis option requires a minimum of 33 credit hours (six of which must be research credits) followed by the submission and oral presentation of a publishable-quality report on an approved topic. The minimum time necessary to complete the master's degree is normally 16 months, out of which at least one academic semester must be undertaken in residence as a full-time student at Clemson University.

Students interested in obtaining a doctoral degree are encouraged to apply directly to the PhD program from their BS degree program, with the PhD program typically requiring about five years to complete following the BS degree or about four years following the MS degree. The selection of courses for the doctoral degree is flexible and depends on the background and objectives of each candidate. A typical program includes 18 or more credit hours of graduate-level courses beyond the MS degree requirements. Candidates for the PhD degree must provide evidence of their potential success in advanced graduate study. This is demonstrated by passing both the qualifying and comprehensive examinations, which are usually taken after the first year of graduate school. The qualifying examination consists of both written and oral exams that cover the basics of bioengineering with an emphasis on the student's area of concentration. The comprehensive examination involves the oral presentation and defense of the student's proposed original research plan before his/her selected research committee and is typically taken within a year of passing the qualification exam. The PhD program culminates with the presentation and successful defense of a doctoral dissertation, which is scheduled following the completion of the student's approved research plan.

Combined Bachelor's/Master's Plans

The Department of Bioengineering offers a combined BS/MS plan. Under the plan, students may reduce the time necessary to earn both a BS degree in Bioengineering, Biological Sciences, or Biosystems Engineering and an MS in Bioengineering by applying graduate credits to both undergraduate and graduate program requirements.

Students are encouraged to obtain the specific requirements for the dual degree from the undergraduate department or the Department of Bioengineering as early as possible in their undergraduate programs to ensure that all prerequisite and other program requirements are met. Enrollment guidelines and procedures can be found under *Academic Regulations* in this catalog.

BIOSYSTEMS ENGINEERING

Master of Science

Doctor of Philosophy

The Biosystems Engineering program, jointly administered with the College of Agriculture, Forestry, and Life Sciences, prepares individuals for leadership, creative accomplishment, continued professional learning, and independent research.

Students may be accepted with backgrounds in any branch of engineering or quantitative-based scientific fields relating to chemistry, mathematics, physics, or biology. Undergraduate prerequisite or corequisite courses may be required for applicants with undergraduate degrees in nonengineering disciplines.

Acceptance is determined by departmental faculty review based on records of academic achievements (including grades from previous programs and GRE scores) and other appropriate professional accomplishments. Additional information is available at www.clemson.edu/agbioeng/biol/.

Each degree program is planned individually to augment the student's previous engineering and science background with adequate breadth in engineering and specialization in an area of biosystems engineering. Coursework includes biosystems and related engineering, mathematics, physics, chemistry, statistics, and biological, environmental, and engineering sciences.

Candidates for the MS degree are required to complete a minimum of 24 credit hour of coursework plus an additional six hours of thesis research and complete an acceptable thesis.

Candidates for the PhD degree are required to complete additional hours of coursework beyond the MS degree at the discretion of the graduate committee, typically 30–36 additional credits. Completion of 18 hours of dissertation research and the submission of an acceptable dissertation are also required.

Combined Bachelor's/Master's Plan

Under this plan, students may reduce the time necessary to earn both degrees by applying graduate credits to both undergraduate and graduate program requirements. Students are encouraged to obtain the specific requirements for the dual degree from the Department of Biosystems Engineering as early as possible in their undergraduate program. Enrollment guidelines and procedures can be found under *Academic Regulations* in this catalog.

CHEMICAL ENGINEERING

Master of Science

Doctor of Philosophy

The Department of Chemical and Biomolecular Engineering offers programs leading to the Doctor of Philosophy and the Master of Science degrees. Graduate programs at Clemson prepare students to apply science and engineering principles to complex problems associated with the chemical, biomolecular, and associated industries. Students develop a rigorous fundamental science base coupled with insight into engineering applications. Graduates can become involved in the research, manufacture, and use of

chemicals, polymers, pharmaceuticals, electronic components, consumer products, and petroleum products. The department has a particular focus on research in polymers, catalysis, and biotechnology.

Although most graduate students have a BS in Chemical Engineering, students with backgrounds in chemistry, physics, or other branches of engineering are encouraged to apply and will be fully considered for admission. To facilitate a transition from BS degrees other than Chemical Engineering, special programs are available.

The MS degree program consists of 30 credit hours including six credit hours of research. Coursework includes CH E 803, 804, and 805. In addition, six hours of approved chemical engineering electives and nine hours of approved technical electives are required. At least six of these 12 elective hours must be selected from courses numbered 800 or above. MS degree candidates must complete a thesis.

The PhD program consists of 36 credit hours of approved graduate courses beyond the BS degree including 12 credit hours of approved graduate courses at Clemson. Doctoral students must satisfy the MS course requirements through courses taken at Clemson University or elsewhere. Each doctoral student must complete at least six credit hours of approved graduate courses offered by departments other than Chemical Engineering. In addition, each student is required to complete 30 credit hours of graduate research including 18 doctoral dissertation research credit hours (CH E 991) taken at Clemson University. These requirements establish minimum coursework and research credit requirements and usually are exceeded at the advice of the individual student's advisory committee.

Minors for doctoral students may be taken in chemistry, physics, mathematics, life sciences, or other branches of engineering.

CHEMISTRY

Master of Science

Doctor of Philosophy

Degree concentrations are offered in analytical, inorganic, organic, physical chemistry, and chemistry education. Research areas also include bio-organic chemistry, polymer chemistry, materials chemistry, chemical physics, and other areas. A PhD degree in Chemistry with a concentration in textile chemistry is offered jointly with the School of Materials Science and Engineering.

MS degree candidates must complete 24 hours of coursework and six hours of research culminating in a satisfactory thesis. PhD degree candidates who have not previously been awarded an MS degree in chemistry must complete a regimen of coursework that is at least equivalent to that which would be required to earn an MS degree.

The primary requirement for the PhD degree is the performance of original research leading to a dissertation. PhD degree candidates must qualify to pursue the degree by completing a core of four courses with at least a B average during the first two years of study. The core courses are taken in four areas: one in organic, one in physical, one in analytical, and one in inorganic chemistry.

Qualification requirements may also be satisfied by examination.

Admission to candidacy for the PhD degree requires completion of either a cumulative or a comprehensive examination in the area of concentration. The examination, the type of which depends upon the area selected by the student, may be followed by an oral presentation before a faculty committee.

CIVIL ENGINEERING

Master of Science

Doctor of Philosophy

The Department of Civil Engineering offers graduate programs leading to the Master of Science and Doctor of Philosophy degrees. Within these degrees, there are six primary emphasis areas: Applied Fluid Mechanics, Construction Materials, Geotechnical Engineering, Project Management, Structural Engineering, and Transportation Systems.

Master of Science

The Master of Science degree program is open to all individuals who have a four-year baccalaureate degree. A degree in engineering is not required for admission, but most entering students have an undergraduate Civil Engineering degree.

There are two options available for students pursuing a Master of Science degree. The student may prepare a research thesis or may take additional courses in lieu of completing a thesis.

The thesis option requires the preparation of a research thesis that is a part of the total credit hours required for the degree. Students intending to pursue a doctoral degree usually choose the thesis option. Completion of a research thesis is excellent preparation for the research necessary for a doctorate if a student is inclined to pursue that degree in the future.

The nonthesis option does not require the preparation of a research thesis but does require completion of additional coursework. This degree option provides the student with additional directed study through coursework. Normally students pursuing the nonthesis option will not pursue a doctorate.

Except for the core courses required by different disciplines, there are no formal course requirements for students pursuing a Master of Science degree. The program normally contains some engineering design and a minimum of ten credits of engineering science, advanced mathematics, and basic science. In addition, each student in the thesis option must complete an advanced research project. All students pursuing an MS degree must satisfactorily complete C E 895. The final program of study must contain at least 30 hours of graduate credit including the core curriculum requirements. Of these 30 credits, no more than six hours may be thesis research (C E 891) for those students pursuing the thesis option. At least half of the remaining hours must be from courses numbered 800 or above.

The final examination for the MS nonthesis option is an oral or written exam (or a combination of the two) consisting of questions related to fundamental knowledge in a student's chosen area of concentration (i.e., applied fluid mechanics,

construction materials, geotechnical engineering, project management, structural engineering, or transportation systems).

The final examination for the MS thesis option is an oral exam consisting of a student's MS thesis defense and questions related to fundamental knowledge in a student's chosen area of concentration (i.e. applied fluid mechanics, construction materials, geotechnical engineering, project management, structural engineering, or transportation systems).

Doctor of Philosophy

The Doctor of Philosophy degree program is open to all individuals who have a baccalaureate degree and preferably a Master's degree in engineering. Except for the core courses required by different disciplines, there are no formal course requirements for students pursuing a PhD degree; however, each student must complete 18 hours of dissertation research (C E 991). All students must complete C E 895.

The purpose of the PhD research dissertation is to afford the student the opportunity to participate in independent specialized engineering research that can advance the state of the art. The research is conducted under the direction of a member of the faculty who will normally serve as chair of the student's academic advisory committee. The research should be sufficiently demanding technically so as to demonstrate the student's ability to assimilate knowledge from several subject areas for the advancement of engineering knowledge.

Student Evaluation—During the first two semesters in residence, a PhD student must select a faculty advisor. The faculty advisor may assign the student specific duties outside normal coursework requirements that include, but are not necessarily limited to, preparing research proposals and literature surveys, conducting classroom lectures, formulating computer models, and executing data collection and analysis. The advisor may, at any time, withdraw as the student's faculty advisor if these assigned duties are not performed consistent with the expectations of the faculty advisor. During this initial two-semester period, an advisor should make a determination as to whether a student is capable of completing the requirements for the PhD degree.

Comprehensive Examination—The PhD comprehensive examination is generally scheduled after all coursework has been completed and the dissertation proposal is ready for approval by the student's graduate committee. The examination, therefore, consists of two parts: (1) a written and/or oral examination by the advisory committee on the student's preparation to complete the proposed research and (2) presentation of the proposed research. The PhD comprehensive examination should be completed within two years of entering the PhD program. The written and/or oral examination may include consideration of graduate coursework, preliminary research, and/or other demonstration of the ability to conduct the proposed research. After passing this examination, the student is officially admitted to candidacy for the PhD degree.

Dissertation Defense—As required by the Graduate School, the candidate for the Doctor of Philosophy degree must pass a final oral examination (dissertation defense). The examination consists of a presen-

tation of the student's doctoral research and an assessment by the committee of the research approach, the significance of the findings, and the contribution to the advancement of civil engineering.

More information about the Department of Civil Engineering is available at www.ce.clemson.edu or by phone at (864) 656-3000.

Combined Bachelor's/Master's Plan

Civil Engineering undergraduates at Clemson may begin a Master of Science degree program while completing the Bachelor of Science degree and use a limited number of courses to satisfy the requirements of both their undergraduate and graduate degrees. The following requirements apply:

1. Undergraduate students must have a minimum cumulative grade-point ratio of 3.4 and must have completed the junior year prior to taking graduate courses. Students are required to maintain this minimum grade-point ratio to continue enrollment in a combined degree program.
2. Graduate Record Examination (GRE) scores are not required to be submitted as part of their Graduate School application; however, applicants are encouraged to submit GRE scores to receive full consideration for graduate fellowships and assistantships upon completion of the BS degree.
3. Up to six semester hours from any 600- or 800-level civil engineering courses may be used to satisfy the requirements of the BS degree. These courses may be counted as technical requirements or electives. Undergraduate students are required to have selected one of their technical requirements from the area of transportation systems, geotechnical engineering, or environmental engineering.
4. Since approval of the graduate program of study is required by the student's graduate advisory committee, students should consult with their academic advisors before selecting courses to be included in the graduate program.
5. Students in a combined degree program are conditionally accepted to the graduate program until completion of the BS degree requirements. Students are not eligible for graduate assistantships until full acceptance is granted.

Students interested in this combined degree program should consult the Civil Engineering Graduate Program Coordinator, the undergraduate advisor, and the Civil Engineering Honors Coordinator (if applicable). Students pursuing an optional emphasis area in their undergraduate degree program may substitute 600-level courses for any 400-level counterpart taken to meet the requirements of an emphasis area. Application for this program should be made by the end of the junior year, but no later than one semester prior to expected BS graduation. Application details are available in the *Academic Regulations* section of this catalog.

COMPUTER ENGINEERING

Master of Science

Doctor of Philosophy

The Computer Engineering program is a combination of computer software, hardware, systems, and applications. Areas of specialization include computer systems architecture, communication networks, digital signal processing, and intelligent systems. Enrollment is open to graduates in any branch of engineering, computer science, or applied mathematics who have an appropriate engineering and/or science background.

For the MS program, students may write a thesis or follow a nonthesis option. The thesis option requires a total of 30 credit hours including six hours of thesis research. For the nonthesis option, 33 credit hours of coursework must be completed.

The PhD degree requires at least 24 credit hours of graduate coursework beyond the master's degree. Specially qualified candidates with a BS degree may apply for direct entry to the PhD program in any of the above areas. The program of study and hours required beyond the baccalaureate degree are specified by the focus area but must be at least 66 hours including coursework and research credit.

The department participates in the University telecampus program which serves off-campus students. Further information is available through the Office of Off-Campus, Distance, and Continuing Education.

Detailed information is available at www.ece.clemson.edu/ecenew/index.shtml.

COMPUTER SCIENCE

Master of Science

Doctor of Philosophy

To receive full admission to graduate study in computer science, a student must have taken intermediate-level undergraduate computer science, including computer organization and data representation, machine and assembly language programming, data structures, file organization and processing, programming systems, theory of computation, and software methodology; and basic mathematics including calculus, probability and statistics, and discrete mathematics. An applicant with minimal deficiencies may be admitted provisionally, while one with several deficiencies may be required to complete satisfactorily prerequisite work as a postbaccalaureate student prior to admission as a graduate student.

A candidate for the MS degree must satisfactorily complete an approved program of at least 30 graduate hours. Students may elect one of three options to satisfy the degree requirements: the research experience, research paper, or thesis option. These options allow the student to count zero, three, or six hours of research credit respectively toward the 30-hour requirement. Students may take up to six hours of approved courses in areas outside the department.

Although formal course requirements for the PhD degree are minimal, a typical program requires two to four years of study beyond the MS degree. Each candidate is required to pass a comprehensive examination, a dissertation proposal, and a defense of the dissertation.

Combined Bachelor's/Master's Plan

Computer Science undergraduates may begin a Master of Science degree program while completing the Bachelor of Science degree and use a limited number of courses to satisfy the requirements of both their undergraduate and graduate degrees. The following requirements apply:

1. Undergraduate students must have a minimum cumulative grade-point ratio of 3.4 and must have completed the junior year prior to taking graduate courses. Students are required to maintain this minimum grade-point ratio to continue enrollment in a combined degree program.

2. Graduate Record Examination (GRE) scores are not required to be submitted as part of the Graduate School application; however, applicants are encouraged to submit GRE scores to receive full consideration for graduate fellowships and assistantships upon completion of the BS degree.

3. Students in a combined degree program are conditionally accepted to the graduate program until completion of the BS requirements. Students with this conditional acceptance are not eligible for a graduate assistantship until the conditional acceptance is removed.

4. Up to nine semester hours from any 600- or 800-level computer science courses may be used to satisfy the requirements of the BS degree.

5. Graduate courses taken as an undergraduate may be included in the graduate program of study; however, any 600-level course that has a corresponding required 400-level counterpart in the BS or BA in Computer Science or the BS in Computer Information Systems may not be counted toward the MS degree. Since approval of the graduate program of study is required by the student's graduate advisory committee, students should consult their academic advisors before selecting courses to be included in the graduate program.

Students interested in this combined degree program should discuss it with the Computer Science graduate program coordinator and undergraduate program advisor. Students pursuing Senior Departmental Honors should also meet with the Computer Science Honors Coordinator. Application to this program should be made by the end of the junior year but may be made at any time from the junior year until one semester prior to the expected BS graduation. Application details are available in the *Academic Regulations* section of this catalog.

The Computer Science Faculty envision students enrolled in this combined degree program will typically complete nine hours of graduate credit while completing their BS degree requirements and complete the remaining requirements for the MS degree in one calendar year or less of graduate study.

DIGITAL PRODUCTION ARTS

Master of Fine Arts

The Digital Production Arts program is a professional degree program offered jointly with the College of Architecture, Arts, and Humanities. See page 52 for the complete program.

ELECTRICAL ENGINEERING

Master of Engineering

Master of Science

Doctor of Philosophy

Students in Electrical Engineering may direct their programs toward the fields of communication systems and networks, digital signal processing, intelligent systems, applied electromagnetics, electronics, or power systems.

For the MS program, students may write a thesis or follow a nonthesis option. The thesis option requires a total of 30 credit hours including six hours of thesis research. For the nonthesis option, 33 credit hours of coursework must be completed.

The Master of Engineering is a special degree offered for off-campus students through the University telecampus program. Degree requirements include 24 credit hours of coursework and six hours of credit for an engineering report. Additional information is available from the Office of Off-Campus, Distance, and Continuing Education.

The PhD program requires at least 24 credit hours of graduate coursework beyond the master's degree. Specially qualified candidates with a BS degree may apply for direct entry to the PhD program in any of the above areas. The program of study and hours required beyond the baccalaureate degree are specified by the focus area, but must be at least 66, including coursework and research credit.

Detailed information on program requirements and application procedures is available at www.ece.clemson.edu/ecenew/index.shtml.

ENVIRONMENTAL ENGINEERING AND SCIENCE

Master of Engineering

Master of Science

Doctor of Philosophy

Environmental engineering and science is concerned with the characterization and control of environmental pollution. Emphasis is placed on applying the fundamental principles of the basic and engineering sciences through research and design to the solution of environmental problems in natural and engineered systems.

The MEng program builds on an ABET-accredited engineering baccalaureate background, while the MS program builds on a student's previous engineering or science background. Students with a baccalaureate degree in any branch of engineering, as well as chemistry, physics, geology, biology, or related majors with a strong mathematical background may be admitted to the program.

Students may specialize in one of six areas: environmental health physics, environmental process engineering, environmental radiochemistry, environmental and waste management, environmental fate and transport, or environmental chemistry. Research master's degree candidates must complete

24 hours of coursework and six hours of research culminating in the presentation of a satisfactory thesis for MS candidates or a special problem report for MEngr candidates. The MS nonthesis option, which requires 30 hours of coursework and three hours of independent study, is available. The coursework for all master's students must include EE&S 802, 843, and 851. A final examination is required of all master's candidates.

The PhD program provides the student with a comprehensive background in the fundamental aspects of environmental engineering and science. The major field of study is generally interdisciplinary in nature, consisting of coursework in several areas of engineering and the basic sciences. Each student's curriculum and research program is tailored to suit his/her personal and professional goals. Qualifying, comprehensive, and final examinations are required. No foreign language is required.

ENVIRONMENTAL TOXICOLOGY

Master of Science

Doctor of Philosophy

The Environmental Toxicology program is jointly administered with the College of Agriculture, Forestry, and Life Sciences. See page 47 for the complete program.

HYDROGEOLOGY

Master of Science

The Master of Science in Hydrogeology is an interdisciplinary program that focuses on groundwater geology and subsurface remediation and draws on the expertise of faculty in the Department of Geological Sciences and the Department of Environmental Engineering and Science. The curriculum is structured to impart a strong background in field experimentation complemented by laboratory studies and computer modeling.

Candidates for the Master of Science degree in Hydrogeology should have a baccalaureate degree in the geosciences; however, students having strong undergraduate backgrounds in other fields of science or related engineering disciplines may be admitted but will be required to correct deficiencies in their geological education during the first year. Specifically, GEOL 101/103, 206, 302; and 314, 316 (or an equivalent), or 413 are required. Students entering this program should also have a strong mathematics background; normally, two semesters of calculus are required and a third semester is recommended.

The degree requires 24 hours of coursework and six hours of thesis research. Candidates must write a thesis based on original research and defend it in an oral examination. Students may pursue a variety of research projects in hydrogeology and related areas such as environmental geochemistry, geophysics, sedimentology/stratigraphy, and multiphase flow modeling. A special nonthesis option is available for students on leave from industry; it requires 30 hours of coursework and a comprehensive written examination.

All candidates must take at least six core courses from a department-approved list, including a modeling course (GEOL (EE&S) 808 is recommended), a field course (GEOL 875 is recommended), and a minimum of three other 800-level geology courses.

INDUSTRIAL ENGINEERING

Master of Science

Doctor of Philosophy

Industrial engineers design, develop, and improve integrated systems that include people, materials, information, equipment, and energy. In addition to these issues, graduates learn to address communications throughout the organization while completing their specialized education. Focus areas for specialization are human factors/ergonomics and production and service systems. Work at the doctoral level includes independent research, dissemination of findings, and preparation for research and teaching careers.

Students with baccalaureate degrees in engineering, the physical sciences, mathematics, or related majors with a strong mathematical background may be admitted into the program. Entering graduate students are assumed to have competence in calculus, probability and statistics, calculus-based physics, and computing. Students admitted without this background will be required to complete successfully additional courses, some of which may not carry graduate credit.

MS Students may select a thesis or nonthesis option. Students in the thesis option must complete a minimum of 30 hours of graduate coursework including six credits of thesis research. Students in the nonthesis option must complete a minimum of 33 hours of graduate coursework.

The PhD program provides the student with a comprehensive knowledge of the field of industrial engineering and a mastery of the methods of research. A minimum of 48 hours of graduate coursework beyond a baccalaureate degree is required. Since a dissertation is mandatory for all PhD candidates, 18 hours of doctoral research are required. A qualifying examination is required, in addition to examinations required by the Graduate School. Additional information is available at www.ces.clemson.edu/ie/.

Undergraduates Involved in Graduate Programs

Undergraduate students majoring in Industrial Engineering at Clemson may take courses for graduate credit in two ways:

1. Seniors with a minimum cumulative grade-point ratio of 3.0 may apply to take graduate courses while continuing to pursue their bachelor's degrees. If successfully completed, these courses may be eligible to be counted towards a master's degree. Students selecting this option *will not* be allowed to count these courses towards the bachelor's degree. (See Graduate School form GS-6 for details.)
2. Students with a minimum cumulative grade-point ratio of 3.4 may apply to take up to 12 semester hours of courses and have them count towards *both* the bachelor's and master's degrees in Industrial

Engineering. To take advantage of this opportunity, students must have a minimum cumulative grade-point ratio of 3.4, must have completed the junior year, and must have been admitted to the graduate program prior to enrolling in courses. Courses eligible for this program include IE 652, 656, 660, 665, 685, 687, 689, 691, 800, 802, 803, 804, 809, 811, 812, 813, 860, 865, 871, 880, 886, 888, and 893. The Undergraduate Curriculum Committee has preapproved these classes as acceptable technical and free electives in a student's BS program. Determination of whether the classes count towards the master's degree will be made by the student's advisory committee after he/she becomes a full-status graduate student. Students should notify the Graduate Coordinator in writing that they wish to be considered for this program. Enrollment guidelines and procedures can be found under *Academic Regulations* in this catalog.

In both programs, the decision on whether courses count towards the bachelor's degree is determined by the undergraduate committee and whether they count towards the master's degree is determined by the advisory committee that is formed after the student becomes a full-status graduate student.

Students should consult with their undergraduate advisor, the Graduate Coordinator, and/or the Honors Coordinator before enrolling in graduate courses.

MATERIALS SCIENCE AND ENGINEERING

Master of Science

Doctor of Philosophy

Materials science and engineering is concerned with the production, properties, and microstructure of the solid materials that are often the primary limitation to the advancement of modern technology. Emphasis is placed on applying the fundamental principles that govern the structure of the solid state to produce optimum mechanical, electrical, optical, and other physical properties.

The curriculum provides for specialization in metallurgy, glasses and ceramics, and polymeric materials including electronic materials, biomaterials, polymer and fiber science, textile science, polymer and textile chemistry, and fiber and composite materials.

The Materials Science and Engineering program prepares graduate students to apply science and engineering principles to solve problems related to the scientific understanding, characterization, and development of new technology necessary for the processing and manufacturing of different materials and related products.

Students with a baccalaureate degree in any branch of engineering, as well as chemistry, physics, and biology majors with strong mathematical backgrounds, may be admitted to the program. The program is designed to produce engineers and scientists whose degrees represent specialization coupled with a broad foundation in all materials.

Master's degree candidates must complete 24 credit hours of coursework and six credits of research. Of these 24 credit hours, a maximum of 12 credits may be taken from 600-level courses. Each master's degree student must take MS&E 826 and 827.

The Doctor of Philosophy degree provides the student with a comprehensive foundation in materials science and engineering. The major field of study is generally interdisciplinary in nature, consisting of coursework in several areas of engineering and science. Comprehensive and final examinations are required. No foreign language is required, but proficiency in one is recommended.

Students should consult their advisors for course requirements. All MS and PhD students must enroll in MS&E 800 every semester.

MATHEMATICAL SCIENCES

Master of Science

Doctor of Philosophy

Entering students are expected to have courses in linear algebra, differential equations, a computer language, and statistics.

For the master's program, both thesis and nonthesis options are available. The curriculum for both options includes foundation courses (advanced calculus, modern algebra, probability, and discrete computing—courses often taken prior to entering the master's program); a breadth requirement (a course from each of algebra, analysis, computing, operations research, and statistics plus one additional course in operations research or statistics); and a concentration area (six courses selected to define an identifiable specialty area). Every student's program is required to include at least one course, possibly chosen from outside the Department of Mathematical Sciences, that emphasizes mathematical modeling. A minimum of 36 graduate credit hours is required for the master's degree. In addition, students in the nonthesis option are required to complete a one-credit-hour project course.

Together with the Department of Mathematics at Kaiserslautern University in Germany, the department offers an exchange program in mathematical sciences. In this program, one year is spent at the host university so that students can obtain two MS degrees, one from their home university and one from the host university. The degree requirements for the Clemson degree are identical to those for the nonthesis MS option.

Students in the doctoral program are expected to satisfy the master's program requirements prior to receiving their doctorate. Including master's study, a doctoral program must have two courses from each of the major areas of the mathematical sciences (algebra, analysis, computing, operations research, and probability/statistics) and generally consists of 60 credit hours of graduate coursework. Students are admitted to candidacy for the PhD degree upon successful completion of a preliminary examination and the comprehensive examination. The preliminary examination consists of tests in three areas chosen from algebra, analysis, computing, operations research, statistics, and stochastic processes. The comprehensive exam assesses the student's readiness to perform independent research and competence in advanced graduate material. The PhD program must include both a concentration area and a supporting area. Additional information is available at www.math.clemson.edu/.

Mathematical sciences courses at the 700-level are applicable to master's degree programs in the School of Education only.

MECHANICAL ENGINEERING

Master of Science

Doctor of Philosophy

Enrollment in the MS and PhD programs is open to students with degrees in physics, applied mathematics, or any branch of engineering.

Students in the MS degree program may choose the thesis or nonthesis option. Students in the thesis program must complete 30 credit hours of coursework, including six hours of thesis research, and write a thesis. Students in the nonthesis program must complete 33 credit hours of coursework and pass an exit examination. Students in the PhD program must pass a qualifying exam, complete 18 hours of dissertation research, and defend a dissertation.

Programs may be selected with concentrations in mechanical and manufacturing systems design (design, dynamics, vibrations, and control, materials and manufacturing), thermal/fluid sciences (computational fluid dynamics, fluid mechanics, heat transfer, thermodynamics, and energy systems), or engineering mechanics (solid mechanics, composite materials, numerical computation methods, and experimental methods).

PHYSICS

Master of Science

Doctor of Philosophy

Graduate studies in physics and astronomy may be pursued by well-prepared students in the physical and mathematical sciences or engineering. As the basic physical science, physics offers unparalleled intellectual opportunities. Theoretical, experimental, or computer-simulated studies of the physical universe, ranging from the macroscopic studies of cosmology to the microscopic world of quanta, are available.

Students beginning graduate studies in physics and astronomy usually enter the MS program. After two semesters, well-prepared students are ready to begin a research program. This program usually culminates in a thesis, although a nonthesis option is available. For the thesis option, 30 credit hours and a final oral examination on the general area of study and thesis defense are required. In the nonthesis option, 36 credit hours are required, including six credit hours of PHYS 890. A written report must be submitted on the directed studies. A final oral examination on the general area and directed activities completes the requirements for the nonthesis option.

Study for the PhD degree begins with the general qualifying examination. A sufficiently high score on this examination may make it possible for a student to bypass the master's degree. An oral examination on the general research area is given within six months after completion of the written qualifying examination. At least three weeks prior to the convocation at which the student expects to receive the PhD degree, a final oral examination on the dissertation must be completed.

POLYMER AND FIBER SCIENCE

Master of Science

Doctor of Philosophy

The MS degree program in Polymer and Fiber Science requires previous undergraduate study in chemistry, physics, mathematics, polymer or fiber science, or an engineering discipline. Students take advanced courses in fiber science, chemistry, physics, textile structure formation, engineering, computer science, and other appropriate areas of study as determined by their graduate committees. Students may concentrate in polymer and fiber chemistry, textile structure formation, textile science, or polymer science. Areas of study include fiber chemistry, fiber physics, chemistry of dyeing, polymer chemistry and physics, advanced polymer systems for fiber and film applications, smart fibers, and others. This degree is highly multidisciplinary in nature. Applicants usually have a BS degree in one of the base sciences or engineering disciplines, mathematics, computer science, textile science, textile chemistry, life science, or a closely allied field. Students may be accepted into the program with deficiencies in chemistry, physics, and mathematics; but the deficiencies must be remedied with appropriate undergraduate courses within a specified time frame.

MS students normally concentrate in fiber and polymer chemistry or physics, dye chemistry, textile science, textile materials formation science, composite materials, or other area of polymer and fiber science. The minor area of study is usually in chemistry, physics, engineering, computer science, life sciences, or mathematics. Each MS candidate must complete an independent scientific or technical investigation and formally report and defend the methodology, results, and conclusions in a thesis. A minimum of 24 credit hours of coursework and six credit hours of research is required for the MS degree. All MS students must enroll in MS&E 800 every semester.

Students in the PhD program may concentrate in polymer science, natural and/or man-made fibers, conversions of new fibers into structures, polymer chemistry and physics, fiber physics, or coloration science. Students are normally admitted to the PhD program after completing the requirements for a BS or MS degree in a base science, engineering, life science, or textile program. Students in the MS program may petition their graduate committees to change to the PhD program after demonstrating an ability to perform at the required level. PhD students should consult their advisors for program requirements. All students must enroll in MS&E 800 every semester. Courses, tailored to the individual's objectives, are selected by the student and his/her advisory committee. The PhD degree requires completion of comprehensive and final examinations. Each candidate must carry out an independent, original scientific investigation and formally report and defend the methodology, results, and conclusions in a dissertation.