SCHOOL OF ENGINEERING

Information about the following subjects may be found in the General Information section at the back of this catalog: Student Life and Services, Admission, Tuition and Fees, Financial Aid, and University Policies and Procedures.

Web Site: *http://www.soe.rutgers.edu*

General Information

HISTORY AND AIMS OF THE SCHOOL

Instruction in engineering began at Rutgers in 1864, when the state of New Jersey designated the Rutgers Scientific School as the State College for the Benefit of Agriculture and Mechanic Arts. The present School of Engineering became a separate entity in 1914 and continues to maintain two principal objectives: the sound technical and cultural education of the student and the advancement of knowledge through research.

The School of Engineering has designed each of its engineering curricula to contain three types of courses: (1) courses covering the basic scientific principles essential to advanced study in any field of science or engineering; (2) nontechnical courses that, with the basic sciences, are a part of the common heritage of educated persons; and (3) technical courses in which the basic scientific principles are applied to problems in a particular engineering field. Throughout all courses, the emphasis is on a thorough understanding of fundamental principles and engineering methods of analysis and reasoning. All curricula are sufficiently comprehensive to form a foundation for a satisfying career as a practicing engineer; for advanced scientific and technical study and research; and for advanced study and careers in business, law, and medicine.

TEACHING GOALS OF THE SCHOOL

Each curriculum within the School of Engineering is designed to ensure that its students have attained (1) an ability to apply knowledge of mathematics, science, and engineering; (2) an ability to design and conduct experiments, as well as to analyze and interpret data; (3) an ability to design a system, component, or process to meet desired needs within realistic constraints; (4) an ability to function on multidisciplinary teams; (5) an ability to identify, formulate, and solve engineering problems; (6) an understanding of professional and ethical responsibility; (7) an ability to communicate effectively; (8) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context; (9) a recognition of the need for an ability to engage in lifelong learning; (10) a knowledge of contemporary issues; and (11) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

THE ENGINEERING PROFESSION

Engineering is a profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied to develop ways to use the materials and forces of nature economically for the benefit of humanity.

Engineering touches every phase of modern life. It extends human physical power through machines; human reasoning power through computers; and human powers of observation through instruments, enabling people to explore the tiniest microscopic structure or the far reaches of the universe. It creates vehicles to move people rapidly and safely to all parts of the earth and into the space surrounding it. It makes possible complex production and distribution systems for providing ample food to urban populations. It permits rapid communication of information among people throughout the world. It has given people great power to control their environment and, with this power, the responsibility to control it wisely. It has provided people with the most sophisticated art form, the art of engineering design.

THE UNIVERSITY ENVIRONMENT

As students at one of the colleges of Rutgers, The State University of New Jersey, engineering students share a rich campus life with students in many other disciplines. Intellectual stimulation abounds in a wide variety of interdisciplinary lectures and seminars, and extracurricular activities include an equally wide range of concerts and athletic and social events. Every student has access to distinguished professors in many fields. In addition, the undergraduate engineering student studies in an atmosphere of scholarly activity enriched by the closely related programs of graduate instruction and research.

Instruction in engineering is centered in Piscataway (adjacent to New Brunswick) on the Busch campus. Housing and all other student services are provided to each engineering student through one of the four residential colleges in the New Brunswick / Piscataway area (Douglass, Livingston, Rutgers, or Cook) with which that student affiliates. See the Student Life and Services section for more information on affiliation.

ACADEMIC PROGRAMS

Undergraduate Curricula and Accreditation

Four-year undergraduate curricula leading to the degree of bachelor of science are offered in the fields of biomedical engineering, bioresource engineering, ceramic engineering, chemical engineering, civil engineering, electrical and computer engineering, industrial engineering, and mechanical engineering. In addition, a flexible four-year curriculum in applied sciences in engineering is administered by an interdepartmental committee. Numerous areas of concentration are available within these disciplines, such as aerospace engineering, biochemical engineering, computer engineering, engineering physics, environmental engineering, materials engineering, packaging engineering, and solid-state electronics. The engineering curricula (with the exception of biomedical engineering) are accredited by the Accreditation Board for Engineering and Technology (ABET). The field of applied sciences in engineering is not a professional engineering curriculum and is not subject to ABET accreditation. The biomedical engineering curriculum was instituted in fall 1999, and it is anticipated that it will be evaluated for ABET accreditation within the next two years. The name of the bioresource engineering degree is planned to change to bioenvironmental engineering effective with the class of 2008.

A five-year, dual-degree program is offered by the School of Engineering in cooperation with three liberal arts colleges in New Brunswick / Piscataway: Douglass College, Livingston College, and Rutgers College. This program leads to a bachelor of science degree in any of the engineering fields listed above, and a bachelor of arts or bachelor of science degree from the cooperating liberal arts college in any major in which that college confers the B.A. or B.S. degree. A five-year, dual-degree program in bioresource engineering also is available in cooperation with Cook College, a professional school that specializes in agricultural and environmental studies. This program leads to B.S. degrees from the School of Engineering and Cook College.

Finally, it is possible for students to take the first two years of either a four-year B.S. program or a five-year B.A. / B.S. program at the Camden College of Arts and Sciences or the Newark College of Arts and Sciences. At the end of the second year, students transfer to the School of Engineering in New Brunswick / Piscataway.

Five-Year B.S./M.B.A. Program

A special joint program offered by the School of Engineering and the Rutgers Business School–Newark and New Brunswick is available for qualified engineering students. This program offers the opportunity to obtain the master of business administration degree within one calendar year of completing the baccalaureate degree requirements.

Graduate Programs

Extensive engineering programs at the graduate level also are available. The degrees of master of science, master of philosophy, and doctor of philosophy are given in a wide range of fields. The graduate programs are described in the catalog of the Graduate School–New Brunswick.

Study Abroad

Students in all engineering majors may arrange individualized programs through the Rutgers Study Abroad Office, which coordinates extensive programs in several countries. Academic advising is provided by the associate dean for academic affairs. In recent years, School of Engineering students have studied in the United Kingdom at the University of Bristol, City University of London, and University College London, and in Australia at the University of Melbourne.

ORGANIZATION OF THE SCHOOL

The school is organized in seven academic departments: Department of Biomedical Engineering, Department of Ceramic and Materials Engineering, Department of Chemical and Biochemical Engineering, Department of Civil and Environmental Engineering, Department of Electrical and Computer Engineering, Department of Industrial and Systems Engineering, and Department of Mechanical and Aerospace Engineering. Courses in bioresource engineering are taught by the faculty of the bioresource engineering program, which is part of Cook College.

To fulfill its obligation to extend the boundaries of knowledge, the school operates the Office of Graduate Education and Research. Through this organization, members of the faculty and students engage in research that may be supported by the university, by industry, or by state or federal government agencies. Since research is an integral part of the educational function of the school, the research laboratories are intermingled with those used for instruction. The result is an academic environment that excites the curiosity of students and stimulates their interest in exploring the frontiers of knowledge.

To support the programs of instruction and research, the school established Engineering Computing Services (ECS). Sophisticated modern computing systems are available through the engineering computer laboratories supported by ECS and through facilities provided by Rutgers University Computing Services (RUCS).

Education in engineering, like that in any other profession, is a lifelong process. Practicing engineers can keep abreast of the latest developments in their field through the Program for Continuing Engineering Studies operated by the school. The school offers short courses and conferences in a wide range of subjects to meet the changing needs of the profession, as well as review courses to prepare for the Fundamentals of Engineering (FE) and Professional Engineers (PE) licensing examinations.

Descriptions of Fields of Study

The School of Engineering offers academic programs leading to the degree of bachelor of science in applied sciences in engineering, biomedical engineering, bioresource engineering, ceramic engineering, chemical engineering, civil engineering, electrical and computer engineering, industrial engineering, and mechanical engineering. The name of the bioresource engineering degree is planned to change to bioenvironmental engineering effective with the class of 2008. The detailed requirements for each program can be found in the Programs of Study chapter. General descriptions of the undergraduate fields of study and various areas of specialization are given in this chapter.

Applied Sciences in Engineering

The curriculum in applied sciences in engineering is intended to meet the needs of students whose goals might not be served by the professional engineering programs. The curriculum permits the development of a wide range of interdisciplinary programs individually tailored to the needs of the student outside the accredited or professional engineering fields. A faculty committee advises each student in the preparation of a sound educational program from courses available in the regular engineering programs. The applied sciences in engineering curriculum is not accredited as a professional engineering program.

Courses are not offered specifically for this curriculum, but must be chosen from among those scheduled by the professional engineering programs. Several areas of specialization currently are available, such as packaging engineering, engineering physics, and preparatory programs for law school or medical school.

Biomedical Engineering

The biomedical engineering (BME) program offers a solid core engineering, mathematics, and science curriculum organized into three main options, called tracks: (1) biomedical computing, imaging, and instrumentation (BCII); (2) biomechanics and rehabilitation engineering (BRE); and (3) tissue engineering and molecular bioengineering (TEMB). The BCII track is designed to train students who are interested in academic or industrial careers that involve the measuring and modeling of physiological systems, medical imaging, medical image processing and analysis, and the graphics and visualization industries. Emphasis is placed both on understanding the physiological system as well as the engineering and development of new sensors and measurement devices. The BRE track offers instruction on mechanical aspects of the body and on the development of load-bearing devices for improved human performance. The biomechanics option has added emphasis on tissue and fluid mechanics whereas the rehabilitation option has an emphasis on prosthetics and assisted devices. The TEMB track is designed for students who desire to apply engineering principles to develop new biocompatible materials for the fields of tissue engineering and regenerative medicine, and to study and solve problems on the cellular and molecular scales.

The broad education provided by these tracks allows students to choose from a wide variety of careers. The degree program is designed to prepare qualified graduates for graduate study leading to the M.S. or Ph.D. degree in biomedical engineering. In addition, students are prepared to meet the graduate entrance requirements for medical and law schools, business administration, and other professional disciplines. Aspiring graduates with industrial experience and outlook can work in large corporations and smaller companies as practicing biomedical engineers. Increasing numbers of graduates are finding rewarding jobs in state and federal institutions, including the National Laboratories.

The achievements of biomedical engineering constantly touch our daily lives. Past and current breakthroughs that were pioneered at Rutgers include heart-assist devices for cardiac surgery; techniques for online analysis and operating room lesioning of brain tissue for Parkinson’s disease; an artificial hand with finger dexterity; the use of virtual reality in the rehabilitation of limbs; revolutionary techniques for making large numbers of new biopolymers for implants; and rapid NMR analysis of protein structure.

There are several exciting opportunities for undergraduates in biomedical engineering to further their training and experience. The Honors Academy is designed for those high achieving students who will immerse themselves in an accelerated research program. The Industrial Internship Program allows students at the end of their sophomore year to apply for a 10-week summer internship at local or national companies. The Co-op Program provides students with an industrial experience to the undergraduate program by complementing their course work into a working engineering environment. The department also participates in the James J. Slade Scholars Program. These selective programs can serve as springboards for qualified students who wish to begin working toward an M.S. or Ph.D. degree in their senior year.

Bioresource (Bioenvironmental) Engineering

Bioresource engineering utilizes the physical and biological sciences in solving problems related to plants, animals, food, wastes, and our natural environment. Graduates of this program have a unique engineering education enabling them to apply the rapid advances being made in the biological and environmental sciences for the benefit of mankind. This program prepares students for immediate employment as practicing engineers with industrial companies, government agencies, and private consulting firms, for international service, or for additional study at the graduate level. The name of the bioresource engineering degree is planned to change to bioenvironmental engineering effective with the class of 2008.

The objectives of the curriculum are as follows:

- to apply their creativity in solving complex environmental engineering design problems, to approach unstructured and interdisciplinary problems, to synthesize and design potential solutions, and to evaluate the impact of their solutions within the broader context of society;
- to provide the following technical skills: the collection, analysis, and interpretation of data relevant to problems arising in the bioresource and environmental sectors; the

methodological and computational skills with which to operate effectively within the bioresource and environmental engineering sectors; skill in current technologies and fundamentals to enable students to adapt to the changing field;
- to provide the following leadership skills: facilitate, lead, coordinate, and participate in interdisciplinary teams as well as understand organizational processes and behavior; to effectively communicate their solutions in the context of written, oral, and electronic media; to participate in professional association and activities in the field;
- to position students for lifelong learning;
- to teach students to understand and be sensitive to the importance of professional ethics and uphold these ethics in their professional practice.

The curriculum currently includes an option in bioenvironmental engineering. This option is concerned with maintaining the quality of man's natural environment. It involves the application of physical, biological, and environmental sciences to land use and waste management problems, air and water pollution, and the conservation of our natural resources. The student gains an understanding of the requirements and tolerances of natural, living ecosystems and the engineering expertise needed to solve serious environmental problems facing our society. This option is for the undergraduate student wanting to gain a full measure of exposure and preparation to practice as a professional environmental engineer following graduation.

The bioresource engineering curriculum provides a strong foundation in engineering, chemistry, and the biological sciences. Upper-level major courses give the graduate the tools to bridge the gap between the sciences and engineering. The faculty has extensive experience in teaching, research, and consulting with private firms and government agencies.

Both four- and five-year programs are available. Students normally matriculate into the four-year program through the School of Engineering or enter the five-year program through Cook College. The latter is a dual-degree program resulting in two bachelor of science degrees, one from the School of Engineering and one from Cook College. The B.S. degree program in engineering is accredited by the Accreditation Board for Engineering and Technology (ABET). Both programs prepare graduates for taking the Fundamentals of Engineering (FE) examination pursuant to becoming a licensed professional engineer.

During the first two years, most of the studies involve mathematics, chemistry, physics, computer programming, writing, humanities, and engineering sciences. The remainder of the academic program involves required and elective courses that prepare the graduate for professional engineering practice in his or her chosen field of interest. The course work is complemented with appropriate laboratory experience.

Ceramic and Materials Engineering

The undergraduate curriculum in the ceramic and materials engineering (CME) program embodies the interplay between structure, processing, and properties of engineering materials, with emphasis on applications and materials design. While all materials are addressed within the curriculum, there is a strong emphasis on ceramic materials. Here, the high-temperature phenomenon in the entire field of inorganic chemistry and physics is addressed with particular emphasis on cutting-edge materials and technologies.

The curriculum covers both the crystalline and glassy phases of many materials types. The core courses and research projects include studies of composition, phase, and structure; the interaction of materials to stress, temperature, varying chemical environments, and radiation of all frequencies; and the processing of complex engineering components and devices.

The curriculum examines engineering fundamentals, but also provides flexibility to allow students to concentrate on a specific field within ceramic and materials engineering. The curriculum culminates in two capstone courses: Engineering Design in Ceramic and Materials Engineering (14:150:411,412) or Senior Ceramic and Materials Engineering Laboratory (14:150:401-402). The Engineering Design in Ceramic and Materials Engineering two-course sequence is intended for students wishing to emphasize production and management in advanced materials. Engineering Design stresses the concept of design of a project related to the fundamentals of plant layout, construction, installation, maintenance, and cost for manufacturing a ceramic product taking into consideration all the economic, safety, and social factors involved. Those students wishing to emphasize research and/or go into advanced degree studies take Senior Laboratory, a two-course sequence, which is their capstone course. In this case, the students are trained in the scientific methods of performing an independent research project. Students choose from a unique set of projects that are presented by members of the faculty. Check the department web site at *http://www.ceramicmaterials.rutgers.edu* for any changes that may occur.

Options and Areas of Specialization

Students, alumni, and employers have a great influence on the curriculum. This is demonstrated by the recent creation of areas of specialization that are critical to today's graduating engineers. In addressing these constituencies, four options have been established: nanomaterials, photonics and optical materials, engineering management, and general studies in CME.

With the creation of these options, a greater degree of freedom is now available for students in their junior and senior years. During these four terms, six potential electives are available for students to concentrate their studies in a particular area. Electives have been spaced to allow a student to select either the nanomaterials option, the photonics and optical materials option, the engineering management option, or the general CME option. Future options may include materials science and engineering, electronic materials, biomaterials, and powder technology.

An option is defined by a student selecting a minimum of four courses (12 credits) from a list of electives in an area of concentration. Students who complete the sequence of four courses will be awarded a certificate. Selection of an option should be made after meeting with an academic adviser at the end of the spring term of the sophomore year.

Internship Programs

Students also may participate in a variety of internship programs ranging from a student technician program to the co-op internship. The co-op internship provides the student with the opportunity to practice and/or apply knowledge and skills in various ceramic or materials engineering professional environments. This internship is intended to provide a real world experience to the student's undergraduate studies by integrating prior course work into a working engineering environment.

Educational Mission of the Department

The Department of Ceramic and Materials Engineering (CME) is committed to providing qualified students with a relevant education in ceramic and materials engineering preparing them for a productive and rewarding career. While this mission is consistent with the overall mission of the university and the School of Engineering, the department focuses on providing an education that is both learning and practice oriented. With its high faculty-to-student ratio, the department provides unique course options and extensive laboratory experiences, along with research and co-op internships that have adapted to the changing requirements of employers and graduate schools.

Through continuous feedback from students, alumni, and employers, the department has developed a curriculum that emphasizes basic science, engineering, and design. Moreover, the curriculum provides flexibility and diversity in allowing students to select areas of concentration that are in the forefront of technology today.

Educational Objectives

Within the scope of the CME mission, the objectives of the ceramic and materials engineering program are to produce graduates with an education relevant to current science and engineering, and an education that will lead to a productive and rewarding career. Furthermore, objectives of the program are to produce graduates who

- are able to practice ceramic and materials engineering in a broad range of industries, including ceramic materials production, and have an extended knowledge of general ceramic technology, management, photonics, and optical materials, or nanomaterials;
- are able to engage in advanced studies in ceramic materials, ceramic engineering, and related or complementary fields of study;
- are able to function independently and in teams and are proficient in written, oral, and graphical communication;
- are capable of responding to societal, ethical, environmental, and engineering constraints to improve the global quality of life;
- are capable of recognizing the need and responding to a rapidly expanding knowledge base through lifelong learning.

Program Outcomes and Their Relationship to ABET Criterion 3

The program outcomes for CME students are divided into two categories. Outcomes 1–11 are applicable to all engineers. Outcomes 12–15 apply to ceramic engineering students. Graduates in ceramic and materials engineering demonstrate the following related to general engineering practice:

1. an ability to apply knowledge of mathematics, science, and engineering;
2. an ability to design and conduct experiments, as well as to analyze and interpret data;
3. an ability to design a system, component, or process to meet desired needs;
4. an ability to function on multidisciplinary teams;
5. an ability to identify, formulate, and solve engineering problems;
6. an understanding of professional and ethical responsibility;
7. an ability to communicate effectively;
8. the broad education necessary to understand the impact of engineering solutions in a global and societal context;
9. the recognition of the need for, and the ability to engage in lifelong learning;
10. a knowledge of contemporary issues;
11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice;
12. an ability to use experimental, statistical, and computational methods to analyze the behavior of ceramic and materials systems;
13. an ability to apply advanced science and engineering principles to ceramic and materials systems;
14. an understanding of the fundamental principles underlying and connecting structure, properties, processing, and performance related to the material systems utilized in ceramic and materials engineering;
15. an ability to apply and integrate knowledge from each of the above four elements of the field to solve material selection and design problems.

Chemical and Biochemical Engineering

Chemical engineering deals with the chemical and physical processes for converting raw materials to valuable products. Students apply principles of physics, chemistry, mathematics, and health and safety sciences to the analysis, design, and automatic control of these processes. The biochemical engineering option focuses on biochemical and biological processes that require the integration of biochemistry and microbiology with the core chemical engineering curriculum and other basic sciences. Special programs are available for those who wish to pursue careers as chemical engineers in medicine or biomedical engineering, polymer process engineering and science, environmental engineering, pharmaceutical engineering, and food engineering.

The achievements of chemical and biochemical engineering constantly touch our daily lives. Past and current breakthroughs include large-scale production of antibiotics; plastics, synthetic rubber, and polymeric fabrics; gasoline and aviation fuel; hydrocarbon-based chemicals from oil, coal, and renewable resources; water and air purification systems; management of hazardous wastes; fertilizers, nutritional synthetic foods, and dietary supplements; dyes, paints, and solvents; kidney dialysis machines and artificial skin; biological production of alcohol or methane gas from controlled microbial digestion of natural and industrial waste materials; and development of bioreactors using enzymes and cells to enhance production of foods and specialty chemicals.

The broad education provided by these options and special programs allows students to choose from a wide variety of careers. Many graduates work in large corporations as well as smaller companies as practicing chemical or biochemical engineers. The degree program also prepares qualified students for graduate study leading to the M.S. or Ph.D. degree in chemical and other engineering disciplines, including specialties in biomedical, environmental, polymer, food, and pharmaceutical engineering. In addition, students are prepared to meet the graduate entrance requirements for medical and law schools, business administration, and other professional disciplines.

The curriculum is designed to prepare and train students for entry into the profession equipped with the fundamental knowledge in core sciences required for problem solving and critical thinking. Graduates will have the tools needed to design and analyze complex chemical engineering systems. Training in ethical, health and safety, and societal concerns as they relate to the chemical engineering profession is also provided. Graduates further learn effective communication skills and gain valuable experience working in a team environment.

Civil and Environmental Engineering

Civil engineering is one of the broadest of the engineering disciplines, extending across many technical specialities. Civil engineers plan, design, and supervise the construction of facilities essential to modern life. These facilities vary widely in nature, size, and scope and include space satellites and launching facilities, offshore structures, bridges, buildings, tunnels, highways, transit systems, dams, airports, harbors, water supply and wastewater treatment plants, and other facilities for mitigating environmental problems. All of the forces of nature, static and dynamic, are included in this field of inquiry, as are the properties of materials, including the soil and rock mantle of the earth. In addition, civil engineering is concerned with the interlocking influences of structures, systems, forces, and materials on one another and on society. Civil engineers work in many diversified areas, such as structural engineering, geotechnical engineering, water resources and environmental engineering, transportation engineering, ocean and coastal engineering, and construction engineering.

Civil engineering activities are intimately involved with the activities of many other professions, such as planning, finance, architecture, and health; with agencies of local, state, and federal governments; and with the business community in general.

The undergraduate program in civil and environmental engineering provides a broad and thorough education to students in civil engineering fundamentals, applications, and design in order to prepare graduates for the practice of professional engineering. To enable graduates to meet challenges posed by an ever-changing society and advancing technology, the program provides a broad background in many of the different areas of civil engineering and sound exposure to engineering sciences, humanities, and social sciences. The undergraduate curriculum permits students to have an area of concentration in structures, geotechnical engineering, construction engineering, transportation engineering, or water resources / environmental engineering. Students have considerable freedom to select a variety of departmental electives, technical electives, and, in the senior year, capstone design courses to form a concentrated area of study.

Electrical and Computer Engineering

Electrical and computer engineering is a rapidly developing and diverse field ranging from integrated circuits and submicron devices to powerful computational systems and massive communication networks, such as those used in the information superhighway. Over the past two decades, increasing numbers of electrical and computer engineering graduates have been engaged in the development and application of solid-state electronic devices, electronic computers and data processing systems, and automatic control systems of increasing sophistication. In turn, these developments have led to further development of the more traditional technologies, such as energy conversion and transmission; electrical circuit synthesis; and particularly to an unprecedented growth of electronic data processing, communication, control, and computer systems.

To prepare its graduates to compete in a fast-changing technical environment, the department depends upon a curriculum with a strong core of required courses in mathematics, physical sciences, and engineering science. In addition, students have considerable freedom to choose electives in these and other areas of study. As a result, electrical and computer engineering undergraduates may structure their programs to accommodate the changes of the electrical and electronic industry and to prepare for graduate study in such diverse areas as control and power systems, communication systems, digital signal processing, computer engineering, solid-state electronics, wireless information networks, and others. The wide range of subject matter enhances the student's opportunity for challenging employment and graduate study.

The department offers two curriculum options for undergraduate students: electrical engineering and computer engineering. The electrical engineering option follows a traditional set of required courses with equal emphasis on all main areas of electrical engineering, yet allows a student to favor one area over another by appropriate selection of elective courses. The computer engineering option, while giving a broad background in electrical engineering, prepares students for careers in the area of computer hardware and software engineering.

Program Objectives

Consistent with the stated mission of the university, the mission of the electrical and computer engineering program is to prepare its graduates for a rapidly changing technological field. Students are provided with a broad and thorough education in electrical and computer engineering fundamentals, applications, and design so as to prepare them for a career in the electrical and computer engineering profession, and for continuing their studies at the graduate level. In pursuit of this mission, the educational objectives are

1. to provide a broadly based educational experience in which the scientific and technical elements of the engineering curriculum are integrated with the humanities and social sciences;
2. to ensure that students are competent in fundamental areas in electrical and computer engineering, such as communications, computer engineering (hardware and software), digital signal processing, systems and controls, solid state electronics, and circuits;
3. to ensure that students are able to identify, formulate, and solve a wide range of electrical and computer engineering problems using modern engineering tools and techniques;
4. to provide students with a major design experience in at least one of the fundamental areas in electrical and computer engineering;
5. to encourage students to continue their professional development by attending graduate school, engaging in continuous learning programs, and / or participating in professional societies.

Program Outcomes

Encompassing the program outcomes set forth in the ABET Engineering Criteria 2000, each graduate of the electrical and computer engineering program is expected to have demonstrated the following by time of graduation:

1. an ability to apply knowledge of mathematics, science, and engineering for analysis and solution of engineering problems;
2. proficiency in fundamental areas of electrical and computer engineering, such as communications, computer engineering (hardware and software), digital signal processing, systems and controls, solid state electronics, and circuits;
3. an ability to design and conduct laboratory experiments and to critically analyze and interpret data in the fundamental areas of electrical and computer engineering;
4. an ability to identify, formulate, and solve a wide range of problems encountered in electrical and computer engineering using the skills, techniques, and modern engineering tools necessary for engineering practice;
5. an ability to perform engineering design by means of design experience integrated throughout the professional component of the curricula, culminating in a major design experience involving teamwork, alternative solutions, and realistic design constraints;
6. an understanding of the importance of personal and professional integrity, ethical responsibility in the practice of electrical and computer engineering, and other professional practice issues;
7. an ability to effectively communicate orally and in writing, both individually and in multidisciplinary teams;
8. a recognition of the need for and an ability to engage in lifelong learning and professional development, including graduate school, continuing education, and participation in professional societies;
9. the broad education necessary to understand contemporary issues and the impact of engineering solutions in a global and societal context.

Industrial and Systems Engineering

In today's complex and competitive world, industrial engineers are in ever greater demand to design, improve, and operate integrated systems of people, materials, equipment, and energy. The industrial engineering discipline applies fundamentals from the mathematical, physical, and engineering sciences to design and analyze efficiently large systems that serve industry and government both in manufacturing and service sectors.

To allow students to understand the impact of engineering solutions in a global / societal context, the undergraduate industrial and systems engineering program provides a broad engineering education along with specialization in the industrial and systems engineering and manufacturing fields. Academic strength in mathematics, physics, and basic engineering science is required. Specializations are offered in mathematical modeling, quality engineering techniques, computer-aided design (CAD), computer-aided manufacturing (CAM), simulation, manufacturing processes, engineering economics, production planning and control, and information technology. Students have access to state-of-the-art laboratory facilities where hands-on instruction is emphasized in CAD / CAM, robotics, machine vision, automated material handling, quality engineering, and computer integration of databases and information systems.

The undergraduate pedagogy focuses on classroom instruction fostered by learning in multidisciplinary project teams. These teams frequently formulate and find engineering solutions to real-world industry problems. The ability to communicate effectively is emphasized by having students provide both oral and written reports.

Our graduates contribute to a wide range of endeavors, including electronic, pharmaceutical, and other manufacturing; health services, transportation, distribution, and communication; and computers, finance, marketing, and management. Students pursue graduate studies in engineering and in management at other leading institutions.

The faculty is dedicated to excellence in teaching, research, and professional service. It brings experience, real-life industrial problems, and enthusiasm to the classroom, setting a standard for students to follow in their professional careers.

Mechanical and Aerospace Engineering

The evolution of our technology into the 21st century has reinforced the importance of the broad technical and professional training of both the mechanical and the aerospace engineer. Each may make his or her professional contribution in many diverse industries, ranging from the automobile and aerospace industries to the manufacture of computers, biomedical devices, and the automation and control of systems. Regardless of the particular product involved, mechanical and aerospace engineers rely upon knowledge of matter and energy conversions, motions, and forces obtained from computer simulations and experimental investigations of processes and systems. Each type of engineer is able to design mechanisms, machines, and structures to serve a specific purpose, such as the manufacture of high-tech materials, including ceramics, composites and biomaterials, and high tech equipment, including spacecraft, robots, and human implants. They also are trained to determine, both experimentally and theoretically, the heat, energy, and mechanical stress that occurs within engineering devices. Examples include internal combustion engines, electronic equipment, robots, solar energy systems, artificial organs, rocket engines, steam and gas turbines, and nuclear reactors. The curriculum in mechanical and aerospace engineering provides these skills and prepares students for graduate study and research.

The undergraduate program in mechanical and aerospace engineering trains students in a technically sound, challenging, and professional manner, laying the foundation for a productive career and enabling graduates to make positive contributions to their profession and society. This is achieved with a thorough preparation in the humanities, mathematics, and basic sciences as well as up-to-date mechanical and aerospace engineering fundamentals and applications using the most advanced tools and methods available. In the senior year, the capstone design and manufacturing course allows students to solve open-ended, multicriteria engineering problems. Emphasis is placed on team work, project management, conceptualization, detailed design, computational analysis, and manufacturing. At the end of the yearlong course, students will have experienced a full product development cycle from concept to construction and testing.

Facilities

The facilities of the School of Engineering for laboratory instruction and other services are housed in buildings on the Busch campus, except for the laboratories of the Program in Bioresource Engineering, which are located on the Cook College campus. The Engineering Center on Busch campus contains spacious quarters for instruction and research in the fields of biomedical, ceramic and materials, chemical and biochemical, civil and environmental, electrical and computer, industrial and systems, and mechanical and aerospace engineering. The following summary of laboratories and equipment is organized by department.

Biomedical Engineering

The School of Engineering has broken ground for a new state-of-the-art, 80,000-square-foot biomedical engineering building on Busch campus to be completed by spring 2006. Features in the new building include student instructional laboratories for physiology, biomaterials and biomechanics, and molecular and cellular engineering, and core research facilities for genomics and proteomics, tissue engineering, advanced microscopy, biomedical optics, microfabrication, and animal-based studies. There will be a high-performance computing and visualization center with several satellite labs as well as a 200-seat auditorium designed for conferences and seminars. The biomedical engineering research laboratories are currently dispersed through engineering and contain special equipment such as epifluorescence optical microscopy, laser-scanning confocal microscopy, atomic force microscopy, an instron for mechanical testing, flow cytometry and cell sorter, and encompass experimental techniques such as computer-assisted dynamic cell motion analysis, biomaterial synthesis and modification, microscale substrate biopatterning, PCR amplification and DNA microarrayers and scanners for gene expression profiling, two-dimensional gel electrophoresis coupled to mass spectrometry for protein expression, and isotopomer balancing for metabolite profiling. Student instructional laboratories dedicated to the biomedical engineering undergraduate are available in our current facility complete with the latest software to educate students in physiological systems analysis and biomedical measurement techniques. A newly developed instructional laboratory dedicated to tissue engineering will expose students to cell culture systems, microscopy and imaging, quantification of cell growth stimulation, and the like. Extensive laboratories of other departments within the university and those of the University of Medicine and Dentistry of New Jersey–Robert Wood Johnson Medical School are also available for research and special studies.

Bioresource (Bioenvironmental) Engineering

Bioenvironmental Engineering Laboratory. The laboratory is well equipped for the analysis of both liquid and solid waste materials and the study of various physicochemical and biological treatment processes. Equipment available includes a gas chromatograph, spectrophotometers, centrifuges, analytical balances, microscopes, an incubator, a bomb calorimeter, an autoclave, a Kjeldahl apparatus, constant temperature baths, ovens and furnaces, turbidmeters, dissolved oxygen, and conductivity and pH meters, together with a full range of ancillary materials and chemicals for chemical and biological testing. Apparatus is available for studying granular media filtration, heat transfer in completely mixed reactors, biodegradability of organic pollutants, activated sludge treatment, and aerobic and anaerobic digestion. Experiments in open-channel flow can be performed with a tilting hydraulic flume. Other equipment includes a pressure membrane apparatus for determining moisture-tension relationships in soil, digital soil-moisture testers, and Campbell Microloggers using gypsum-block sensors. Also available are hydrometers, tensiometers, infiltrometers, tipping-bucket rain gauges, and continuous digital rainfall-recording equipment. Apparatus for determining soil texture, suspended sediment, and pollutant concentrations is available, as well as workstations for signal conditioning and data acquisition and processing. Surveying equipment for instructional use includes levels, transits, plane tables, planimeters, and electronic distance measuring (EDM) instruments.

Instructional Computing Laboratory (ICL) is a fully functional computer-based teaching lab. The primary facilities of the ICL include an instructor workstation and 15 student PC-based workstations. The lecture station can present material in many media formats: computer-based, DVD, videotape, live TV from RU-TV's 65 channel lineup, transparencies, and a live in-lab camera feed. The ICL also has flatbed, 35-mm slide, microscope slide, and filmstrip scanners. The student workstations are outfitted with the latest in software including AutoCAD, MathCAD, MultiSim, MS Office Suite, and a host of communication packages. Students have several printing options, including large capacity laser, color inkjet, and 36-inch poster plotter printers. The ICL is available for open-use when classes are not scheduled and after-hours on a prearranged basis.

Ceramic and Materials Engineering

The Department of Ceramic and Materials Engineering contains extensive instructional and research facilities focusing on the analysis, characterization, manufacturing, and control of the wide variety of conventional and advanced materials including ceramics; glasses; composites; electrical, optical, magnetic materials; and nanomaterials required by modern technology. Students who utilize the laboratory equipment and facilities learn to solve problems related to the design, processing, and evaluation of conventional and specialty materials. Special equipment exposes our students to the preparation and evaluation of the newer types of ceramics, metals, polymers, and composites required in aerospace, advanced engine, biotechnology, photonics, and electromagnetic applications.

An attractive feature of the department is the small class sizes, which makes instruction more interactive. The curriculum includes a large number of laboratory courses, which provides hands-on experience and learning to our students. Generally, the laboratories are located within the A-wing of the Engineering Building, the Center for Ceramic Research Building, or the Fiber Optic Materials Research Building.

Equipment is housed in an instructional facility and several advanced technology centers, including the Center for Ceramic Research, the Fiber Optic Materials Research Center, and the Center for Advanced Materials via Immiscible Polymer Processing (AMIPP). Recent major grants from industry and the New Jersey Commission on Science and Technology have provided these instructional and research facilities. In 2002, the New Jersey Commission on Higher Education Workforce Excellence Program provided $2.5 million for the creation of the Nanomaterials Option. Three new undergraduate laboratories are now available.

Evaluation and Measurement. Microscopy equipment includes petrographic and metallographic microscopes, a transmission electron microscope, and scanning electron microscopes. Several X-ray diffraction units provide the capability of identifying phases, with computer-automated, high-resolution systems available for advanced study of particle size, strains, and quantitative phase analysis. Chemistry can be evaluated with techniques such as energy dispersive spectroscopy, atomic absorption, inductively coupled plasma, Fourier transform IR, and laser Raman. Energy dispersive X-ray analysis systems used with the scanning electron microscopes permit microchemical analysis. Virtually all types of particle-size analysis are represented. A surface analysis system provides scanning Auger microscopy coupled with secondary ion mass, X-ray photoelectron, and ion scattering spectroscopies.

Thermal analysis equipment includes simultaneous differential thermal analysis, thermogravimetric analysis, differential scanning calorimetry, thermomechanical analysis, and high-temperature X-ray diffraction.

Dielectric properties of ceramic materials can be measured over a frequency range from 0.01 hertz to 10^{10} hertz. There is equipment for measuring heat capacity, thermal expansion, thermal conductivity, and thermal diffusivity over a wide temperature range. Mechanical properties that may be measured and that are currently being studied include elasticity, viscosity, and plasticity.

Mechanical testing instrumentation includes microhardness, toughness, and modulus- and strength-testing equipment, including advanced computer-controlled servo-hydraulic, electromechanical, and high-temperature creep systems. Various room- and elevated-temperature viscometers permit rheology to be determined. An advanced torque rheometer permits optimization of such industrial processes as mixing, extrusion, and injection molding. Tribology is studied with a specially designed, automated machine that measures friction and wear.

Packaging. Equipment is available to determine tensile, compression, tear, rub, and puncture properties of paper, plastic, metal, wood, glass, and composite material. Water vapor, oxygen, and carbon dioxide permeation of polymer materials is measured with the latest MOCON equipment. Materials and packaged product interaction is measured by gas chromatography. A gel permeation chromatograph is available to measure molecular weight distributions of polymers. Melt index of polymers can be determined. Thermal analysis equipment applicable to transition, degradation, and melting temperatures of polymeric packaging materials is available for both instructional and research use.

Design and testing equipment is available to determine fragility of packaged objects by subjecting them to mechanical shock and sine wave and random vibration. Cushioning for packages can be designed and testing done to evaluate protection offered using the Damage Boundary Curve. An ISTA-certified test laboratory is used by students to evaluate packages they design, with results reported internationally. A professional, corrugated box sample maker is available.

A laboratory packaging line consisting of equipment for weighing, proportioning, or counting of products; handling, filling, and closing of packages; and code dating and checkweighing enables students to run actual line trials and obtain performance data, such as production, weight accuracy, and closure integrity.

Preparation and Forming. Common and special-purpose types of pulverizers, mixers, blungers, extruders, presses, and furnaces are available for pilot-plant production of whitewares, refractories, dielectrics, glass, and other types of ceramics. Microprocessor- and computer-controlled kilns with carefully controlled atmospheres and closely regulated temperatures are especially suitable for sintering studies.

Hot pressing and hot extrusion of special ceramics may be done in a wide range of presses and furnaces, including both cold and hot isostatic presses, atmosphere-controlled hot presses, nitriding furnaces, and injection molders. A wide variety of conventional and novel gas-fired, electric, and radio-frequency furnaces is available.

Advanced ceramic production technologies include special equipment for composites; laser synthesis of ultrafine, perfect powders; R.F./D.C. film sputtering; chemical vapor deposition; and evaporation-deposition. The properties of electronic substrates, packages, and magnetic and superconducting ceramics and devices can be studied in the Howatt Laboratory for Electronic Ceramics. A complete fiber optics laboratory includes an internal chemical vapor deposition lathe, a preform preparation clean room, and two instrumented fiber drawing towers. Extensive online and offline quality control and testing equipment for optical fiber also is available.

Laboratories

Computer Laboratory. This laboratory is equipped with 15 Silicon Graphics workstations with links to the Rutgers computer center for massively parallel computing and to supercomputers at the national level. Computations are performed in CAD/CAM related to design, manufacture, and properties of materials; in molecular dynamic simulations of materials; and in theory of materials.

Electron Microscopy Laboratory. This laboratory is equipped with a field emission scanning electron microscope (FESEM) and a transmission electron microscope, JOEL 100 CX, and various specimen-preparation facilities. The transmission electron microscope operates at up to 125 KV and is capable of 630˚ tilting with a top entry specimen holder stage. Materials research by conventional electron microscopy techniques is carried out routinely with the use of this electron microscope. The supporting equipment includes an evaporator, chemical and electropolishing units for thin foils, and darkroom facilities.

Materials Research Laboratory. This laboratory provides the necessary equipment and facilities for the study of structure and structural defects in metals, alloys, and other materials and for the study of techniques, such as the controlled use of precipitate particles or rearrangement of the existing dislocation structures to improve the engineering properties of materials. Among the various facilities of this laboratory are electron microscopes, X-ray facilities, equipment for the preparation and examination of opaque and transparent specimens, electrolytic polishing equipment, Servomet erosion spark cutters for sectioning and planing, various optical microscopes, various induction furnaces and zone-refining equipment for the growth of crystals, and a stress-corrosion test apparatus.

Mechanics and Materials Laboratory. The facilities of this laboratory are used for instruction in determining the mechanical and physical properties of various materials. The available facilities include a hydraulically controlled Instron testing machine with a high- and low-temperature environmental chamber, an Instron universal testing machine, a torsional pendulum apparatus, a sonic modulus tester, a differential scanning calorimeter, an infrared apparatus, a density gradient column, and an apparatus for the study of surface friction.

Nanomaterials and Devices Laboratory. The remarkable structural, mechanical, and electronic properties of nanomaterials have generated considerable interest. The laboratory is equipped with state-of-the-art synthesis as well as electrical measurement apparatuses. Specifically, we are equipped with a single wall nanotube furnace, a plasma enhanced chemical vapor deposition (PECVD) apparatus for aligned multiwall nanotube growth, and the submerged arc apparatus for synthesis of nanotubes, nanoonions, and nanohorns. The laboratory also has RF sputtering, thermal evaporation, and filtered cathodic arc apparatuses for catalyst and thin film deposition. In addition to nanomaterials synthesis, we have also set up a fully automated probe station with an Agilent 4155A semiconductor analyzer for electrical characterization of our nanoelectronic devices.

Scanning Probe Laboratory. Scanning probe microscopes can be used to study a wide range of properties with a resolution of one namometer or less. The laboratory is equipped with several atomic force microscopes including a Digital Instruments Nanoscope IV and a Park Instruments AFM. These are used to study nanoscale surface morphology, surface forces, frictional forces, structure of physisorbed films, and the conformation of biomolecules. In addition, there is a near-field scanning optical microscope that enables optical characterization to be performed with a resolution of around 25 nm. Nanoscale mechanical characterization is performed using a Hysitron Tribo-indenter which combines many features of an AFM with the mechanical capabilities of a nanoindentation system.

X-Ray Laboratory. This laboratory provides a variety of X-ray equipment used to determine crystal structure, characterize the defect structure of both metallic and polymeric materials, identify unknown materials, carry out accurate measurements of lattice parameters, and conduct phase identification. The facilities include two Rigaku-Denki rotating anode X-ray generators, Tennelec position-sensitive detectors with Tracor Northern pulse height analysis system, nine X-ray diffraction units including two microfocusing units and two X-ray units with divergent-beam source, four X-ray double-crystal diffractometers that were specially developed at the materials research laboratory for the study of lattice defects in single crystals as well as in polycrystalline specimens, one Lang X-ray micro-camera for the study of dislocation structure in crystals, a special X-ray small-angle scattering apparatus connected to a microfocusing X-ray tube, and one proportional counter plus circuits and automatic microdensitometer for X-ray intensity studies.

Chemical and Biochemical Engineering

The department's instructional laboratories for chemical engineering majors contain numerous modern analytical instruments and process engineering apparatus. Most equipment, such as the computer-coupled, closed-loop, continuous-flow distillation unit, features advanced microprocessor design, representing the state-of-the-art in automation. The department also maintains its own personal computer laboratory. This facility, which is conveniently located within the department's laboratory complex, contains 18 Dell Pentium 4 computers. The PC-laboratory also has two Hewlett-Packard laserjet printers and plotters, a local area network, and extensive software for problem solving. The facility also provides ready access to the Rutgers network.

As a special feature, the department's research equipment is available for students in the James J. Slade Scholars Program. The impetus for this unique offering stems from the department's strong commitment to graduate research and its active involvement with sponsored research projects at the university and state high-tech centers. Research is in such areas as biotechnology, process system engineering, fiber optics, kinetics and catalysis, polymer science and engineering, and pharmaceutical engineering among others.

The department's major instructional laboratories include a chemical-process engineering laboratory, a biochemical engineering laboratory, and laboratories for the study of polymer processes and materials. The chemical-process engineering laboratory is devoted to the study of chemical reactions and physical phase separations for multicomponent systems. Typical apparatus includes distillation, gas absorption, liquid extraction, wiped-film evaporation, falling-film evaporation, and computer-coupled process control units. Special devices are used for the study of fluid flow in pipe systems and heat transfer in heat exchangers. Analyses of changes in chemical compositions are aided by gas chromatographs, UV and IR spectrophotometers, refractometers, and many other modern analytical instruments.

The department's biochemical engineering laboratory is devoted to the study of biochemical engineering processes and the detection and separation of biospecies resulting from these bioprocesses. Specific experiments in enzyme and fermentation kinetics, for batch and continuous systems, are provided. This fully equipped biolaboratory contains a wide range of analytical instruments and specialized devices, including a Pharmacia Fine-Chemicals microprocessor-controlled and automated liquid chromatograph analyzer, and a computer-coupled BIOFLOW III fermentor system. A modern pilot-scale fermentation facility, located at the Waksman Institute of Microbiology, is used in conjunction with department facilities to provide excellent practical experience for students in the biochemical option. Also, a fully equipped immunotechnology laboratory for specialized experiments concerned with monoclonal antibody production, identification, and purification is open for use by select groups of students in the James J. Slade Honors Program.

The polymer electroprocessing laboratory is a unique facility directed toward the study of structure / electroprocessing / properties. It contains a wide array of equipment used to provide diverse thermal, mechanical, and electric field histories. These include hydraulic presses and film drawing devices, computer-controlled current density compared with electric field measurement systems for the study of ferroelectric polymers, a Rheolograph Solid® (Toyo Seiki), a computer-controlled state-of-the-art apparatus for measuring the piezoelectric, dielectric, and dynamic mechanical response of polymers as functions of temperature and frequency, a DSC and FTIR, and a wide array of X-ray diffraction equipment. The ion-containing polymer characterization laboratory contains various equipment, especially for light scattering and mechanical testing. Light scattering instruments include low-angle light scattering, wide-angle and dynamic light scattering, and a differential refractometer. Mechanical testing instruments include a Minimart Tester and a dynamic mechanical thermal analyzer (polymer laboratory). There also is a facility for the investigation of theoretical properties of polymers by thermodynamics and statistical mechanics and other methods, and for computer modeling of their behavior.

Civil and Environmental Engineering

The curriculum requires that all students obtain firsthand experience in the use of a wide range of modern experimental equipment. The purpose of the laboratory instruction is to complement the theoretical and analytical course work and to verify the fundamentals learned in the courses. The department's laboratory facilities are located in the Civil Engineering Laboratory Building and the Civil Engineering Building, which are equipped to carry out a broad spectrum of sophisticated research and instruction in virtually all aspects of civil engineering.

Concrete Structures and Materials Laboratory. This laboratory has facilities for instrumentation and testing for failure of reinforced and prestressed large-span beams, columns, connections, and large-panel slabs. The equipment includes a 1,000,000 lb. capacity compression tester; a 650,000 lb. capacity girder and frame tester for testing simple and continuous girders; a 350,000 lb. capacity slab, pipe, and frame tester; two Hewlett-Packard 100-channel data acquisition and processing systems; a 20 2 25 ft. temperature- and humidity-controlled environmental chamber; and facilities for rapid freezing and thawing tests.

Environmental Engineering Laboratory. This laboratory is equipped for performing basic and analytical work for the analysis of water and wastes and the unit processes associated with treatment. Molecular level and advanced analytical chemical measurements are available for complex environmental samples, including water and air matrices.

The equipment includes a high pressure liquid chromatograph / mass spectrometer within trap detection (LCMS), a total carbon / total nitrogen analyzer, gas chromatographs, total organic carbon analyzer, atomic absorption analyzer, pH meters, centrifuges, constant-temperature water baths, ovens, an exhaust hood, various mixing devices, and pumps. It also includes equipment for assessment of the effect of hazardous liquids on the geohydrologic properties of soils, such as flexible type permeameters.

Fluid Mechanics and Hydraulics Laboratory. This laboratory contains state-of-the-art equipment for student instruction. Three multipurpose hydraulic benches are equipped with attachments designed to demonstrate the basic principles of mass, momentum, and energy conservation and transfer. A tilting flume is available for similar experiments and demonstrations. Apparatus to study sediment transport hydrology and water quality also is available.

Large-Scale Structures Laboratory. This laboratory features a 25 2 50 ft. reaction floor having tie-down points designed to resist uplift forces of 30 kips each. A 5-ton bridge crane spans the floor. "Erector set" type fixtures are utilized to provide maximum flexibility for testing a variety of full-scale structural components. Hydraulic jacks with capacities of up to 100 tons are available for application of structural loads. An MTS Closed Loop Electrohydraulic Test System capable of more than 125,000 lb. of force and velocities of up to 350 in. per minute is available for the application of dynamic and repeated loads.

Microcomputer Laboratory. Undergraduates use this facility extensively for course and laboratory work and computer graphics. The laboratory is equipped with the latest personal computers. There is an ample number of printers and plotters. More than 40 software packages are available for computer-aided design, construction engineering, geotechnical engineering, structural engineering, and water resources. The laboratory is updated continually as computer technology advances.

Rutgers Intelligent Transportation Systems (RITS) Laboratory. Rutgers Intelligent Transportation Systems Laboratory has a cluster of Pentium PCs, a powerful file server, and various peripherals networked together. RITS lab has recently acquired a specially built trailer called POGO instrumented with two video cameras and other equipment and a number of other automated image processing hardware. Traffic signal control and interfacing hardware for conducting hardware-in-the-loop simulations have also been recently acquired for hands-on research and education activities. A number of commercially available state-of-the-art transportation engineering software packages and several unique transportation databases are also part of the RITS lab.

Soil Dynamics Laboratory. This laboratory is equipped to study wave propagation characteristics through soil and rock, the basic dynamic properties of particulate materials, and the interaction between foundation structures and underlying soils. The equipment consists of a resonant column device, a high-strain amplitude torsional shear test apparatus, a cyclic triaxial shear system, and a miniature electrodynamic exciter used for studying the response of dynamically loaded model footings. A cross-hole apparatus and a wave analyzer are available for subsurface investigation.

Soil Mechanics and Foundation Engineering Laboratory. This laboratory contains up-to-date equipment for the performance of soil identification and classification tests and for the determination of physical, hydraulic, and mechanical properties. The equipment includes standard as well as back-pressured consolidometers; direct, triaxial, and laboratory vane shear strength devices; and various permeameters. An automatic triaxial testing system also is available. A large-capacity environmental chamber is available for temperature and humidity control testing.

Solid Mechanics Laboratory. This laboratory is equipped to determine the strength and physical properties of engineering materials. There are universal testing machines, with a maximum capacity of 60,000 lb. for tension and compression tests; a torsion machine; Brinell and Rockwell hardness testers; an impact machine; beam-testing rigs; and strut buckling apparatus.

Electrical and Computer Engineering

Departmental Computer Facilities. A network of SUN workstations running UNIX on PC computers running Windows NT is available in the undergraduate instructional labs. More specialized instructional labs associated with the courses in digital signal processing, electromagnetic fields and radiation, microwaves, and microelectronics are provided with a large number of PC-Pentium computers and laser printers. The department has high speed networking capability. In addition, terminals provide access to the School of Engineering computer systems hosting state-of-the-art CAD / CAM software packages. Sophisticated engineering packages are available such as Mentor Graphics, Cadence, EESOF, SPICE, Matlab, Maple V, SPW, and a variety of graphics packages.

Communication Systems Laboratory. This laboratory contains equipment for the study of analog, pulse, and digital modulation methods. Facilities include multimeters, wideband signal generators, oscilloscopes, and spectrum analyzers. The range of topics involve communication circuit and system design, using breadboarded components through the sophisticated subsystem module interconnection. In addition, computer simulation methods are used to verify system performance. A graphics-based communication systems simulator software package is available.

System performance is investigated for amplitude, phase, and frequency modulation techniques, including pulse position, width, and amplitude data transmission schemes, binary and M-ary digital modulation and receiver structures, and spectral occupancy versus power constraints.

Computer Architecture Laboratory. This laboratory consists of experimental stations that provide students with opportunities to gain experience with the internal workings of a microcomputer, learn assembly programming for a standard commercial microprocessor, and learn how to interface input / output memory, serial I / O, and parallel I / O chips to a standard microprocessor.

Digital Logic Design Laboratory. This laboratory provides practical experience with the design and hardware implementation of digital circuits for sophomore students. The laboratory is based on a CAD tool from Viewlogic to simulate and debug a circuit that is then implemented in hardware using SSI and MSI ICs. The experiments cover all the relevant topics about combinational and sequential logic with circuits of increasing complexity.

Digital Signal Processing Laboratory. This laboratory is available for undergraduate instruction and special projects. Microprocessor-based workstations provide flexibility in the design and analysis of various real-time digital filtering operations. Experiments in speech and audio signal processing demonstrate digital methods used in processing analog signals. Other facilities include a digital image-processing laboratory and a variety of special-purpose signal processors.

Electronics Laboratory. This laboratory contains equipment for the study of solid-state devices and circuits. Experiments involve studies of biasing and low-frequency operations of discrete solid-state devices, frequency response, and the effect of feedback on single- and multistage BJT and MOSFET amplifiers. Further studies include OP-AMP parameters, frequency response, and OP-AMP linear and nonlinear circuits and systems. The laboratory is well-equipped for a range of student projects in electronic circuit designs.

Microelectronics Research Laboratory (MERL). MERL provides students an opportunity to familiarize themselves with the integrated circuit fabrication and semiconductor device processing techniques in a modern, clean-room environment. Students become familiar with the photolithography, oxidation and diffusion processes, ion implantation, metallization, plasma etching, silicon micromachining, interconnects, and fabrication of different devices. In addition, a well-equipped simulation laboratory is used for the modeling of circuits, devices, and processes related to the experimental and theoretical aspects of semiconductor technology.

Solid-State Electronics Laboratory. In addition to the facilities provided by the microelectronics research laboratory (MERL), facilities exist for the study of microwave devices, high-current switching devices, electro-optical modulation, heterojunction lasers, and electrical characterization of materials, as well as their use in communications, different solar cells, and related devices.

Virtual Reality Laboratory. This laboratory provides facilities for students to gain hands-on experience with several Virtual Reality (VR) specific interfaces, such as stereo glasses, 3-D trackers, force feedback joysticks, and sensing gloves. It also has facilities to train students in the intricacies of 3-D graphics and real-time simulation programming.

VLSI Design Laboratory. This laboratory consists of Sun and HP engineering workstations, a color plotter, automatic test equipment for VLSI chip testing, and a laser printer. Students are able to design integrated circuits and in some cases may be able to have them fabricated and tested. The laboratory has the Generator Development Tool industrial chip design software that supports silicon compilation mixed-level circuit simulation (including SPICE), automatic chip layout generation from circuit schematics, and the VHDL hardware description language.

In addition to the above-mentioned laboratories, students interested in special projects in computer engineering may take advantage of the many well-equipped faculty-supervised research laboratories, available in such specialties as robotics, computer graphics, computer database design, speech processing, image processing, machine vision, and software engineering.

Wireless Information Network Laboratory (WINLAB). WINLAB is an industry-university collaborative research center that provides facilities for undergraduate and graduate research in the area of wireless communications and networking. Experimental resources at WINLAB include the RF / Modem Lab, Mobile Networking Lab, and Wireless System-on-chip lab, covering a range of hardware and software design / prototyping. Current lab equipment includes radio propagation measurement tools, a DSP / FPGA software radio setup, and the NSF-sponsored open architecture wireless network testbed (ORBIT). The center supports undergraduate research on topics such as radio propagation studies, modem signal processing, wireless local area networks, and mobile computing applications.

Industrial and Systems Engineering

Information Technology Laboratory. The laboratory has the state-of-the-art client / server network with Apache and WebLogic application servers, database, and middleware. This lab is mainly used for research, teaching, and practice in the logistics of supply chain, warehousing, and distribution systems. The lab is equipped with simulation modeling software G2, e-score, and ReThink, as well as SAP's IDES training system. The IT research in the lab includes operations at marine terminals, C / S transaction processing middleware design, and military ammunition supply chain operations among others.

Manufacturing Automation Laboratory. The laboratory is equipped with state-of-the-art equipment in CAD / CAM (computer-aided design and computer-aided manufacturing) and manufacturing automation equipment. It includes full-scale CNC milling machines; a CNC lathe; Puma, Mitsubishi, and Seiko robots; an automated storage and retrieval system; a material handling carousel; and a wide arrangement of CAD software, including IDEAS and MASTERCAM. CAD stations and graphics terminals also are available.

Manufacturing Information Systems Laboratory. This laboratory is equipped with state-of-the-art programmable logic controllers and microcontrollers for controlling manufacturing processes, as well as binary and analog sensors for monitoring manufacturing processes, and bar code equipment and other automatic data acquisition devices used in manufacturing plants. State-of-the-art microcomputers with database management tools and data acquisition software are networked with programmable controllers to emulate supervisory control and data acquisitions systems in a factory environment.

Manufacturing Processing Laboratory. Basic machine tools such as turning, milling, drilling, grinding, and measuring machines are available to help the student become familiar with metal-processing operations. The equipment also is used to perform laboratory experiments in heat treatment, chip formation, tool life, cutting forces, temperature, chip metallurgy, and power consumption.

Microcomputer Laboratory. This laboratory is equipped with state-of-the-art microcomputers, printers, and visual aids. The lab has a large number of simulation software, such as Arena, LINDO, and Stratgraphics among others, used in a number of courses. It has software for simulation, optimization, quality control, plant layout, production control, statistical analysis, and text processing. The computers are connected to a universitywide network.

Quality and Reliability Engineering Laboratory. This laboratory allows students to have hands-on experience in actual methods of quality control and reliability engineering. A variety of software for control charts, sampling plans, and design of experiments is available. The laboratory has a wide array of materials testing equipment, roundness measurement equipment, temperature chambers, vibration tests, and voltage stressing equipment. Labview and Statgraphics software are available for students' use.

Mechanical and Aerospace Engineering

The laboratory curriculum in mechanical and aerospace engineering has been structured to help students integrate physical understanding with theoretical knowledge, and to familiarize them with advanced engineering systems and instrumentation for multidisciplinary problem solving in the 21st century. Laboratory exercises begin with introductions to basic measurement concepts and culminate in the exploration of complex, open-ended engineering problems. Facilities are continuously upgraded to provide an effective learning environment. State-of-the-art facilities, which are integral parts of the undergraduate laboratory experience, include a stereolithography rapid prototyping machine, a Mach 4 supersonic wind tunnel, and a pair of industrial-quality robotic arms. The undergraduate and research laboratory space is integrated physically to provide personal, often informal, contact and communication among undergraduate students, graduate students, and faculty. Undergraduate participation in research is widespread and strongly encouraged. A summary listing of facilities comprising the undergraduate laboratories follows.

Biomechanics. This laboratory is designed to teach the fundamental principles and methods involved in biosolid and biofluid mechanics. The students get hands-on experience in performing tests and making clinical interpretations of the tests. These experiments include two material (bone and device) construct tests, bone porosity tests, soft tissue tests, arterial resistance biofluid test, and bifurcation biofluid experiment. These experiments are linked to the biomechanical option courses offered by the department.

Design and Manufacturing. Mechanical and aerospace engineering analysis, design, and synthesis problems are investigated in the Computer-Aided Design (CAD) laboratory. Students gain hands-on experience on CAD workstations through exercises in computer-aided drafting, 3-D solid modeling and parametric design, simulation of kinematic and dynamic problems, and stress analysis using finite element methods. Extensive software is available, including AutoCAD, Inventor, Pro / Engineer, ANSYS, Matlab, Maple, and programming in C / C++ and Fortran. Exposure to advanced manufacturing techniques is provided through machine-shop training as well as utilization of two Rapid Prototyping (RP) machines (3-D Viper System and Stratasys Fused Deposition 3000 System). CAD and RP are available on the Internet and the design iteration cycles have been reduced significantly. A complete design cycle experience from concept to fabrication, followed by evaluation, has been implemented.

Dynamics and Controls. Prediction and control of the response of structures subject to dynamic loadings are a central component of mechanical and aerospace engineering design and analysis. Experiments have been designed to illustrate dynamic response of single and multiple degree of freedom systems, as well as to carefully examine frequency and amplitude response of structural components. Diagnostics are conducted using advanced laboratory computers and digital spectrum analyzers, in addition to conventional strain gages and impact hammers.

Fluid Dynamics. Fundamental principles and advanced systems involving fluid flows, ranging from demonstrating Bernoulli's principle to assessing the lift and drag characteristics of airfoil designs, are examined in the undergraduate curriculum. Facilities include four low-speed wind tunnels and a mach 4 supersonic wind tunnel; a large free surface water tunnel also is used for undergraduate participation in independent or sponsored research. Advanced instrumentation includes hot-film anemometry with computerized data acquisition and optical diagnostics techniques.

Material Characterization. Mechanical properties of materials are examined in the newly completed solid mechanics laboratory. Facilities include three Instron tensile testing machines with digital data acquisition and control and three hardness-testing machines. Laboratory exercises have been structured to highlight phenomena associated with deformation and failure of engineering materials. Additional research quality facilities available to undergraduates include larger MTS and Instron testing machines. These instruments are used in research on biomechanical systems and composite materials, respectively. Undergraduate research also may be conducted in a high pressure, ~100,000 psi, materials testing / processing laboratory.

Nanomaterials. Nanostructured materials synthesis and characterization are examined in the laboratories. Facilities include flame-based chemical vapor condensation / deposition chambers and plasma reactors. Laboratory exercises involve synthesis of nanoparticles and carbon nanotubes, probing of the processing flow field using laser-based spectroscopic techniques, and characterization of the properties of the resulting nanomaterials. The lab courses include introduction to atomic force microscopy, scanning electron microscopy, X-ray diffraction, and scanning mobility particle sizing. These dual-purpose educational / research laboratories engage significant undergraduate independent research, as well as high school outreach through internships.

Robotics and Mechatronics. Critical concepts in system control as well as advanced theories of robotics and mechatronics are investigated using a series of industrial robots including a three-axis SCARA robot (Adept Cobra s600), a three-axis planar transportation system (Genmark AVR-3000), and two five-axis general purpose robots (Mitsubishi RV-M2). Kinematics, motion planning, hybrid force / position control for object manipulation, and automated assembly operations are the topics addressed in the laboratory exercises. This dual-purpose educational / research laboratory enjoys a particularly high degree of undergraduate student participation in the research component.

Thermal Sciences. A variety of energy-related experiments are offered in the undergraduate curriculum from basic sciences of thermodynamics and heat transfer to assessing the performance and environmental impact of a steam turbine power generating system. Specific experiments include convection and radiation heat transfer exercises, and experiments carried out in an internal combustion engines laboratory and the steam power generator facility. A partnership with local industry to design the applied engineering laboratories has provided students with realistic simulations of actual engineering problems and scenarios.

Computers

Computer facilities are available at the university, school, and departmental levels. Rutgers University Computing Services (RUCS) manages the facilities and services offered at the university level that are described elsewhere in this catalog and at *http://rucs.rutgers.edu*. School of Engineering facilities are managed by Engineering Computing Services (ECS), *http://ecs.rutgers.edu*. Each School of Engineering department also maintains its own computer laboratories that provide specialized software for the use of its students and faculty. All facilities are connected to RUNet via the high-speed engineering backbone.

On the New Brunswick / Piscataway campuses there are 14 public computer laboratories or hubs provided by RUCS, including the Busch Campus Computing Center that is near the Engineering complex and the university facility most used by engineering students. The Busch campus facility offers over 200 varied workstations including Dell PCs operating Windows 2000 and Power Macintosh G4s. Scanning and printing services and a wide range of software are also provided. The Busch campus facility also contains the Digital Media Lab, featuring state-of-the-art microcomputing graphics technology.

Engineering Computing Services maintains two major instructional laboratories within the Engineering complex. These include the Design, Simulation, and Visualization (DSV) Lab and the Engineering Information Technology (EIT) Lab. Each facility is available for instruction, research, and general student use. The DSV Lab consists of 60 Dell dual boot Windows / Linux workstations. It is also equipped with a smart board projection system with a color projector, and a variety of software including MATLAB and ProEngineer. The EIT Lab consists of 34 1 GHz Dell computers running Windows 2000 and Linux. It also has a smart board projection system and a video component that allows several modes of operation, including linkage with a 10 CPU Linux cluster to produce a high resolution, multiprojector system for scientific modeling in real time.

Libraries

With holdings of over three million volumes, the Rutgers University Libraries rank among the nation's top research libraries. Composed of 26 libraries, centers, and reading rooms on Rutgers' campuses in New Brunswick / Piscataway, Camden, and Newark, and RU-Online, a digital library, the Libraries provide the resources and services necessary to support the university's mission of teaching, research, and service. Details regarding facilities and services are available at *http://www.libraries.rutgers.edu*.

Engineering students and faculty are primarily served by the Library of Science and Medicine located on the Busch campus near the Engineering complex. Other smaller specialized libraries on the Busch campus house collections in chemistry, mathematical sciences, and physics. Students and faculty can also access the catalog, a wide variety of electronic indexes and abstracts, full-text electronic journals and research guides, and other library services online, both from campus and remotely. At the Library of Science and Medicine, professional librarians, including an engineering librarian, assist students and faculty with engineering resources. Library instruction classes are also available to improve students' information-seeking skills for lifelong learning.

Academic Policies and Procedures

Note: See also the University Policies and Procedures section for regulations that pertain to all the undergraduate colleges at Rutgers–New Brunswick / Piscataway.

STUDENT RESPONSIBILITY TO KEEP INFORMED

The academic policies and procedures in this chapter apply to all students enrolled at the School of Engineering. Students in one of the five-year, dual-degree programs also should consult the section in this catalog that deals with the college from which they will earn their second degree. Similarly, students in the first two years of the four- or five-year program at the Camden College of Arts and Sciences or the Newark College of Arts and Sciences are responsible for the information in the catalog of one of those colleges. In addition to the material in this catalog, engineering students are responsible for information appearing in the *Undergraduate Schedule of Classes* and Official Notices distributed to all Rutgers University student email addresses via the New Brunswick Official Student Listserv (NBOSL) printed every Tuesday in the *Daily Targum* and sent via campus mail or electronic mail. All students are responsible for maintaining an active campus post office box and a university email account.

ACADEMIC CREDIT

Advanced Placement

Degree credit and placement are granted for grades of *4* and *5* in the College Board Advanced Placement Examinations, provided the subject matter is equivalent to those courses satisfying the engineering curriculum requirements. Each student has the option of presenting advanced placement results for degree credit or of taking the equivalent course at Rutgers for degree credit and a grade. Students may not receive credit for both advanced placement and the equivalent Rutgers course.

Proficiency Examinations

With the approval of the associate dean for academic affairs and the department that offers the course, students may pay a fee and take a proficiency examination in order to fulfill a prerequisite or satisfy a course requirement. Satisfying a course requirement by this means alone does not entitle the student to degree credit unless specific approval is obtained from the associate dean for academic affairs prior to taking the examination. Proficiency examinations may not be used to obtain credit for a course that a student has failed. A grade of *B* or better on the proficiency examination is required for degree credit. Grades on such examinations are not included in the cumulative grade-point average.

Transfer Credit from Institutions Other Than Rutgers

Engineering students who have transferred to Rutgers from another institution may receive degree credit only for those courses that are equivalent in content and credits to courses required in their curriculum and passed with a grade of *C* or better. Transfer credit for required engineering courses of the junior and senior years is granted only for courses taken in curricula accredited by the Accreditation Board for Engineering and Technology. Credit is granted at the time of entrance to the college for new transfer students. Students enrolled at the School of Engineering who wish to receive credit from another institution must receive prior approval from the associate dean. Transfer credits and grades from institutions other than Rutgers are not included in the student's cumulative grade-point average. This policy applies both to transfer credits granted at the time of admission and to any summer or special work taken at other institutions while the student is a candidate for a bachelor's degree at Rutgers. An official transcript of all work at other institutions of higher learning is required whether or not transfer credit is claimed.

Transfer Credit from Other Programs at Rutgers

A student who has transferred to the School of Engineering from a nonengineering program at Rutgers may receive credit toward the bachelor of science degree for those courses that satisfy engineering curriculum requirements. The student's cumulative grade-point average is based on grades earned in all courses taken at Rutgers prior to transfer and all subsequent courses taken for credit after entry into the engineering program.

REGISTRATION AND COURSE INFORMATION

Academic Advising

First-year engineering students are advised by the assistant dean for first-year students. After selecting a major, students are assigned to and advised by a faculty member in their major curriculum. In the first two years of a five-year, dual-degree program, students are assigned to advisers through the office of the dean of the college that has academic jurisdiction.

Students are required to consult their advisers at least once each term prior to registering for the next term. Students must assume full responsibility for conforming to the academic regulations of the college and for taking specific courses required in the appropriate term for the chosen curriculum. Students also must be careful to ascertain that they have the proper prerequisites for any course for which they register. Students are encouraged to consult the associate dean for academic affairs, the assistant dean for first-year students, the assistant dean for special programs, and any other member of the engineering faculty for advice regarding their educational or professional development.

Registration

Registration for matriculated students begins in November for the following spring term and in April for the following fall term. Matriculated students register through the Rutgers Touchtone Telephone Registration System (RTTRS) or online web registration system *(http://webreg.rutgers.edu).* Registration is completed upon full payment of tuition and fees by the announced deadline prior to the start of the term. The university reserves the right to restrict registration in all courses offered and, when necessary, to cancel courses previously announced. See the Tuition and Fees section for further information on registration.

Change of Courses. See the University Policies and Procedures section for drop / add procedures.

Course Load

All engineering curricula contain carefully integrated sequences of courses that must be taken in the proper order. It is generally advisable for the student to follow the program as shown in the Programs of Study chapter later in this section. When necessary, a student may modify his or her program to take from 12 to 21 credits in any term. No modification beyond these limits may be made without the approval of the associate dean for academic affairs. Before making any changes, the student should look ahead and assess the possible effects on future scheduling of courses.

Withdrawal and Readmission

Withdrawal. A student who wishes to withdraw from the university with grades of *W* must consult the associate dean for academic affairs and fill out a withdrawal form. Students who leave the college without officially withdrawing receive a grade of *F* in each incomplete course. Unless excused because of reasons beyond their control, students who withdraw after the 12th week of the term receive a grade of *F* in all courses. The refund of tuition is calculated from the effective date as indicated by the dean on the withdrawal form submitted to the registrar.

Readmission. Students who interrupt their registration in the School of Engineering and wish to return must apply for readmission to the associate dean for academic affairs.

Those who leave in good academic standing and who do not have outstanding financial obligations to the university ordinarily will be readmitted if they apply by December 1 for January entrance or August 1 for September entrance. Later applications receive special attention if space is available.

For the college's policy on readmission after dismissal for academic reasons, see the Scholastic Standing section later in this chapter.

Course Information

Graduate Courses. An undergraduate student may enroll for a graduate-level course with the approval of the course instructor or the graduate director and the administrator of the graduate school offering the course. The student must submit an application form to the graduate school. In general, approval is given only to seniors who have cumulative grade-point averages of 3.0 or better.

Pass/No Credit Courses. An engineering student may take one elective course (not exceeding 4 credits) on a *Pass/No Credit* basis in any two terms of the curriculum. An application to enroll in a course for *Pass/No Credit* must be filled out by the student and presented to the office of the associate dean before the end of the 12th week of the term. For courses taken during Summer Session, the application must be submitted by the end of the first week of classes. Students taking a course for *Pass/No Credit* must take all quizzes and examinations and are subject to attendance requirements. Grades of *A, B,* and *C* correspond to *Pass*, and *D* and *F* correspond to *No Credit*. These grades do not affect the cumulative grade-point average.

Auditing Courses. Upon obtaining the permission of the instructor of the course and subject to the availability of space, full-time matriculated students may audit courses without registration. No academic credit is earned in this manner and no notation is made on the student's academic transcript.

Summer Courses. For courses taken at institutions other than Rutgers, the prior approval of the associate dean for academic affairs of the School of Engineering is required in order to receive degree credit. Students in the first two years of a five-year program must obtain approval from the office of the dean of the college that has academic jurisdiction during that time period.

Only courses taken at divisions of Rutgers are included in the cumulative grade-point average. For courses taken elsewhere, it is the student's responsibility to have an official transcript mailed directly to the office of the associate dean. Degree credit is granted only for those courses that are equivalent in content and credits to courses required in the student's curriculum and passed with a grade of *C* or better.

Attendance. Students are expected to attend all scheduled course meetings. No special provisions are made for reporting occasional absences from class. However, when absences are so excessive as to impair the student's academic achievement in any course, a report is sent by the instructor to the associate dean of the School of Engineering. Reasons for the absences are then investigated and a report is sent to the instructor. Students are expected to notify the associate dean if they find that they will be absent from class for one week or more.

The makeup of work missed due to class absences is the responsibility of the student. The extent to which such work is counted toward the student's grade is left to the discretion of the instructor. A student absent from class because of required religious observance is excused without penalty.

Examinations. Final examinations are held at the end of each term. All students enrolled in a course in which a final examination is given must take the examination. During the term, unannounced and announced tests may be held at the discretion of each instructor. Common hour examinations in multisection courses may be scheduled during the evening hours on Monday through Thursday. They are not scheduled on Saturdays, except in those courses that regularly meet on Saturdays.

Declaration and Change of Curriculum

Choice of Curriculum. Students in the four-year program choose the curriculum in which they will major at the end of the first year. Students in the five-year B.A./B.S. program choose an engineering curriculum at the end of the second year.

Change of Curriculum. Students wishing to change their curriculum must fill out an application form that may be obtained from the office of the associate dean for academic affairs. The change is not effected until approved by the old and new departments and until the completed form is filed with the registrar and appropriate deans.

SCHOLASTIC STANDING

Cumulative Grade-Point Average

The student's cumulative grade-point average is based on all grades in courses completed at Rutgers and accepted for credit by the faculty of the School of Engineering, including courses failed and repeated. The university cumulative grade-point average includes all courses taken in the university. The grade-point average within the major includes specific courses identified by each department as comprising the grade-point average for the major. Generally, this includes all courses required of the major except the common core courses required of all majors in engineering and the humanities/social sciences and general electives. Courses that comprise the major grade-point average are identified by "m" prefixes in the registration system and on unofficial student transcripts. See the University Policies and Procedures section for information on the computation of the grade-point average and other grading regulations.

Repeated Courses

When failed courses are repeated, both the *F* and the new grade are included in the cumulative grade-point average. Courses in which a grade of *D* is earned may also be repeated, but only once, with both the original and new grades included in the cumulative grade-point average. A withdrawal with a *W* grade is not counted as a repeat. Courses in which a grade of *C* or higher is earned may not be repeated for inclusion in the cumulative grade-point average. If such courses are repeated, the second grade will not be included in the cumulative grade-point average.

Grade Replacement

When courses offered by the student's engineering major department are repeated, the original grade of *F* or *D* normally is not removed from the cumulative grade-point average. For all other courses, students are allowed a maximum of four grade replacements. After the course has been repeated, the student submits a form at the Office of Academic Affairs (ENB 100) and an *E* prefix is applied to the original grade which removes it from the grade-point average.

Class Designation

A student's class designation is determined by the predicted year of graduation. This designation depends not only on the number of earned degree credits, but also on the completion of key prerequisite courses in the curriculum.

Dean's List

At the end of each term, the Dean's List is published, recognizing those students who have obtained the following term averages with no grades of *F* while enrolled in a minimum of 12 credits of engineering or engineering-related courses: seniors, 3.5 or better; juniors, 3.4 or better; sophomores, 3.3 or better; and first-year students, 3.2 or better. All courses for which a student is enrolled must be completed and grades must be recorded at the time the Dean's List is prepared. Students on the Dean's List receive a letter from the dean and a special designation on their university transcript.

Poor Academic Performance

Academic Review. At the end of each term, the Committee on Scholastic Standing, composed of elected faculty and representatives of the dean of the college, reviews and may take action on the record of every student whose university term or cumulative grade-point average is 2.0 or less or whose cumulative grade-point average within the major is 2.0 or less. Students who were placed on probation at the end of the previous term also are reviewed. These students may be given a warning, placed on probation, or dismissed from the School of Engineering.

Probation. Students are placed on probation when the academic record indicates that the student is in danger of being dismissed unless substantial improvement is shown. Students are notified in writing of probationary status and the conditions of probation before the start of the next term. While on academic probation, students are advised to consult with faculty advisers regularly, curtail extracurricular activities including employment, and attend class regularly. Removal from probation depends on academic performance, including grades and progress in the major, in the following term.

Students placed on probationary status may appeal in writing to the associate dean. Grounds for appeal include technical error and/or changes in temporary grades. Letters of appeal must state the reasons for appeal and must be written by the student, although advice from others may be sought in formulating the appeal.

Dismissal. Except for students in their first term, students may be dismissed if (1) the university cumulative grade-point average is 2.0 or less, or (2) the cumulative grade-point average in the major is 2.0 or less, or (3) the term grade-point average is 1.4 or less, or (4) there have been two prior terms in which the student was placed on probation. Students in their first term may be dismissed if their grade-point average for the term is less than 1.0. Students are notified in writing of academic dismissal.

Students dismissed from the college by action of the Committee on Scholastic Standing may appeal their dismissal in writing to the committee chairperson. Grounds for appeal include technical error, changes in temporary grades, extenuating circumstances, and / or additional information not previously available to the committee. The letter of appeal must state the reasons for appeal and, when possible, should be accompanied by appropriate documentation. Letters of appeal must be written by the student, although advice from others may be sought in formulating the appeal. The appeal must be received by the committee within one week after the date of the dismissal letter. Action by the committee is final.

Readmission. Students who have been dismissed from the college because of poor academic performance may not apply for readmission until they can produce evidence to indicate that the causes of failure have been overcome. Normally, this evidence consists of the satisfactory completion of one year of work at another accredited college in a program of study approved in advance by the associate dean for academic affairs. The program of study should include at least 24 credits of engineering or engineering-related courses. Students are usually not considered for readmission after a second dismissal action. Juniors and seniors are considered for readmission only in special cases with the approval and advice of the associate dean for academic affairs.

Each application for readmission is considered on its own merits. In no case may it be assumed that satisfactory grades at another institution will lead automatically to readmission.

DISCIPLINARY PROCEDURES

The Board of Governors of Rutgers, The State University of New Jersey, has established a list of offenses that may result in separation from the university. These offenses are handled through the University Code of Student Conduct. (See the University Policies and Procedures section.) In addition, each college has a hearing procedure for use in instances where charges against a student are not of sufficient gravity to lead to separation from the university. For School of Engineering students, hearings in academic dishonesty cases are conducted by the associate dean for student development. For nonacademic offenses, hearings are conducted by the dean of students of the student's affiliated college. The hearing procedures are available in the Office of the Dean.

Degree Requirements

REQUIREMENTS

Credits and Residency

Students must complete a prescribed program of study in their declared major, outlined in the Programs of Study chapter, including the distribution requirements for departmental, technical, general, and humanities / social sciences electives. The total number of credits required for graduation varies from 127.5 to 135 credits in the four-year program, depending on the student's major.

Students in the five-year, dual-degree (B.S. / B.A. or B.S. / B.S.) program must complete an additional 30 credits of electives acceptable toward the second degree and must plan a total program that satisfies all the degree requirements of both the School of Engineering and the college offering the second degree. See the Programs of Study chapter for further information.

No degree is awarded to any student who has earned fewer than 30 credits at Rutgers. Not more than 12 of the last 42 credits for the degree may be taken outside Rutgers.

Minimum Scholastic Requirements

The degree of bachelor of science from the School of Engineering is not awarded to any candidate whose university cumulative grade-point average is less than 2.000 or whose cumulative grade-point average in the major is less than 2.000.

GRADUATION

Degrees are conferred by the university upon recommendation of the faculty only at annual commencement at the end of the spring term. Students completing degree requirements in October or January may ask the registrar for a certificate attesting to their completion of degree requirements after October 1 or after February 15. All students are required to file a diploma information card with the registrar (available at *http://registrar.rutgers.edu*), normally at the beginning of the senior year.

Degrees are conferred *in absentia* when the candidate has advised the registrar in advance of inability to attend commencement. Diplomas are withheld from all students whose financial or library accounts are not cleared.

Graduation with Honors

General honors are noted on the student's diploma and in the list of degrees and honors conferred.

Students whose cumulative grade-point averages at the end of the senior year are at least 3.200, 3.400, or 3.650 may be graduated with "Honors," "High Honors,'' or "Highest Honors," respectively.

Programs of Study

The following curricula are offered by the School of Engineering. The numbers indicate the curriculum code for each major program.

4-Year	Curriculum	5-Year
073	Applied Sciences in Engineering	072
125	Biomedical Engineering	123
127	Bioresource (Bioenvironmental) Engineering	128, 129
150	Ceramic Engineering	151
155	Chemical Engineering	156
180	Civil Engineering	181
332	Electrical and Computer Engineering	333
540	Industrial Engineering	541
650	Mechanical Engineering	651

Students in the first year of a four-year curriculum are assigned curriculum code 004. Students in the first two years of a five-year B.A./B.S. program are assigned curriculum code 005. Current information and additional details about each of these programs may be found at *http://www.soe.rutgers.edu*.

SUMMARY OF ACADEMIC PROGRAMS

Four-Year Undergraduate Programs

Students who wish to pursue four-year engineering curricula normally take the entire program in the School of Engineering at New Brunswick/Piscataway. In the four-year programs, the first year is common to all curricula. At the end of the first year, the student selects a curriculum in which to specialize. Guidance in selecting a curriculum is provided principally through the introductory engineering course. Departmental advisers also are available. For program details, see Four-Year Engineering Curricula in this chapter.

It is possible for a student to complete the first two years of a four-year program at the Camden College of Arts and Sciences (CCAS) or the Newark College of Arts and Sciences (NCAS). Some curricula may require attendance at Summer Session or an extra year of study in New Brunswick/Piscataway in order to complete degree requirements. For program details, see Transfer Programs with Camden and Newark in this chapter.

Five-Year, Dual-Degree Undergraduate Programs

The five-year programs offer dual degrees in conjunction with various other undergraduate colleges at Rutgers. A B.A./B.S. program is offered in cooperation with three liberal arts colleges in New Brunswick/Piscataway: Douglass College, Livingston College, and Rutgers College. Students normally enroll at one of the liberal arts colleges initially and then select a particular engineering curriculum at the end of the second year when they transfer to the School of Engineering. Alternatively, students enrolled in the four-year program at the School of Engineering may apply at any time prior to their final year to one of the liberal arts colleges for admission to the B.A./B.S. program. A B.S./B.S. program (in bioresource engineering only) is offered in cooperation with Cook College. For program details, see Five-Year Engineering Curricula in this chapter.

It also is possible for a student to complete the first two years of a five-year B.A./B.S. program at CCAS or NCAS. For program details, see Transfer Programs with Camden and Newark in this chapter.

Precurriculum Preparation

Some students may choose or be required to take designated courses in order to prepare adequately for success in the required curricula outlined below. These courses may include, but are not limited to, the subject areas of mathematics, physics, chemistry, biology, computer programming, and English. Selection of these courses is on the basis of placement tests administered upon admission to the School of Engineering. They are viewed as necessary additions to the required curriculum and do not replace any of the designated curriculum courses.

Other Academic Programs

For further information about the following programs, see the appropriate heading later in this chapter.

Five-Year B.S./M.B.A. Program. This special joint program between the School of Engineering and the Rutgers Business School: Graduate Programs enables qualified students to earn the master of business administration degree within one calendar year of completing the baccalaureate degree requirements.

Honors Program. The School of Engineering offers an honors program for outstanding students. Information concerning the honors program is located at the end of this chapter.

Study Abroad

Engineering students may enroll in programs coordinated by the Rutgers Study Abroad Office *(http://studyabroad .rutgers.edu)*. The associate dean for academic affairs should be contacted for detailed information and advising.

Declaration of Major

Students in the four-year B.S. program declare the engineering major after the first year. Five-year B.A./B.S. students who enroll at a liberal arts college initially declare the engineering major at the end of their second year. Currently, all students in the School of Engineering are admitted to the major of their choice. The School of Engineering faculty reserves the right, however, to restrict enrollments in certain majors if the need arises.

Minors and Second Majors

Students enrolled at the School of Engineering are eligible to earn minors and/or second majors offered by any program at the Faculty of Arts and Sciences (FAS). Students declare the minor or second major at the Office of Academic Affairs, Room B100, in the Engineering Building, and are responsible for meeting the requirements set by FAS departments as outlined in this catalog. Completion of the minor or second major is certified by the appropriate FAS department in the last term prior to graduation, and is recognized by a notation on the student's academic transcript.

Students who wish to have the second major associated with a second degree must apply and be accepted by Douglass, Livingston, or Rutgers College for enrollment in the five-year, dual-degree program. (See the Douglass, Livingston, or Rutgers College sections of this catalog.)

Electives

All engineering curricula provide an opportunity for students to select from a wide range of elective courses to meet their individual needs. The following types of electives are used in the programs outlined in this chapter.

Departmental Electives. Departmental electives must be selected from among the course offerings of the department whose subject code is indicated. For example, "14:650:___ departmental elective" indicates a course offered by the Department of Mechanical and Aerospace Engineering.

Electives (for Five-Year B.A./B.S. Program). Each five-year engineering curriculum leading to the B.A. and B.S. degrees must contain a minimum of 48 credits of electives that satisfy the major requirements and any other degree requirements of the liberal arts college offering the B.A. degree. Eighteen of these 48 credits also must satisfy the humanities / social sciences elective requirement of the School of Engineering as described below. The total number of credits required for the dual-degree program must be at least 30 credits more than is required for the B.S. degree alone. See Five-Year Engineering Curricula in this chapter for further information.

Engineering Electives. An engineering elective refers to courses offered by the School of Engineering. (This elective occurs only in the applied sciences in engineering curriculum.)

General Electives. The general electives shown in all engineering curricula may be chosen from any subject area other than individual and team activities in exercise science and sport studies (377). A student who wishes to carry more credits of general electives than are shown may add these credits to the normal curriculum. All credits taken in excess of degree requirements will be counted in the university cumulative grade-point average. Normally, general electives may be scheduled at any time as long as the load for any given term does not exceed 21 credits. General elective credit is not allowed for remedial courses such as precalculus and other courses offered at a level below that of required courses.

Humanities/Social Sciences Electives. Each four-year curriculum must contain a minimum of 18 credits (or equivalent) of humanities / social sciences electives, which are chosen with the advice and approval of the appropriate faculty adviser. These electives must include an expository writing course, such as 01:355:101 or its equivalent, 01:220:200 Economic Principles and Problems, and a minimum of 6 credits of upper-level courses. Upper level refers to courses with numbers in the 300s or 400s. At least 3 credits of upper-level course work must be taken in a subject in which the student has had a prior course.

The humanities / social sciences electives must meet generally accepted definitions. Humanities are the branches of knowledge concerned with people and their cultures, while social sciences study individual relationships in and to society. Subjects such as accounting, industrial management, finance, personnel administration, introductory modern language courses, and ROTC studies normally do not fulfill the objectives of this elective. Skills courses are acceptable only if a substantial amount of material relating to cultural values is involved, as opposed to routine exercises that enhance the student's performance. An extensive listing of acceptable courses offered by the various units of Rutgers is available from the Office of Academic Affairs *(http://www.soe.rutgers.edu).* Normally, these electives may be scheduled at any time as long as the load for any given term does not exceed 21 credits. The faculty of the School of Engineering views this requirement as an important and integral part of the overall curriculum.

Technical Electives. Technical electives are courses in engineering or related areas as determined by the department and are chosen with the approval of the appropriate faculty adviser. Lists of acceptable technical electives are available at department web sites at *http://www.soe.rutgers.edu*.

Four-Year Engineering Curricula

FIRST-YEAR PROGRAM

Curriculum Code 004
(common to all four-year curricula)

First Term		
01:160:159	General Chemistry for Engineers	3
01:160:171	Introduction to Experimentation *	1
01:355:101	Expository Writing I *or* 14:440:127 Introduction to Computers for Engineers	3
14:440:100	Engineering Orientation Lectures	1
01:640:151	Calculus for Mathematical and Physical Sciences	4
01:750:123	Analytical Physics I	2
humanities / social sciences elective		3
Second Term		
01:160:160	General Chemistry for Engineers	3
14:440:127	Introduction to Computers for Engineers *or* 01:355:101 Expository Writing I	3
14:440:221	Engineering Mechanics: Statics	3
01:640:152	Calculus for Mathematical and Physical Sciences	4
01:750:124	Analytical Physics I	2
humanities / social sciences elective		3
	Total Credits	35

APPLIED SCIENCES IN ENGINEERING

Four-Year Curriculum Code 073

* May be taken in the second term.

First Year

See First-Year Program		35

Sophomore Year

First Term

14:440:222	Engineering Mechanics: Dynamics	3
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1
engineering or technical elective		3
humanities / social sciences elective		3

Second Term

01:220:200	Economic Principles and Problems	3
01:640:244	Differential Equations for Engineering and Physics	4
01:750:228	Analytical Physics IIB	3
01:750:230	Analytical Physics II Laboratory	1
engineering or technical elective		3
engineering or technical elective		3

The last two years of the program must be developed with the assistance of the designated faculty adviser. The overall program must meet the student's career objectives and must be sufficiently different from the accredited engineering programs so as not to permit incorporation into an existing program. Applied sciences in engineering is not accredited as a professional engineering program; it is an individualized interdisciplinary program that is not subject to professional accreditation.

The minimum degree requirement is 135 credits. In addition to other specific requirements, the following distribution of courses must be completed:

Humanities / social sciences electives: 12 credits
Engineering electives: 10 courses of 3 credits or more
General electives: 9 credits
Technical electives: 33 credits

Some examples of possible concentrations in applied sciences in engineering are listed below. Other fields may be covered to meet the special interests of engineering students. Courses are not offered specifically for this curriculum. Appropriate courses are to be selected from those offered by the departments (see course descriptions at the end of this chapter). Since departmental course offerings may change from year to year, availability of a particular course cannot be guaranteed.

Biomedical Science and Engineering (Premed). This specialty is intended primarily for those students who plan to go on to medical school or graduate study in biomedical engineering and who wish to take advantage of the flexibility in curriculum planning that the applied sciences program offers. Engineering electives may be chosen from any engineering discipline, including undergraduate courses offered by the Department of Biomedical Engineering.

Engineering Physics. This concentration allows students to combine a background in the basic engineering subjects with the courses of a physics curriculum. It provides preparation for work in a physics research laboratory, for further study in engineering, or for graduate study in physics. The first two years are the same as those in any of the regular engineering curricula, although some substitutions are suggested. The last two years include courses in modern physics, electricity and magnetism, thermal physics, solid-state physics, and partial differential equations. Coupled with these are laboratory courses and other courses in engineering, physics, computer science, mathematics, or other sciences, to be chosen in consultation with an adviser in the Department of Physics. Students in this option generally would simultaneously complete a second major in physics.

Packaging Engineering. The packaging engineering concentration is designed to prepare engineers and scientists for a major role in the field of packaging. The program is structured to meet the technical requirements for the development and growth of total packaging systems. (See course descriptions under Ceramic Engineering for information.)

BIOMEDICAL ENGINEERING

Four-Year Curriculum Code 125

First Year

See First-Year Program		35

Sophomore Year

First Term

01:119:101	General Biology	4
14:125:201	Introduction to Biomedical Engineering	3
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1
humanities / social sciences elective		3

Second Term

01:119:102	General Biology	4
01:220:200	Economic Principles and Problems	3
14:125:210	Biomedical Devices and Systems	3
14:125:211	Biomedical Devices and Systems Laboratory	1
01:640:244	Differential Equations for Engineering and Physics	4
01:750:228	Analytical Physics IIB	3
01:750:230	Analytical Physics II Laboratory	1

Junior Year

First Term

14:125:303	Biomedical Transport Phenomena	3
14:125:305	Numerical Modeling in Biomedical Systems	3
14:125:315	BME Measurement and Analysis Laboratory	2
01:146:356	Systems Physiology	3
01:160:307	Organic Chemistry or technical elective *	4 / 3

Second Term

14:125:306	Kinetics and Thermodynamics of Biological Systems	3
14:125:308	Introduction to Biomechanics	3
01:160:308	Organic Chemistry II or technical elective *	4 / 3
01:160:311	Organic Chemistry Laboratory or technical elective *	2 / 3
life science elective		3

* Organic chemistry and laboratory are required for the premedical option and strongly recommended for the tissue engineering and molecular biology (TEMB) track. Students not in the premedical or TEMB track may choose technical electives in place of organic chemistry and laboratory.

Senior Year

First Term

14:125:401	Biomedical Engineering Senior Design I	3
14:125:___	departmental elective	3
14:125:___	departmental elective	3
technical elective		3
humanities / social sciences elective		3

Second Term

14:125:402	Biomedical Engineering Senior Design II	3
14:125:___	departmental elective	3
14:125:___	departmental elective	3
technical elective		3
general elective		3
	Total Credits	131 (*132)

BIORESOURCE (BIOENVIRONMENTAL) ENGINEERING

Four-Year Curriculum Code 127

First Year

See First-Year Program 35

Sophomore Year

First Term

01:119:101	General Biology *or* 01:119:103 Principles of Biology	4
14:180:215	Engineering Graphics	1
14:440:222	Engineering Mechanics: Dynamics	3
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1

Second Term

14:180:243	Mechanics of Solids	3
14:332:373	Elements of Electrical Engineering	3
11:375:203	Physical Principles of Environmental Sciences	3
01:640:244	Differential Equations for Engineering and Physics	4
general elective		3

Junior Year

First Term

01:160:209	Elementary Organic Chemistry	3
01:160:211	Elementary Organic Chemistry Laboratory	1
14:180:387	Fluid Mechanics	3
14:180:389	Fluid Mechanics Laboratory	1
11:375:201	Biological Principles of Environmental Sciences	3
11:375:202	Chemical Principles of Environmental Sciences	3
14:650:351	Thermodynamics	3

Second Term

11:127:413	Unit Processes in Bioenvironmental Engineering I	3
01:220:200	Economic Principles and Problems	3
11:375:423	Environmental Fate and Transport *or* 11:375:345 Environmental Transport Phenomena	3
technical elective		3
humanities / social sciences elective		3

Senior Year

First Term

11:127:414	Unit Processes in Bioenvironmental Engineering II	3
11:127:424	Bioenvironmental Engineering Unit Processes Laboratory II	1
11:127:462	Design of Solid Waste Treatment Systems	3
11:127:474	Air Pollution Engineering	3
11:127:488	Bioresource Engineering Design I	2
14:180:429	Water and Wastewater Engineering	3
11:375:303	Numerical Methods in Environmental Sciences *or* 300-400 level statistics	3

Spring Term

11:127:468	Hazardous Waste Treatment Engineering	3
11:127:489	Bioresource Engineering Design II	2
humanities / social sciences elective		3
technical elective		3
technical elective		3
technical elective		3
	Total Credits	134

Technical electives may be selected from the following: 11:127:490, 494, 495, 496; 14:155:453; 14:180:372 and 374, 382, 443, 448; 11:375:408, 409, 411 and 413, 422, 430, 444; 01:460:428; 14:540:343; 14:650:481.

CERAMIC ENGINEERING

Four-Year Curriculum Code 150

First Year

See First-Year Program 35

Sophomore Year

First Term

14:150:203	Introduction to Materials and Science Engineering	3
14:150:205	Crystal Chemistry and Structure of Materials	3
14:150:253	Laboratory I	2
01:640:251	Multivariable Calculus	4
14:650:215	Introduction to Computer-Aided Drafting and Machining	1
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1

Second Term

14:150:204	Ceramic Processing I	3
14:150:206	Thermodynamics of Materials	3
14:150:212	Physics of Materials	3
14:150:254	Laboratory II	2
01:220:200	Economic Principles and Problems	3
01:640:244	Differential Equations for Engineering and Physics	4

* Organic chemistry and laboratory are required for the premedical option and strongly recommended for the tissue engineering and molecular biology (TEMB) track. Students not in the premedical or TEMB track may choose technical electives in place of organic chemistry and laboratory.

Junior Year

First Term

14:150:303	Phase Diagrams	3
14:150:305	Ceramic Processing II	3
14:150:307	Kinetics of Materials Processes	3
14:150:309	Characterization of Materials	3
14:150:355	Laboratory III	2
14:150:___	departmental elective	3

Second Term

14:150:304	Ceramic Compositions	4
14:150:306	Ceramic Processing III	3
14:150:312	Glass Engineering	3
14:150:314	Strength of Materials	3
14:150:___	departmental elective	3

Senior Year

First Term

14:150:403	Ceramic and Materials Engineering Seminar	1
14:150:411	Engineering Design in Ceramic and Materials Engineering I *or*	3
14:150:401	Senior Ceramic and Materials Engineering Laboratory I	
14:150:___	departmental elective	3
01:960:401	Basic Statistics for Research	3
humanities / social sciences elective		3
technical elective		3

Second Term

14:150:404	Ceramics and Materials Engineering Seminar	1
14:150:412	Engineering Design in Ceramic and Materials Engineering II *or*	3
14:150:402	Senior Ceramic and Materials Engineering Laboratory II	
14:150:414	Electronic Optical and Magnetic Properties of Materials	3
14:150:___	departmental elective	3
humanities / social sciences elective		3
general elective		3
	Total Credits	135

CHEMICAL ENGINEERING

Four-Year Curriculum Code 155

The chemical engineering curriculum includes two options: chemical and biochemical.

First Year

See First-Year Program 35

Sophomore Year

(common to both options)

First Term

14:155:201	Chemical Engineering Analysis I	3
01:160:307	Organic Chemistry *	4
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1

Second Term

14:155:208	Chemical Engineering Thermodynamics	3
01:160:308	Organic Chemistry *	4
01:220:200	Economic Principles and Problems	3
01:640:244	Differential Equations for Engineering and Physics	4
humanities / social sciences elective		3

Chemical Option

Junior Year

First Term

14:155:303	Transport Phenomena in Chemical Engineering I	3
14:155:307	Chemical Engineering Analysis II	3
01:160:311	Organic Chemistry Laboratory	2
01:160:327	Physical Chemistry I	4
01:640:421	Advanced Calculus for Engineering	3
humanities / social sciences elective		3

Second Term

14:155:304	Transport Phenomena in Chemical Engineering II	3
14:155:324	Design of Separation Processes	3
01:160:328	Physical Chemistry II	4
general elective		3
general elective		3

Senior Year

First Term

14:155:409	Chemical Systems Safety and Health Engineering Management	1.5
14:155:415	Process Engineering I	4
14:155:441	Chemical Engineering Kinetics	3
14:155:___	departmental technical elective	3
technical elective		3

Second Term

14:155:416	Process Engineering II	4
14:155:422	Process Simulation and Control	3
14:155:424	Chemical Engineering Design and Economics	4
14:440:407	Mechanical Properties of Materials	3
	Total Credits	129.5

Biochemical Option

Junior Year

First Term

14:155:303	Transport Phenomena in Chemical Engineering I	3
14:155:307	Chemical Engineering Analysis II	3
01:160:341	Physical Chemistry: Biochemical Systems	3
01:447:390	General Microbiology †	4
01:640:421	Advanced Calculus for Engineering	3

Second Term

14:155:304	Transport Phenomena in Chemical Engineering II	3
14:155:324	Design of Separation Processes	3
01:160:342	Physical Chemistry: Biochemical Systems	3
01:694:301	Introductory Biochemistry and Molecular Biology	3

* 01:160:315, 316 are accepted in place of 01:160:307, 308.
† The official prerequisite (01:119:101-102 General Biology) is waived if 01:160:307-308 Organic Chemistry has been completed. See associate dean for academic affairs for prerequisite override.

01:694:313	Introductory Biochemistry Laboratory	1
humanities / social sciences elective		3

Senior Year

First Term

14:155:409	Chemical Systems Safety and Health Engineering Management	1.5
14:155:411	Introduction to Biochemical Engineering	3
14:155:415	Process Engineering I	4
14:155:441	Chemical Engineering Kinetics	3
general elective		3

Second Term

14:155:416	Process Engineering II	4
14:155:422	Process Simulation and Control	3
14:155:426	Biochemical Engineering Design and Economics	4
14:440:407	Mechanical Properties of Materials	3
	Total Credits	127.5

CIVIL ENGINEERING

Four-Year Curriculum Code 180

First Year

See First-Year Program	35

Sophomore Year

First Term

01:220:200	Economic Principles and Problems	3
14:440:222	Engineering Mechanics: Dynamics	3
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1
humanities / social sciences elective		3

Second Term

14:180:216	Introductory Computer-Aided Design and Drafting	3
14:180:243	Mechanics of Solids	3
01:355:302	Scientific and Technical Writing	3
01:640:244	Differential Equations for Engineering and Physics	4
humanities / social sciences elective		3

Junior Year

First Term

14:180:305	Construction Engineering	3
14:180:318	Elements of Structures	3
14:180:387	Fluid Mechanics	3
14:180:389	Fluid Mechanics Laboratory	1
14:440:407	Mechanical Properties of Materials	3
01:960:379	Basic Probability and Statistics	3

Second Term

14:180:320	Design of Steel Structures	3
14:180:345	Properties of Materials Laboratory	1
14:180:364	Transportation Engineering I	3
14:180:372	Soil Mechanics	3
14:180:374	Soil Mechanics Laboratory	1
14:540:343	Engineering Economics	3

Senior Year

First Term

14:180:411	Reinforced Concrete	3
14:180:421	Reinforced Concrete Laboratory	1
14:180:429	Water and Wastewater Engineering	3
14:180:473	Foundation Engineering	3
14:180:___	departmental elective	3
technical elective		3

Second Term

14:180:482	Professional Issues in Civil Engineering	1
14:180:___	departmental elective (capstone design)	4
14:180:___	departmental elective	3
technical elective		3
general elective		3
	Total Credits	128

1. Departmental courses may be used for technical electives, but technical courses outside the department may not be used as departmental electives. The department publishes annually a list of acceptable technical electives. The following technical courses are strongly recommended:
   - 14:332:373 Elements of Electrical Engineering
   - 14:650:351 Thermodynamics
2. At least one of the following capstone design courses is required:
   - 14:180:407 Construction Projects
   - 14:180:426 Structural Design
   - 14:180:431 Design of Environmental Engineering Facilities
   - 14:180:438 Transportation Engineering II
   - 14:180:474 Geotechnical Engineering Design
3. With a combination of the required and elective departmental courses and the available general and technical electives, a student may pursue a general program or a program having an area of concentration in structural engineering, geotechnical engineering, construction engineering, transportation engineering, and water resources / environmental engineering.

ELECTRICAL AND COMPUTER ENGINEERING

Four-Year Curriculum Code 332

The electrical and computer engineering curriculum includes two options: electrical engineering and computer engineering.

First Year

See First-Year Program	35

Sophomore Year

(common to both options)

First Term

14:332:221	Principles of Electrical Engineering I	3
14:332:223	Principles of Electrical Engineering I Laboratory	1
14:332:231	Digital Logic Design	3
14:332:233	Digital Logic Design Laboratory	1
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1

Second Term

14:332:202	Discrete Mathematics	3
14:332:222	Principles of Electrical Engineering II	3
14:332:224	Principles of Electrical Engineering II Laboratory	1

14:332:252	Programming Methodology I	3
14:332:254	Programming Methodology I Laboratory	1
01:640:244	Differential Equations for Engineering and Physics	4
01:750:228	Analytical Physics IIB	3
01:750:230	Analytical Physics II Laboratory	1

Electrical Engineering Option

Junior Year

First Term

14:332:321	Probability and Random Processes	3
14:332:345	Linear Systems and Signals	3
14:332:347	Linear Systems and Signals Laboratory	1
14:332:361	Electronic Devices	3
14:332:363	Electronic Devices Laboratory	1
humanities / social sciences elective		3

Second Term

14:332:322	Principles of Communications Systems	3
14:332:331	Computer Architecture and Assembly Language	3
14:332:333	Computer Architecture Laboratory	1
14:332:346	Digital Signal Processing	3
14:332:348	Digital Signal Processing Laboratory	1
14:332:366	Digital Electronics	3
14:332:368	Digital Electronics Laboratory	1
humanities / social sciences elective		3

Senior Year

First Term

14:332:362	Analog Electronics	3
14:332:364	Analog Electronics Laboratory	1
14:332:___	Prerequisite to capstone design	3
14:332:___	electrical elective	3
14:332:___	electrical elective	3
technical elective		3

Second Term

01:220:200	Economic Principles and Problems	3
14:332:___	capstone design elective	3
14:332:___	electrical elective	3
technical elective		3
general elective		3
	Total Credits	133

Computer Engineering Option

Junior Year

First Term

14:332:331	Computer Architecture and Assembly Language	3
14:332:333	Computer Architecture Laboratory	1
14:332:345	Linear Systems and Signals	3
14:332:347	Linear Systems and Signals Laboratory	1
14:332:351	Programming Methodology II	3
14:332:361	Electronic Devices	3
14:332:363	Electronic Devices Laboratory	1

Second Term

01:198:416	Operating Systems Design	4
14:332:346	Digital Signal Processing	3
14:332:348	Digital Signal Processing Laboratory	1
14:332:366	Digital Electronics	3
14:332:368	Digital Electronics Laboratory	1
computer elective		3
humanities / social sciences elective		3

Senior Year

First Term

01:220:200	Economic Principles and Problems	3
14:332:321	Probability and Random Processes	3
14:332:437	Concepts in Digital Systems Design	3
computer elective		3
technical elective		3
humanities / social sciences elective		3

Second Term

14:332:452	Introduction to Software Engineering	3
14:332:___	capstone design elective	3
technical elective		3
general elective		3
	Total Credits	133

Note: A list of each type of elective (computer, departmental, design, restrictive, technical) is published by the department. These courses must be selected from the appropriate lists.

INDUSTRIAL ENGINEERING

Four-Year Curriculum Code 540

First Year

See First-Year Program	35

Sophomore Year

First Term

01:220:200	Economic Principles and Problems	3
14:540:201	Work Design and Ergonomics	3
14:540:202	Work Design and Ergonomics Laboratory	1
14:540:213	Industrial Engineering Laboratory	1
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1

Second Term

14:180:243	Mechanics of Solids	3
14:440:222	Engineering Mechanics: Dynamics	3
14:540:210	Engineering Probability	3
01:640:244	Differential Equations for Engineering and Physics	4
01:750:228	Analytical Physics IIB	3
01:750:230	Analytical Physics II Laboratory	1

Junior Year

First Term

14:180:215	Engineering Graphics	1
14:332:373	Elements of Electrical Engineering	3
14:440:407	Mechanical Properties of Materials	3
14:540:338	Probability Models in Operations Research	3
14:540:343	Engineering Economics	3
14:540:382	Computer Control of Manufacturing Systems	3
14:540:383	Computer Control of Manufacturing Systems Laboratory	1

Second Term

01:355:302	Scientific and Technical Writing	3
14:540:303	Manufacturing Processes	3
14:540:304	Manufacturing Processes Laboratory	1
14:540:311	Deterministic Models in Operations Research	3

14:540:384	Simulation Models in Industrial Engineering	3
14:540:399	Design of Engineering Systems I	3

Senior Year

First Term

33:010:310	Accounting for Engineers	3
14:540:400	Design of Engineering Systems II	3
14:540:433	Quality Engineering and Statistics	3
14:540:434	Quality Engineering Laboratory	1
14:540:453	Production Planning and Control	3
humanities / social sciences elective		3

Second Term

14:540:462	Facilities Layout and Materials Handling	3
departmental or technical elective (List A) *		3
departmental or technical elective (List B) *		3
humanities / social sciences elective		3
general elective		3
	Total Credits	132

MECHANICAL ENGINEERING

Four-Year Curriculum Code 650

The mechanical engineering curriculum includes three options: mechanical engineering, aerospace engineering, and biomechanical engineering. †

First Year

See First-Year Program	35

Sophomore Year

(common to all options)

First Term

01:220:200	Economic Principles and Problems	3
14:440:222	Engineering Mechanics: Dynamics	3
01:640:251	Multivariable Calculus	4
14:650:231	Mechanical Engineering Computational Analysis and Design ‡	3
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1

Second Term

14:332:373	Elements of Electrical Engineering	3
14:332:375	Elements of Electrical Engineering Laboratory	1
01:640:244	Differential Equations for Engineering and Physics	4
14:650:215	Introduction to Computer-Aided Drafting and Machining ‡	1
14:650:291	Introduction to Mechanics of Materials ‡	3
01:750:228	Analytical Physics IIB	3
01:750:230	Analytical Physics II Laboratory	1

Mechanical Engineering Option

Junior Year

First Term

14:540:343	Engineering Economics ‡	3
01:640:421	Advanced Calculus for Engineering ‡	3
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3–4
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3
humanities / social sciences elective		3

Second Term

14:440:407	Mechanical Properties of Materials ‡	3
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3–4
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3
14:650:388	CAD in Mechanical Engineering ‡	3
technical elective		3

Senior Year

First Term

14:650:431	Mechanical Engineering Laboratory I	1
14:650:443	Vibrations and Controls ‡	3
14:650:486	Design of Mechanical Systems I	3
14:650:4__	departmental elective	3
technical elective		3
humanities / social sciences elective		3

Second Term

14:650:432	Mechanical Engineering Laboratory II	1
14:650:481	Heat Transfer ‡	3
14:650:487	Design of Mechanical Systems II	3
14:650:4__	departmental electives	6
general elective		3
	Total Credits	130–132

Aerospace Engineering Option

Junior Year

First Term

14:540:343	Engineering Economics ‡	3
01:640:421	Advanced Calculus for Engineering ‡	3
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3–4
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3
humanities / social sciences elective		3

Second Term

14:440:407	Mechanical Properties of Materials ‡	3
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3–4
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3
14:650:388	CAD in Mechanical Engineering ‡	3
14:650:4__	Aerospace option	3

* Lists of electives (List A and List B) are published each year by the department.
† Aerospace option courses to be selected from 14:650:447, 458, 459, 460, 463, 465.
‡ May be taken during the first or second term, within the listed year.
§ Junior-year required courses to be selected from 14:650:312, 342, 349 and 350, 351. (Note that 14:650:349 and 350 must be taken concurrently for 4 credits total.)

Senior Year

First Term

14:650:431	Mechanical Engineering Laboratory I	1
14:650:443	Vibrations and Controls ‡	3
14:650:486	Design of Mechanical Systems I	3
14:650:4__	Aerospace option †	3
technical elective		3
humanities / social sciences elective		3

Second Term

14:650:433	Aerospace Engineering Laboratory	1
14:650:481	Heat Transfer ‡	3
14:650:487	Design of Mechanical Systems II	3
14:650:4__	Aerospace option †	3
general elective		3
technical elective		3
	Total Credits	130–132

Biomechanical Engineering Option

Junior Year

First Term

14:540:343	Engineering Economics ‡	3
01:640:421	Advanced Calculus for Engineering ‡	3
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3–4
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3
humanities / social sciences elective		3

Second Term

14:440:407	Mechanical Properties of Materials ‡	3
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3–4
14:650:3__	Junior-year required course(s) in mechanical and aerospace engineering §	3
14:650:388	CAD in Mechanical Engineering ‡	3
14:650:4__	Biomechanical option ||	3

Senior Year

First Term

14:650:431	Mechanical Engineering Laboratory I	1
14:650:443	Vibrations and Controls ‡	3
14:650:486	Design of Mechanical Systems I	3
14:650:4__	Biomechanical option ||	3
technical elective		3
humanities / social sciences elective		3

Second Term

14:650:434	Biomechanical Engineering Laboratory	1
14:650:481	Heat Transfer ‡	3
14:650:487	Design of Mechanical Systems II	3
14:650:4__	Biomechanical option ||	3
general elective		3
technical elective		3
	Total Credits	130–132

* Lists of electives (List A and List B) are published each year by the department.
† Aerospace option courses to be selected from 14:650:447, 458, 459, 460, 463, 465.
‡ May be taken during the first or second term, within the listed year.
§ Junior-year required courses to be selected from 14:650:312, 342, 349 and 350, 351. (Note that 14:650:349 and 350 must be taken concurrently for 4 credits total.)
|| Biomechanical option courses to be selected from 14:650:471, 472, 473.

Five-Year Engineering Curricula

FIVE-YEAR B.A./B.S. PROGRAM IN NEW BRUNSWICK

The five-year, dual-degree program in engineering and the liberal arts / sciences is offered by the School of Engineering in cooperation with the following liberal arts colleges: Douglass College, Livingston College, and Rutgers College. (Students also may begin the five-year program at the Camden College of Arts and Sciences or the Newark College of Arts and Sciences. See Transfer Programs with Camden and Newark later in this chapter.) The five-year program leads to a bachelor of science degree in any of the engineering curricula listed at the beginning of this chapter and a bachelor of arts or bachelor of science degree in any major offered by the cooperating liberal arts college.

Students interested in the five-year program may apply prior to their first year to one of the liberal arts colleges under whose jurisdiction they remain for the first two years. Transfer to the School of Engineering at the end of the second year is not automatic; students' records are reviewed at the end of the third term by the School of Engineering. After acceptance, students come under the academic jurisdiction of the School of Engineering for the remaining three years of the program. Alternatively, students in the four-year program may apply to a liberal arts college after their first year and prior to their final year for admission to the program.

In all five-year curricula, the engineering portion of the program for the first two years is common. Selection of a particular engineering field of study is made at the end of the second year. After transferring to the School of Engineering, students remain affiliated with their liberal arts college for student services and continue to be responsible for completion of that college's requirements for the B.A. (or B.S.) degree. Both degrees are conferred at the end of the fifth year. The program requires that both degrees must be conferred at the same time even if requirements for one degree is completed before the other.

Distribution of Electives for Five-Year Students

Engineering students pursuing the five-year B.A. / B.S. program jointly with Douglass, Livingston, or Rutgers College must complete a minimum of 48 credits of liberal arts course work, including 01:355:101 Expository Writing I, 01:220:200 Economic Principles and Problems, and courses designated as electives in the following curriculum outline. (In the fourth and fifth years, the humanities / social sciences electives should be used toward these 48 credits.) These courses must satisfy the requirements for a departmental major in a B.A. or B.S. program as well as any other degree requirements of the student's liberal arts college. The student should consult the Degree Requirements chapter of the appropriate college for further information. In addition, 18 of these 48 credits must satisfy the humanities / social sciences electives requirement of the School of Engineering. These electives should be chosen with the advice and approval of the advisers for both the B.A. and B.S. programs. Students who affiliate with Rutgers College with a major in mathematics, computer science, or the sciences must complete a minor in a subject within the humanities or social sciences. Students in the five-year program should consult with the designated five-year engineering adviser during each term of the first two years. The total number of credits required for the dual-degree program must be at least 30 credits more than is required for the B.S. program alone.

First Year

Curriculum Code 005
(common to all five-year curricula)

First Term

01:160:159	General Chemistry for Engineers	3
01:160:171	Introduction to Experimentation *	1
01:355:101	Expository Writing I	3
01:640:151	Calculus for Mathematical and Physical Sciences	4
01:750:123	Analytical Physics I	2
elective		3

Second Term

01:160:160	General Chemistry for Engineers	3
01:640:152	Calculus for Mathematical and Physical Sciences	4
01:750:124	Analytical Physics I	2
electives		6

Second Year

Curriculum Code 005
(common to all five-year curricula)

First Term

14:440:100	Engineering Orientation Lectures	1
14:440:221	Engineering Mechanics: Statics	3
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1
electives		6

Second Term

14:440:127	Introduction to Computers for Engineers	3
01:640:244	Differential Equations for Engineering and Physics	4
01:750:228	Analytical Physics IIB †	3
01:750:230	Analytical Physics II Laboratory †	1
electives		6

Third Year

(common to all five-year curricula except as noted)

First Term

__:___:___	Engineering major ‡	3–8
14:440:222	Engineering Mechanics: Dynamics §	3
electives		9

Second Term

01:220:200	Economic Principles and Problems *	3
__:___:___	Engineering major †	3–8
electives		9

* May be taken in the second term.
† Not required for bioresource, ceramic, chemical, and civil engineering.
‡ See the sophomore year of the four-year program in the student's curriculum.
§ Not required for biomedical, ceramic, chemical, or electrical and computer engineering.

Fourth Year

See the junior year of the four-year program in the student's curriculum.

Fifth Year

See the senior year of the four-year program in the student's curriculum.

FIVE-YEAR B.S./B.S. PROGRAM WITH COOK COLLEGE

The five-year, dual-degree program in bioresource engineering is offered by the School of Engineering in cooperation with Cook College. The curriculum provides an option in bioenvironmental engineering. This program allows a greater depth of specialization at the undergraduate level than can be achieved by completing the four-year program.

Students in the five-year program apply to Cook College, under whose jurisdiction they remain for the first two years. Assuming satisfactory progress, the students come under the academic jurisdiction of the School of Engineering for the remaining three years of the program. However, the students continue to affiliate with Cook College and must select humanities / social sciences electives to satisfy Cook College requirements. Four-year bioresource engineering majors may apply to Cook College for transfer to the dual-degree, five-year program at any time prior to their fourth year.

First Year

Curriculum Code 129

First Term

11:015:101	Perspectives on Agriculture and the Environment	2
01:119:101	General Biology	4
11:127:100	Introduction to Bioresource Engineering	1
01:355:101	Expository Writing I	3
01:640:151	Calculus for Mathematical and Physical Sciences	4
01:750:123	Analytical Physics I	2

Second Term

01:119:102	General Biology	4
14:440:127	Introduction to Computers for Engineers	3
14:440:221	Engineering Mechanics: Statics	3
01:640:152	Calculus for Mathematical and Physical Sciences	4
01:750:124	Analytical Physics I	2

Second Year

First Term

01:160:161	General Chemistry	4
01:160:171	Introduction to Experimentation	1
14:180:215	Engineering Graphics	1
14:440:222	Engineering Mechanics: Dynamics	3
01:640:251	Multivariable Calculus	4
01:750:227	Analytical Physics IIA	3
01:750:229	Analytical Physics II Laboratory	1

Second Term

11:127:290	Biosystems Engineering Measurements	3
01:160:162	General Chemistry	4
14:332:373	Elements of Electrical Engineering	3

01:640:244	Differential Equations for Engineering and Physics	4
11:704:351	Principles of Applied Ecology	4

Bioenvironmental Engineering Option

Third Year

First Term

01:160:209	Elementary Organic Chemistry	3
01:160:211	Elementary Organic Chemistry Laboratory	1
14:180:387	Fluid Mechanics	3
14:180:389	Fluid Mechanics Laboratory	1
11:375:201	Biological Principles of Environmental Sciences	3
11:375:202	Chemical Principles of Environmental Sciences	3
general elective		3

Second Term

14:180:243	Mechanics of Solids	3
01:220:200	Economic Principles and Problems	3
11:375:203	Physical Principles of Environmental Sciences	3
14:650:351	Thermodynamics	3
Cook College elective		3

Fourth Year

First Term

11:127:462	Design of Solid Waste Treatment Systems	3
11:375:303	Numerical Methods in Environmental Science	3
11:375:333	Environmental Law I	3
Cook College elective		3
Cook College elective		3
general elective		3

Spring Term

11:127:413	Unit Processes in Bioenvironmental Engineering I	3
11:375:423	Environmental Fate and Transport	3
general elective		3
technical elective		3
Cook College elective		3

Fifth Year

First Term

11:015:400	Junior / Senior Colloquium	3
11:127:414	Unit Processes in Bioenvironmental Engineering II	3
11:127:424	Bioenvironmental Engineering Unit Processes Laboratory II	1
11:127:474	Air Pollution Engineering	3
11:127:488	Bioresource Engineering Design I	2
14:180:429	Water and Wastewater Engineering	3
Cook College elective		3

Second Term

11:127:468	Hazardous Waste Treatment Engineering	3
11:127:489	Bioresource Engineering Design II	2
technical elective		3
technical elective		3
technical elective		3
Cook College elective		3
	Total Credits	167

Technical electives may be selected from the following: 11:127:494, 495, 496; 14:180:372 and 374, 382, 443, 448; 11:375:334, 408, 409, 411 and 413, 422, 430, 444; 01:460:428; 14:540:343; 14:650:481.

Transfer Programs with Camden and Newark

Two transfer programs are available to students who initially attend either the Camden College of Arts and Sciences (CCAS) or the Newark College of Arts and Sciences (NCAS). The Two-Plus-Two Transfer Program is a four-year program leading to a bachelor of science degree in engineering.
In addition, the Five-Year, Dual-Degree Program in Engineering and Liberal Arts / Sciences, which leads to both a bachelor of arts degree and a bachelor of science degree, may be started at either of these colleges. In both cases, transfer to the School of Engineering after two years is not automatic; students' records are reviewed at the end of the third term by the School of Engineering.

Two-Plus-Two Transfer Program

Students apply to either CCAS or NCAS and attend one of these colleges for the first two years of the program. After two years, students transfer to the School of Engineering in New Brunswick / Piscataway and come under the academic jurisdiction of that college for the remaining two years. At that time, the student also chooses a liberal arts college in New Brunswick / Piscataway (Douglass College, Livingston College, or Rutgers College) with which to affiliate for university housing and student services. The program leads to a B.S. degree in the selected engineering curriculum. Elective courses during the first two years must be selected with the aid and approval of the student's faculty adviser in Camden or Newark. Some curricula may require attendance at one or more summer sessions or an extra year of study in New Brunswick / Piscataway due to the lack of availability of second-year courses for some engineering majors at CCAS or NCAS. Specific information regarding curriculum requirements during the first two years is available in the Rutgers–Newark or Rutgers–Camden catalog.

Five-Year Transfer Program

Students apply to either CCAS or NCAS and attend one of these colleges for the first two years of the program. After two years, students transfer to the School of Engineering in New Brunswick / Piscataway and come under the academic jurisdiction of that college for the remaining three years. At that time, the student chooses a liberal arts college in New Brunswick / Piscataway (Douglass College, Livingston College, or Rutgers College) with which to affiliate for student services. During the first term of enrollment in New Brunswick / Piscataway, the student applies to one of the liberal arts colleges for admission for the second degree. If accepted, the student must satisfy that college's requirements for the B.A. degree. The B.A. degree in a liberal arts or science discipline and the B.S. degree in engineering are both conferred at the end of the fifth year.

Elective courses during the first two years must be selected with the aid and approval of the student's faculty adviser in Camden or Newark. See the respective catalogs for CCAS and NCAS for information on suitable electives for the first two years. Also see the paragraph on the distribution of electives under the five-year B.A./B.S. program in New Brunswick/Piscataway earlier in this chapter.

Other Academic Programs

B.S./M.B.A. PROGRAM

Qualified candidates for the bachelor of science (B.S.) degree in the School of Engineering are offered the opportunity to obtain the master of business administration (M.B.A.) degree from Rutgers Business School: Graduate Programs–Newark and New Brunswick in one calendar year of academic work following completion of requirements for the B.S. degree.

Ordinarily, candidates for the M.B.A. degree must complete 60 credits of academic work at Rutgers Business School: Graduate Programs–Newark and New Brunswick. However, with careful curriculum planning, candidates for the B.S. degree in engineering may reduce this requirement by at least 12 credits by completing courses required for the M.B.A. while enrolled in the School of Engineering.

Admission Requirements for Dual-Degree Program

Students interested in pursuing the dual-degree program must apply for admission to Rutgers Business School: Graduate Programs–Newark and New Brunswick during the spring term of their junior year. Students must take (usually in the fall term of their junior year) the Graduate Management Admissions Test (GMAT) that is administered by the Educational Testing Service and have the scores sent to Rutgers Business School: Graduate Programs–Newark and New Brunswick. Applicants also should submit a completed application form, official transcripts of all college and graduate level work, two letters of reference, a letter from the associate dean for academic affairs at the School of Engineering authorizing application, and the required nonrefundable application fee. The application and all supporting material must be received by Rutgers Business School: Graduate Programs–Newark and New Brunswick no later than June 1.

Applicants who place in the top quartile on the GMAT examination and who have earned a cumulative grade-point average of 3.0 or better through the first term of the junior year may be admitted conditionally to the M.B.A. program; the admission becomes official upon satisfactory completion in good standing of the B.S. degree requirements.
For more information visit *http://business.rutgers.edu/graduate/bamba.*

HONORS PROGRAM

The School of Engineering offers an honors program for undergraduate engineering students who exhibit outstanding academic ability. Students who have a combined math-verbal SAT score of 1350 or better, including minimum scores of 700 in math and 600 in the verbal section, a high school rank in the top 10 percent of their graduating class, and math placement in Honors Calculus are eligible for consideration for admission to the program.

During the first year of the undergraduate program, students register for 01:640:191-192 Honors Calculus; 01:750:271-272 Honors Physics; 01:355:103 Exposition and Argument; and 14:440:191 Honors Introduction to Engineering. During the second year, students take 01:640:291 Honors Calculus; 01:750:273 Honors Physics; and 14:440:291 Honors Engineering Mechanics: Statics. With special permission, they may register in a college honors seminar given by their college of affiliation. In the third year, students may be eligible to participate in the James J. Slade Scholars Program.

James J. Slade Scholars

In the third year, students who have maintained a 3.2 university cumulative grade-point average may apply to the chairperson of their major department to be admitted into the James J. Slade Scholars Program.

Upon admission to the program, each scholar prepares a plan of study under the guidance of a faculty committee and the Honors Committee of the School of Engineering. The chairperson of the student's committee acts as the thesis adviser and should be a member of the student's major department. Although great flexibility is permitted, each engineering program is planned to meet the definition of an engineering curriculum as stated by the Accreditation Board for Engineering and Technology. A Slade scholar's program requires independent research and a thesis that results in a total number of credits that is 6 credits beyond the minimum required for graduation. The thesis, describing the student's investigations, is presented at a public seminar of the college. With the approval of the student's committee, courses of equivalent stature may be substituted for any four of the required technical courses in the regular program. Any course that is below the student's current status in his or her major field is counted as an additional overload.

At the end of each term, the student's committee formally reports on the candidate's progress to the Honors Committee of the college. Continuance as a designated candidate depends upon continued satisfactory progress. Upon successful completion of the honors program and with the recommendation of the committee, department, and the Honors Committee, the student receives a special honors certificate. Successful completion of the honors program is also noted in the list of degrees and honors conferred in the commencement program.

Course Listing

Explanation of Three-Part Course Numbers

The number preceding each course title is divided into three parts. The first two digits are the administrative code (standing for a faculty or a school), the next three digits are the subject code, and the final three digits are the course code.

Administrative Codes

The School of Engineering administrative code is 14. For a complete list of administrative codes used in this catalog, see the beginning of the Programs of Study for Liberal Arts Students section.

Subject Codes

A subject code comprises the third through fifth digits in all course numbers and indicates the subject matter of the course. Courses with the following subject codes are listed in this chapter. (This list does *not* constitute a list of majors.)

125 Biomedical Engineering
127 Bioresource Engineering
150 Ceramic Engineering
155 Chemical and Biochemical Engineering
180 Civil and Environmental Engineering
332 Electrical and Computer Engineering
440 General Engineering
540 Industrial and Systems Engineering
650 Mechanical and Aerospace Engineering

Course Codes

The course code comprises the sixth, seventh, and eighth digits in all course numbers. Course codes from 100 to 299 are used for introductory and intermediate undergraduate courses usually offered in the first two years. Codes from 300 to 499 indicate advanced undergraduate courses normally taken in the junior and senior years. Courses coded from 500 to 799 are graduate courses and are described in the catalog of the Graduate School–New Brunswick.

Two course numbers separated by a comma indicate that each term may be taken independently of the other (example: 14:150:411,412). Two course numbers separated by a hyphen indicate that satisfactory completion of the first term is a prerequisite to the second term (example: 14:332:221-222); the first term may be taken for credit without taking the second, except where a statement is added to indicate that both term courses must be completed in order to receive credit.

Credits awarded for the successful completion of each course are indicated in parentheses following the course title. The notation BA indicates that the number of credits is determined by arrangement with the department offering the course.

Unless otherwise indicated, a course normally meets for a number of lecture hours equal to the number of credits to be earned. Special hours or modes of class, other than lecture, are usually indicated in italics below the course title.

Consult the *Undergraduate Schedule of Classes* for the name(s) of the faculty member(s) teaching each course.

BIOMEDICAL ENGINEERING 125

14:125:201. Introduction to Biomedical Engineering (3)
Prerequisites: 01:640:152, 01:750:124.
Overview of applications of engineering in medicine and health care. Introduction to biological and biomedical problems using fundamental concepts and tools from electrical, mechanical, and chemical engineering.

14:125:210. Biomedical Devices and Systems (3)
Prerequisites: 01:640:251, 01:750:227 and 229, 14:125:201. Corequisite: 14:125:211.
Time and frequency domain analysis of electrical networks; hydrodynamic, mechanical, and thermal analogs; basic medical electronics, and energy conversion systems. Design of biological sensors.

14:125:211. Biomedical Devices and Systems Laboratory (1)
Prerequisites: 14:125:201 and 01:640:251, 01:750:227 and 229. Corequisite: 14:125:210.
Experiments and demonstrations dealing with basic medical electronics and signal analysis. Provides an overview of current biomedical technology and its uses.

14:125:303. Biomedical Transport Phenomena (3)
Prerequisites: 14:125:201, 210 and 211, 01:640:244.
Biomedical mass transport processes involving diffusion, diffusion-convection, and diffusion-reaction schemes; introduction to biofluid dynamics; transport processes in the cardiovascular system, hemorheology, extracorporeal mass transport devices, and tissue engineering.

14:125:305. Numerical Modeling in Biomedical Systems (3)
Prerequisites: 14:125:201 and 210, 01:640:244, 14:440:127.
Introduction to modeling and simulation techniques in the analysis of biomedical systems. Application of numerical methods for the solution of complex biomedical process problems. Development and use of PC software for the analysis and solution of engineering problems.

14:125:306. Kinetics and Thermodynamics of Biological Systems (3)
Prerequisites: 01:119:102, 01:160:160, 01:640:244, 14:125:303 and 305.
Fundamentals of thermodynamics and kinetic analysis as applied to biomedical systems and technologies. Essential principles in thermodynamics introduced, including First Law, Second Law, and interrelationships among thermodynamic variables. Fundamental tools in kinetic analysis are also covered, including interpretation of rate data, enzyme kinetics, and pharmacokinetics. Application to biological systems and biomedical technologies are provided.

14:125:308. Introduction to Biomechanics (3)
Prerequisites: 01:640:244, 01:750:228 and 230, 14:125:303 and 305, 14:440:221.
Relationship between applied and resultant forces and stresses acting on the musculoskeletal system. Basic concepts of vectors, internal and external forces, functional anatomy, trusses and equilibria of spatial force systems, moments, and work and energy concepts. Stress and strain tensors, principal forces, viscoelasticity, and failure analysis from classical mechanics.

14:125:315. BME Measurement and Analysis Laboratory (2)
Prerequisites: 14:125:210 and 211.
Experiments and demonstrations dealing with the measurement and analysis of various physiological quantities of cardiovascular and respiratory systems, and the measurement of cellular viability, metabolism, morphogenesis, and protein and nucleic acid composition.

14:125:401-402. Biomedical Engineering Senior Design I,II (3,3)
Prerequisites: 14:125:303, 305, 306, 308, 315. Prerequisite for 402 is 401.
Students gain design experience in the biomedical engineering field by completing a design project under the supervision of a faculty member. Project typically involves experimental or computational study of a design-oriented problem in biomedical engineering.

14:125:403. Cardiovascular Engineering (3)
Prerequisites: 14:125:303, 306, 308, 315.
Introduction to modeling and measurement methods for the cardiovascular system, analysis of blood flow dynamics, the function of the heart, and noninvasive approaches. Applications to cardiovascular instrumentation, basic cardiovascular system research, assist devices, and disease processes.

14:125:404. Introduction to Biomaterials (3)
Prerequisites: 14:125:303, 305, 308.
Introduction to material properties, testing, biomaterial requirements, and device design. Main objective is to convey basic knowledge of this large volume of information and to provide an elementary understanding of the terminology used in academic and commercial settings as preparation for future study or work.

14:125:405. Introduction to Neural Processes (3)
Prerequisites: 14:125:303, 305, 306, 308, 315.
Introduction to the function of the nervous system and its building blocks, the neurons. Basic functional characteristics of neurons as individual elements and as parts of neuronal assemblies; generator and action potentials; conduction in nerve fibers and across synaptic junctions; analysis of sensory and neuromuscular systems; EEG and EKG waveforms. Introduction to artificial and electronic equivalents of neurons or neural networks.

14:125:407. Fundamentals of Computer Tomography (3)
Prerequisites: 14:125:303, 305.
Principles of 3D reconstruction from projections in medicine. Mathematics of reconstruction from projections; application to X ray, Magnetic Resonance Emission Tomography, and Ultrasound.

14:125:410. Sensory Processes, Mechanisms, and Computational Models (3)
Prerequisites: 14:125:305 and 315.
General principles of information processing in the human sensory organs, as well as in the early, low-level neural mechanisms and pathways that transmit the signals to the cortex. Emphasis placed on the sensory organs and pathways of vision and audition. Mechanisms covered from a neurophysiological, a computational modeling, and a psychophysical point of view.

14:125:414. Vision Research and Instrumentation (3)
Prerequisites: 14:125:303, 305, 306, 315.
Comprehensive overview of the visual system, beginning with fundamental properties and progressing to the level of current research in vision. Evaluation of experimental and modeling results in vision research, in-depth review of journal articles, and hands-on demonstrations of state-of-the-art visual system instrumentation.

14:125:416. Pattern Recognition in Machines and Biological Systems (3)
Prerequisite: 14:125:315.
Principles of pattern recognition in the visual system within the context of information processing in living organisms and computers. Topics include pattern formation, interpretation, and classification; computer vision compared to biological vision.

14:125:424. Biomedical Instrumentation Laboratory (3)
Prerequisite: 14:125:315.
Practical hands-on designs of biomedical instrumentation including biopotential and physiological signal processing amplifiers, electrodes, biosensor and transducers, electro-optical, acoustic, and ultrasonic devices.

14:125:432. Cytomechanics (3)
Prerequisite: 14:125:303.
Structural and mechanical components of cells, with emphasis on the regulatory roles of physical forces in cell function. Emphasis on processes that drive tissue growth, signaling and metabolism, gene expression, and biomechanical properties of cells and their components.

14:125:433. Fundamentals and Tools of Tissue Engineering (3)
Prerequisite: 14:125:303.
Fundamentals of polymer scaffolds and their use in artificial tissues. Regulation of cell responses in the rational design and development of engineered replacement tissue. Understanding the biological, chemical, and mechanical components of intra- and intercellular communication. Preliminary discussions on real-life clinical experiences.

14:125:434. Tissue Engineering II: Biomedical and Biotechnological Applications (3)
Prerequisite: 14:125:433 or permission of instructor.
Applications of tissue engineering and builds upon the prior course fundamentals and tools. Emphasis is placed on applying the fundamental principles and concepts to problems in clinical medicine and large scale industrial manufacturing. Topics include skin replacement, cartilage tissue repair, bone tissue engineering, nerve regeneration, corneal and retinal transplants, ligaments and tendons, blood substitutes, artificial pancreas, artificial liver, tissue integration with prosthetics, vascular grafts, cell encapsulation, and angiogenesis.

14:125:436. Introduction to Molecular and Cellular Bioengineering (3)
Prerequisites: 14:125:303, 306, 315.
Overview of existing and emerging technologies that exploit our knowledge of molecular and cell biology for applications related to medicine. Topics include genome sequencing; gene expression measurements and applications; protein structure, activity, and detection; biomolecular network analysis and cellular integration of biological signals; cellular processes; cells at interfaces; design and integration of biological components for devices and advanced therapeutics.

14:125:450. Science and Engineering in Medicine (3)
Prerequisite: 14:125:210 or permission of instructor.
Scientific principles on which a variety of medical instruments are based and evaluation of the impact of these technologies on the practice of medicine. Review of the technologies from pathology, neurosurgery, ophthalmology, radiology, cardiothoracic surgery, orthopedic surgery, and plastic surgery.

14:125:491,492. Special Problems in Biomedical Engineering (3,3)
Prerequisite: By permission.
Independent study under the guidance of a faculty member in specific areas of interest in biomedical engineering.

14:125:493,494. Advanced Research in Biomedical Engineering (3,3)
Prerequisite: Biomedical Engineering Honors Academy students only.
Advanced research immersion activity and the supporting educational tools for members of the BME Honors Academy who participate within a formalized two-year research experience. Students work independently with faculty members on a research project of relevance to biomedical engineering. In addition, students meet monthly for roundtable discussions of a wide range of scientific ethical and professional issues.

14:125:496,497. Co-op Program in Biomedical Engineering (3,3)
Prerequisites: Senior standing in biomedical engineering and special permission.
Provides the student with the opportunity to practice and apply knowledge and skills in various biomedical engineering environments. Provides a capstone experience to the undergraduate experience by integrating prior course work into a working engineering environment.

BIORESOURCE ENGINEERING 127

Bioresource engineering courses with the administrative code 11 are taught by Cook College. The following 127 courses are relevant for the bioresource engineering student.

11:127:100. Introduction to Bioresource Engineering (1)
Overview of specializations within bioresource engineering. Expanding role of biological and environmental sciences in engineering. Analysis of selected problems. Review of professional opportunities.

11:127:240. Elements of Horticultural Engineering (3)
Elements of controlled environment horticulture in crop production systems: greenhouse design, environmental control, intensive plant production methods, and postharvest handling and storage.

11:127:290. Biosystems Engineering Measurements (3)
Prerequisite: 01:750:227 or equivalent. Pre- or corequisite: 14:332:373 or equivalent.
Measurement principles including error analysis and transducers. Statistical analysis of experimental data. Electrical measurements. AC and DC circuits. Frequency response and transient analysis. Measurement and interpretation of physical properties of biological materials.

11:127:413. Unit Processes in Bioenvironmental Engineering I (3)
Prerequisite: 14:155:303 or 14:180:387 or 14:650:312.
Application of theoretical concepts from mass, momentum, heat transfer, and reaction kinetics to the design and analysis of unit processes in environmental engineering, with an emphasis on physicochemical operations.

11:127:414. Unit Processes in Bioenvironmental Engineering II (3)
Prerequisites: 01:447:390, 11:127:413, or permission of instructor.
Biological principles and operations, including microbial ecology, stoichiometry and kinetics of organic contaminant degradation and biomass growth, modeling of ideal biochemical reactors, design criteria for several named biochemical operations used for wastewater treatment.

11:127:423. Bioenvironmental Engineering Unit Processes Laboratory I (1)
Prerequisite: 01:160:171 or equivalent. Corequisite: 11:127:413.
Demonstration of physicochemical operations used in the treatment of municipal and industrial wastewater, including coagulation, flocculation, sedimentation, filtration, carbon adsorption, chemical oxidation, heat transfer, oxygen transfer, and residence time distribution.

11:127:424. Bioenvironmental Engineering Unit Processes Laboratory II (1)
Prerequisite: 01:160:171 or equivalent. Corequisite: 11:127:414.
Demonstration of biochemical operations used in the treatment of municipal and industrial wastewater, including biodegradability and biodegradation kinetics, energy balance in a biological reactor, respirometry, activated sludge, anaerobic toxicity, and aerobic digestion.

11:127:450. Applied Instrumentation and Control (4)
Prerequisite: 11:127:290 or equivalent.
Digital electronics, advanced sensing techniques, signal conditioning. Computer-based data acquisition, analysis, and control applications.

11:127:462. Design of Solid Waste Treatment Systems (3)
Open only to junior and senior engineering students.
Design of integrated solid waste management systems, including waste minimization, collection, composting, materials recovery, recycling, incineration, and landfilling.

11:127:468. Hazardous Waste Treatment Engineering (3)
Prerequisites: 11:127:413, 01:160:209, 14:180:382, 01:447:390, or permission of instructor.
Engineering and process design aspects of hazardous waste management. Waste reduction and recovery, waste treatment, and site remediation. Case studies. Engineering solutions to model hazardous waste problems.

11:127:474. Air Pollution Engineering (3)
Prerequisite: 14:155:303 or 14:180:387 or 14:650:312 or permission of instructor.
Engineering design techniques for air quality control. Control of particulate and gas emissions from stationary sources. Control of mobile source emissions. Design for indoor air quality and regional air quality control.

11:127:488. Bioresource Engineering Design I (2)
Open only to seniors in bioresource engineering.
Design morphology. Case studies and special design problems. Solutions developed using creative design processes that include analysis, synthesis, and iterative decision making. Safety and professional ethics.

11:127:489. Bioresource Engineering Design II (2)
Prerequisite: 11:127:488.
Completion of bioresource engineering senior design project. Evaluation. Presentation of final report.

11:127:490. Structural Design and Environmental Control (3)
Prerequisites: 14:180:215, 243.
Functional requirements and design aspects for controlled environment plant production systems, including structures, energy flows and balances, and environmental control equipment.

11:127:491. Phytomation (3)
Prerequisites: 14:440:221, 222.
Analysis and design of mechanization and automation for controlled environment plant production systems with special emphasis on flexible automation, machine vision, mechatronics, and knowledge-based systems.

11:127:492. Energy Conversion for Biological Systems (3)
Prerequisite: 14:650:351.
Principles of energy conversion techniques and their application to various biomechanical systems, including solar energy systems, compostation, methane and alcohol production, and the internal combustion engine.

11:127:493. Unit Processes for Biological Materials (3)
Pre- or corequisite: 14:155:308 or 14:650:351.
Theory and design of unit operations for handling and processing of biological materials with emphasis on particulate solids separation, comminution, mixing, heat transfer, dehydration, and process control.

11:127:494. Land and Water Resources Engineering (3)
Prerequisite: 14:180:387.
Engineering aspects of land and water conservation: basic hydrology, soil-water-plant relationships, surface and subsurface drainage, flood control, irrigation, and groundwater pollution.

11:127:495. Environmental Systems Analysis for Engineers (3)
Prerequisite: Permission of instructor.
Principles of procedural and heuristic systems analysis. Overview of mathematical modeling. Techniques of simulation and optimization. Topics of applied intelligence. Solutions for environmental engineering problems by systems analysis methods.

11:127:496. Planning and Design of Land Treatment Systems (3)
Prerequisite: 14:180:387.
Engineering design of land treatment systems for municipal and industrial wastewater, including spray irrigation, overland flow, infiltration / percolation, and subsurface soil absorption systems. Facilities planning.

11:127:497,498. Special Problems in Bioresource Engineering (BA,BA)
Prerequisite: Permission of department.
Studies of special interest in some selected area of bioresource engineering.

CERAMIC ENGINEERING 150

Junior Inspection Trip (0)
Visits to various types of ceramic manufacturing plants. Written report required.

Senior Inspection Trip (0)
Visits to various types of ceramic manufacturing plants. Written report required. Seniors are encouraged to attend the annual meeting of the American Ceramic Society.

14:150:201. Glass in the Modern World (3)
No prerequisite. For students with little or no background in the physical sciences or engineering, especially liberal arts students seeking an elective. Not open to engineering majors.
Role of glass in contemporary society.

14:150:202. Fundamentals of Materials Engineering (3)
For students with little background in mathematics or the physical sciences. Not open to engineering majors.
Introduction to the field of materials. Surveys the broad principles of materials and relates them to each principal area in the discipline.

14:150:203. Introduction to Materials and Science Engineering (3)
Prerequisite: 01:160:160 or 162.
General field of ceramics, including its development and present scope, the classification of the industry by major divisions, and discussion of the technology of these industries. The broad principles of ceramics based on an approach from crystal physics and unit processes.

14:150:204. Ceramic Processing I (3)
Prerequisite: 14:150:203.
Investigation of the methods and techniques of producing ceramic raw materials from mined ores, with an emphasis on the fundamental processes of liberation and separation, and the engineering of these materials to suit specific ceramic processes and applications. Types of raw materials and their applications, mining methods, and control parameters are considered broadly. Emphasis is placed on modern beneficiation technology. Ceramic raw materials for advanced ceramics are studied and discussed in the context of their predominantly chemical origin. Important properties of both chemical and mineral raw materials are examined with respect to processing and property requirements. Recovery and use of wastes, raw material blending, and the use of previously unusable materials are discussed in the context of the characterization and reformulation concept.

14:150:205. Crystal Chemistry and Structure of Materials (3)
Prerequisite: 01:160:160 or 162.
Introduction of concepts of crystal chemistry applied to ceramics, oxides, and nonoxides. Theories of bonding, the unit cell, crystallography, and symmetry as a basis for structure-property relationships.

14:150:206. Thermodynamics of Materials (3)
Prerequisites: 01:160:160 or 162, 01:640:251.
The laws of thermodynamics, chemical potentials and activities, condensed phase equilibria, phase diagrams and microstructure, the reactions between solids and gases, gas-gas reactions.

14:150:212. Physics of Materials (3)
Prerequisite: 01:640:251.
This course extends the coverage of structure-processing-property relationships and emphasizes properties. It includes an introduction to thermal processes, thermal properties, and optical properties.

14:150:253. Laboratory I (2)
Lec. 55 min., lab. 3 hrs.
Develops skills for planning, execution, and reporting of formal experimental results relating to processing of ceramic materials. Fabrication methods, powder processing, porcelain enameling, and melt forming.

14:150:254. Laboratory II (2)
Lec. 55 min, lab. 3 hrs. Prerequisite: 14:150:253.
Develops skills for planning, execution, and reporting of formal experimental results relating to the characterization of ceramic materials, particle size measurement, phase identification, and dilatometry.

14:150:302. Introduction to Packaging Engineering (3)
Prerequisites: 01:640:152, 01:750:124.
Overview of the various principles and practices involved in packaging science and packaging engineering. Topics such as packaging materials, properties and processing, package design and development, and packaging production lines and their components.

14:150:303. Phase Diagrams (3)
Prerequisites: 14:150:206, 01:160:160 or 162.
Applications of phase rule to one-, two-, and three-component systems with special emphasis on silicates and other oxide systems of interest in ceramics.

14:150:304. Ceramic Compositions (4)
Lec. 3 hrs., lab. 3 hrs.
Experimental design; the effect of composition on electrical, mechanical, thermal, and chemical properties. Triaxial ware, glazes, oxide, and nonoxide structural and electrical ceramics. Ferrous and nonferrous metal compositions.

14:150:305. Ceramic Processing II (3)
Prerequisite: 14:150:204.
Emphasizes batch preparation and organic additives. Provides understanding of processing steps that precede forming. Fundamentals of powder processing, organic chemistry, rheology, and colloid science, with examples in various ceramic casting technologies.

14:150:306. Ceramic Processing III (3)
Prerequisite: 14:150:305.
Engineering methods for forming densified ceramic shapes from ceramic raw materials (fibers, etc.). Role of processing variables in determining microstructure and product quality is a major theme. Specific equipment configurations used in industry; accessing information from reference literature; nonconventional forming processes.

14:150:307. Kinetics of Materials Processes (3)
Prerequisites: 14:150:205, 206.
Phenomenological approach to the solid-state reactions involved in ceramic processing, including phase transformations, phase separation, mechanisms, and transport phenomena.

14:150:309. Characterization of Materials (3)
Prerequisite: 14:150:205.
Interactions of electromagnetic radiation, electrons, and ions with matter and their application in X-ray diffraction and X-ray, IR, UV, electron, and ion spectroscopies in the analysis of ceramic materials. Nonspectroscopic analytical techniques also are covered.

14:150:312. Glass Engineering (3)
Prerequisites: 14:150:204, 303.
Basic physical and chemical properties of glass, chemical durability, stress release, annealing and tempering, mechanical strength, raw materials and melting, and methods of manufacture. Design of composition for desired engineered properties.

14:150:314. Strength of Materials (3)
Prerequisite: 01:640:244.
The mechanical behavior of ceramics is discussed with emphasis on brittle behavior at room temperature and the transition to a limited plasticity regime at high temperatures. The interplay of basic deformation mechanisms with microstructural features and the implication for design and processing of ceramics are considered.

14:150:321. Structural, Mechanical, and Chemical Applications of Nanostructures and Nanomaterials (3)
Prerequisite: 14:150:330.
Fundamentals of grain boundaries and surfaces; application of nanomaterials to batteries, fuel cells, and catalysts; mechanical applications such as hardness, yield strength, superplasticity, tribology, and wear; and microelectric-electromechanical systems (MEMS).

14:150:322. Photonic, Electronic, and Magnetic Applications of Nanostructures and Nanomaterials (3)
Prerequisite: 14:150:330.
Electronic applications of nanomaterials such as quantum dots, nanowires, field effect transistors, and nanoelectromechanical systems. Magnetic applications include information storage, giant and colossal magnetoresistance, and superparamagnetism. Photonic applications include nanolasers, photonic band gap devices, and dense wavelength multiplexers.

14:150:323. Biological Applications for Nanomaterials (3)
Begins with the fundamentals of nanoscience in biology and medicine, and progresses to the current state of research in nanomaterials and nanotechnology as applied to biological applications. Key topics include nanoparticles and phagocytosis, nanoscale drug delivery systems, nanopatterning, scanning probe microscopy, and nanomachines in medicine. Due to the rapidly evolving nature of nanomaterials research, the course contents may change considerably from year to year to reflect the latest advances.

14:150:330. Introduction to Nanomaterials (3)
Open to all science and engineering students who have completed 60 credits.
Nanotechnology involves behavior and control of materials and processes at the atomic and molecular levels. This interdisciplinary course introduces the student to the theoretical basis, synthetic processes, and experimental techniques for nanomaterials. This course is the introduction to three advanced courses in (1) Photonic, Electronic, and Magnetic Applications of Nanostructures and Nanomaterials; (2) Structural, Mechanical, and Chemical Applications of Nanostructures and Nanomaterials; and (3) Biological Applications for Nanomaterials.

14:150:331. Structural, Mechanical, and Chemical Applications of Nanostructures and Nanomaterials Laboratory (1)
Prerequisite: 14:150:330. Corequisite: 14:150:321.
This laboratory complements Structural, Mechanical, and Chemical Applications of Nanostructures and Nanomaterials (150:321) and reinforces the subjects with hands-on experiments.

14:150:332. Photonic, Electronic, and Magnetic Applications of Nanostructures and Nanomaterials Laboratory (1)
Prerequisite: 14:150:330. Corequisite: 14:150:321.
This laboratory complements Photonic, Electronic, and Magnetic Applications of Nanostructures and Nanomaterials (150:322) and reinforces the subjects with hands-on experiments.

14:150:333. Biological Applications for Nanomaterials Laboratory (3)
Familiarizes students with experimental methods used in the characterization of nanoscale biological materials. Includes four modules: BET surface area measurement, particle size measurement by dynamic light scattering, electrophoresis, and atomic force microscopy. Laboratory modules may change from year to year to reflect advances in nanoscale instrumentation.

14:150:340. Electrochemical Materials and Devices (3)
Introduction to basic electrochemistry, principles of electrochemical devices; electroactive materials used in such devices; and case studies of batteries, fuel cells, and sensors. An emphasis is placed on the integration of electrochemical principles and materials science for application in modern electrochemical devices.

14:150:355. Laboratory III (2)
Lec. 55 min, lab. 3 hrs. Prerequisite: 14:150:254.
Focuses on helping the student develop skills for the planning, execution, and reporting of formal experimental results relating to the measurement of ceramic materials properties. Properties investigated are optical, electrical, and mechanical in nature. The measurement method as well as the structure—property relationship found in ceramic materials—will be stressed. Principles of electrical engineering relevant to the property measurements will also be emphasized.

14:150:373. Packaging Evaluation Methods (3)
Methods for evaluating and characterizing packaging materials and manufactured packages discussed, with emphasis on package development and established test protocols.

14:150:374. Package Design Laboratory (1)
Lab. 3 hrs.
Application of principles learned in 14:150:372 to design a package. Concept search through prototype production and testing.

14:150:375. Packaging Evaluation Laboratory (1)
Lab. 3 hrs.
Experiments performed to evaluate the performance of manufactured packages and materials used for packaging. Mechanical and chemical properties of packaging materials determined.

14:150:376. Package Manufacturing Processes (3)
Manufacturing methods for glass, metal, plastic, paper, and composite packages studied and observed on field trips.

14:150:377,378. Packaging Materials and Mechanical Properties I,II (3,3)
Chemistry, structure, and physical and mechanical properties of materials used in packaging studied along with the effect of manufacturing processes.

14:150:401-402. Senior Ceramic and Materials Engineering Laboratory I,II (3,3)
Conf. 1 hr., lab. 6 hrs. Prerequisites: 14:150:306, 307, 309, 401.
Training in methods of independent research. Students, after consultation, assigned a problem connected with some phase of ceramics or ceramic engineering in their elected field of specialization.

14:150:403,404. Ceramic and Materials Engineering Seminar (1,1)
Current trends and topics of special interest in ceramics discussed by faculty, students, and representatives from the ceramics industry.

14:150:406. Refractories (3)
Physical and chemical principles involved in the development, production, and use of refractories, including carbides, nitrides, oxides, and silicates. Emphasis on modern, high-temperature applications.

14:150:407. Ceramic Microscopy (3)
Indicatrix theory. Use of thin-section and polished-section techniques in optical microscopy; application of scanning electron microscopy with sections, fractures, and powders. Application to ceramic products and processes.

14:150:408. Instrumental Techniques for Research (3)
Lec. 2 hrs., lab. 3 hrs.
Study of the instrumentation used in the analysis and evaluation of ceramic materials. Instruction on X ray, DTA/TGA, electron microscope, and electron microprobe.

14:150:411,412. Engineering Design in Ceramic and Materials Engineering I,II (3,3)
Prerequisites: 14:150:305-306. Corequisites: 14:150:411, 413.
Fundamentals of equipment and plant design, construction, installation, maintenance, and cost for manufacture of ceramic products. Assignment of a problem in elected field of specialization.

14:150:413. Ceramic and Materials Engineering Venture Analysis (3)
Prerequisite: 14:540:343.
Product innovation and development techniques for ceramic materials based on traditional venture-analysis techniques. Aspects of marketing, engineering design, framework structuring, and decision and risk analysis.

14:150:414. Electronic Optical and Magnetic Properties of Materials (3)
Prerequisites: 14:150:205, 355.
Theoretical and practical considerations of dielectric loss, ferroelectricity, ferromagnetism, and semiconductivity in ceramic systems (glass, crystal, glass-crystal composites). Variation of properties with composition, structure, temperature, and frequency.

14:150:416. Physical and Chemical Properties of Glass (3)
Two 80-min. lectures. Offered even years only. Prerequisites: 14:150:312, 01:160:160 or 162.
Provides an atomistic understanding of the role of composition on the structure and properties of glasses.

14:150:419. Packaging Thermodynamics (3)
Introduction to the laws of thermodynamics, phase equilibria, equilibrium reaction effects, surface science, interfacial thermodynamics, bonding forces, and adhesion principles.

14:150:420,421. Packaging Senior Design I,II (3,3)
Open to seniors in packaging engineering.
Two-term sequence in packaging design and development under the supervision of the program faculty.

14:150:422. Abrasives (1.5)
Manufacture, development, and properties of abrasives.

14:150:423. Structural Ceramics (1.5)
Fundamental engineering aspects of structural ceramics.

14:150:424. Hydraulic Setting Materials (1.5)
Cements, limes, and plasters; their manufacture, properties, and uses.

14:150:425. Ceramic Colors (1.5)
Fundamental aspects of color and pigments are reviewed with specific examples related to glazes and enamels.

14:150:426. Ceramic-Metal Systems (3)
Vitreous enamels, refractory coatings, electronic components, composite systems, and cemented carbides from the standpoint of engineering production methods, physical properties, and fundamental principles.

14:150:431. Fiber Optics Engineering (3)
Light propagation in transparent materials, waveguide materials and structures, fiber drawing and characterization, basic fiber measurement techniques, optical data links, advanced applications of optical fibers.

14:150:432. Applications of Fiber Optics (3)
Prerequisite: 14:150:431.
Applications of fiber optics in sensors, medicine, and surgery. Unconventional fibers, such as infrared fiber optics, discussed.

14:150:433. Optical Materials (3)
Fundamentals of optical materials (crystals, glasses, polymers). Relation of structure with optical properties and applications. Spectral characteristics of thin materials.

14:150:435. Glass Packaging Engineering (3)
Open to ceramic majors by special permission only. Offered odd years only.
Nature of glass; history and economics of glass packaging; soda-lime and other glass families; batching, furnaces, and forming; color; decoration and enameling; container strength; glass recycling; pharmaceutical packaging.

14:150:451. Fiber Optics Engineering Laboratory (1)
Lab. 3 hrs.
Optical spectroscopy, cleaving and splicing, loss, numerical aperture, dispersion measurements, mechanical properties, environmental effects, source and detector evaluation, optical link measurements, fiber optic sensors.

14:150:457. Ceramic Microscopy Laboratory (1)
Lab. 3 hrs. Corequisite: 14:150:407.
Optical and scanning electron microscopes used for the examination of demonstration specimens. Preparation of polished and thin-section specimens; identification of phases present; quantitative amounts of each phase, grain size, and general microstructure.

14:150:460. Surface Decoration of Packaging (3)
Fundamentals of printing techniques used on glass, metal, plastic, paper, and composite packages with attention to relevant topics on physical chemistry of packaging material surfaces.

14:150:467. Whitewares (3)
Prerequisites: 14:150:203, 303, 304, or special permission from instructor.
Intended for students interested in expanding their knowledge of clay-based bodies and glazes: raw materials, body formulations, forming techniques, glaze compositions, glaze application technology, and firing technology. Students presented with a series of problems typical of those found in whitewares industries.

14:150:468. Applications of Industrial Materials (3)
Prerequisite: 14:150:204 or special permission from instructor.
Provides a broad profile of the structure, processing, properties, and uses of the most widely mined and used minerals. Comprehensive overview of how and why these minerals are used in paints, coatings, pharmaceuticals and pesticides, adhesives, paper, rubber, sealant, and plastics.

14:150:471. Distribution Packaging (3)
Design, development, and evaluation of distribution packaging. Physical distribution management as a systems approach to the flow, storage, and control of the product. Equipment used in distribution packaging. Economics of package design.

14:150:472. Materials Electronic Packaging (3)
Materials and processes for packaging with ceramics, polymers, and metals. Thermal, mechanical, and electrical properties of composite packaging structures. Printed circuits, ceramic substrates, thin and thick films, protective coatings. Multilayers, multichip configurations, and design trends.

14:150:473. Distribution Packaging Laboratory (1)
Lab. 3 hrs.
Experiments in design of distribution packages, cushioning of products, and testing in a simulated distribution environment. Builds on principles studied in 14:150:471.

14:150:476. Packaging Machinery (3)
Study of packaging machinery with some review of materials and considerations of the interrelationship between machinery and materials. Analysis of the development of package production lines. Principles of machine design and selection emphasizing the synthesis of knowledge.

14:150:478. Packaging Machinery Laboratory (1)
Lab. 3 hrs.
Laboratory experimentation to accompany 14:150:476. Designed to augment the principles and practices presented in the lectures. Complete packaging line used by students for experiments.

14:150:479,480. Packaging Practice I,II (3,3)
By permission of the program director.
Internships with major corporations serving as paid packaging engineers. Term paper required.

14:150:481,482. Special Problems in Packaging I,II (3,3)
Individual or group projects, under the guidance of a faculty member, on special areas of interest in packaging engineering.

14:150:491,492. Special Problems in Ceramics (BA,BA)
Individual or group study or study projects, under the guidance of a faculty member, on special areas of interest in ceramic engineering.

14:150:496-497. Co-op Internship in Ceramic and Materials Engineering (3,3)
Prerequisite: Permission of department. Graded Pass/No Credit.
Provides the student with the opportunity to practice and apply knowledge and skills in various ceramic and materials engineering professional environments. Intended to provide a capstone experience to the student's undergraduate studies by integrating prior course work into a working engineering environment. Credits earned for the educational benefits of the experience and granted only for a continuous, six-month, full-time assignment.

CHEMICAL AND BIOCHEMICAL ENGINEERING 155

14:155:201. Chemical Engineering Analysis I (3)
Prerequisites: 01:160:160, 171; 01:640:152.
Introductory course. Mass and energy balances, recycle and bypass calculations. First Law of Thermodynamics and application to closed and open systems. Formulation of simple chemical equilibria. Analysis and solution of mass and energy balance problems for complex processes.

14:155:208. Chemical Engineering Thermodynamics (3)
Prerequisite: 14:155:201.
Thermodynamics from a chemical engineering viewpoint. First Law as it applies to nonflow and steady-flow processes, pressure-volume-temperature behavior of fluids and heat effects, the Second Law and its applications, thermodynamic properties of pure fluids and fluid mixtures, phase equilibria, and chemical reaction equilibria. Thermodynamics of polymers and biosystems.

14:155:303. Transport Phenomena in Chemical Engineering I (3)
Prerequisites: 14:155:208, 01:640:244 or equivalent.
Introduction to fluid dynamics of chemical systems. Application of basic equations to steady-state and unsteady-state flow processes. Description of laminar and turbulent-flow regimes leading to the determination of velocity distributions and friction factors. Design equations for flowing fluids, with computer applications.

14:155:304. Transport Phenomena in Chemical Engineering II (3)
Prerequisites: 14:155:303, 01:640:421 or equivalent.
Energy and mass transfer in chemical engineering processes, with computer applications. Steady-state and unsteady-state heat conduction and molecular diffusion. Energy and mass transfer in fluids undergoing flow, phase change, and / or chemical reaction. Radiant heat transfer. Heat exchangers and mass transfer equipment.

14:155:307. Chemical Engineering Analysis II (3)
Prerequisites: 14:155:201, 14:440:127, 01:640:244 or equivalent.
Introduction to modeling and simulation techniques in the analysis of chemical and biochemical engineering systems. Application of numerical methods for the solution of complex chemical process problems. Development and use of PC software for the analysis and solution of engineering problems.

14:155:324. Design of Separation Processes (3)
Prerequisites: 14:155:304, 208.
Application of mass transfer theory to the design and analysis of chemical engineering separation processes. Distillation, liquid extraction, gas absorption, and other separation processes. Computer software for the design and analysis of various separation processes.

14:155:409. Chemical Systems Safety and Health Engineering Management (1.5)
Open only to seniors in the department.
Modern principles and practices of chemical systems analyses of engineering safety and health problems in the industrial, government, and public sectors of society. Emphases on engineering management duties and responsibilities, particularly as related to codes and standards of OSHA, EPA, the Consumer Product Safety Commission, ANSI, ASTM, Underwriters' Laboratory, NFPA, the National Electric Code. Case studies of chemical safety and health mishaps, including legal and ethical aspects of engineering design negligence.

14:155:411. Introduction to Biochemical Engineering (3)
Prerequisites: 14:155:304, 01:447:390, 01:694:30l.
Integration of the principles of chemical engineering, food science, biochemistry, cell and molecular biology, and microbiology with applications to the analysis, control, and development of industrial, biochemical, and biological processes. Quantitative, problem-solving methods emphasized.

14:155:415. Process Engineering I (4)
Lec. 1 hr., lab. 9 hrs. Prerequisites: 14:155:304, 307.
Original experiments developed using existing pilot-scale or bench-scale equipment. Working independently under faculty supervision, students use modern instruments, operate equipment under various open- and closed-loop control conditions, perform experiments, take data and assay samples, and write reports of professional quality. OSHA-type laboratory safety and health practices taught and utilized.

14:155:416. Process Engineering II (4)
Lec. 1 hr., lab. 9 hrs. Prerequisite: 14:155:415.
Projects different in kind and scale from those of the first term. Emphasis on professional-quality data and individual contributions, particularly process evaluation, scale-up, and design criteria. Also, orientation on careers, job opportunities, professional societies, licensing, rights and responsibilities of licensed engineers, and safety-risk management.

14:155:422. Process Simulation and Control (3)
Prerequisite: 14:155:304.
Modern simulation techniques and automatic control theory as applied to process dynamics of chemical and biochemical engineering systems. Use of analytical methods and computer software for solving complex problems. Structure and design of closed-loop, computer-controlled processes. Discussion of safety engineering in the final process of control design.

14:155:424. Chemical Engineering Design and Economics (4)
Prerequisites: 14:155:324, 441, or permission of instructor.
Design of large chemical plants. Economics involved in the design, construction, and operation of chemical plants using modern computer software packages. Plant safety practices and OSHA concerns. Design problems using basic engineering principles.

14:155:426. Biochemical Engineering Design and Economics (4)
Prerequisites: 14:155:324, 441, or permission of instructor.
Design of large biochemical plants. Economics involved in the design, construction, and operation of biochemical and biological plants using basic engineering principles and computer software packages. Safety and OSHA issues discussed.

14:155:441. Chemical Engineering Kinetics (3)
Prerequisites: 14:155:304, 01:160:328 or 342.
Fundamental theories of kinetics. Ideal reactor analysis; single reactions, parallel and series reactions. Consideration of real reactors. Principles of heterogeneous catalysis, combined mass transfer / kinetic phenomena, and approaches to catalytic reactor design using computer methods.

14:155:453. Chemical Environmental Engineering (3)
Prerequisite: Permission of instructor required for nonmajors.
Distribution, transport pathway, fate, and effects of natural and synthetic chemicals in the environment. Relationships between waste minimization, unit processes employed in end-of-pipe treatment, and alternative materials, in terms of economics and regulatory controls. Site remediation. Hazardous and extremely hazardous substances.

14:155:491,492. Special Problems in Chemical and Biochemical Engineering (BA,BA)
Individual work under the guidance of a faculty adviser on special problems in a specific area of chemical or biochemical engineering. Interdisciplinary cooperation encouraged where applicable. Projects may be one or two terms in length, although the latter is preferred. Normally, no more than 3 credits are awarded per term, except for students in the James J. Slade Scholars Program.

14:150:496-497. Co-op Internship in Chemical and Biochemical Engineering (3,3)
Prerequisite: Permission of department. Graded Pass/No Credit.
Intended to provide a capstone experience to the student's undergraduate studies by integrating prior course work into a working chemical and biochemical engineering professional environment. Credits earned for the educational benefits of the experience and granted only for a continuous, six-month, full-time assignment.

CIVIL AND ENVIRONMENTAL ENGINEERING 180

14:180:215. Engineering Graphics (1)
Lab. 3 hrs. Not for civil engineering majors.
Principles of computer-aided drafting and design (CADD): graphic entities, hatch patterns, layering, part file creation and information extraction. Two-dimensional drafting and pictorial drawings using a CADD system. Introduction to three-dimensional modeling and surface revolution.

14:180:216. Introductory Computer-Aided Design and Drafting (3)
Lec. 1 hr., lab. 3 hrs., rec. 1 hr. Open to civil engineering majors only.
Principles of computer-aided drafting and design (CADD): graphic entities, hatch patterns, layering, part file creation, and information extraction. Two-dimensional drafting and pictorial drawings using a CADD system. Introduction to three-dimensional modeling and surface revolution. Descriptive geometry. CADD applications in civil engineering.

14:180:243. Mechanics of Solids (3)
Prerequisites: 01:640:251, 14:440:221 or equivalent. Corequisite: 01:640:244.
Axial force, shear, moment, and torque in structural members; stress, strain, and stress-strain relations; principal stresses and strains; torsion of circular shafts; bending of singly symmetric beams; compound loading; buckling of columns; statically indeterminate systems.

14:180:305. Construction Engineering (3)
Prerequisite: 14:180:243.
Construction planning and practices. Utilization of heavy construction equipment. Economic and operational considerations in selection of construction equipment. Use of computer spreadsheets for cost recording and economic decisions. Formwork design. Quality and productivity control.

14:180:318. Elements of Structures (3)
Prerequisites: 14:180:243, 14:440:222.
Structural analysis of statically determinate trusses, frames, cables, and arches. Computation of deflections in trusses and plane frames. Influence lines for beams and trusses. Introduction to indeterminate structures.

14:180:320. Design of Steel Structures (3)
Lec. 2 hrs., rec. 1 hr. Prerequisites: 14:180:243, 318; 14:440:222.
Design of bolted and welded connections; design of components of structural systems in tension, compression, bending, and combined axial and bending loads. Use of computers for design and detailing.

14:180:345. Properties of Materials Laboratory (1)
Prerequisite: 14:180:243.
Mechanical properties and behavior of structural elements under a variety of load conditions.

14:180:364. Transportation Engineering I (3)
Principles of transportation engineering with application to various modes; planning, selection, formulation, and administration of transportation systems. Economic, environmental, and political constraints; land-use studies; applications; term project to include proposal and analysis to meet a specific transportation requirement.

14:180:372. Soil Mechanics (3)
Prerequisites: 14:180:243, 387.
Elements of engineering geology; mechanical and hydraulic properties of soils; soil-water systems and fluid flow; stresses in soils; compressibility, consolidation, and settlement; shearing resistance; lateral earth-pressures; slope stability; bearing capacity; numerical methods and computer applications.

14:180:374. Soil Mechanics Laboratory (1)
Lab. 3 hrs. Corequisite: 14:180:372.
Engineering classification of soils and rocks. Laboratory studies of physical properties and shear strength of soils such as Atterberg limits, compaction, permeability, unconfined compression, and direct shear tests.

14:180:382. Hydraulic and Environmental Engineering (3)
Prerequisite: 14:180:387.
Basic concepts of viscous flows; conservation laws (mass, momentum, and energy); pipe flows and open-channel flows; water distribution systems; hydraulic modeling (stream and marine pollution); air, stream, and marine pollution problems. Computer applications.

14:180:387. Fluid Mechanics (3)
Prerequisites: 14:440:222, 01:640:244.
Fluid properties, statics and kinematics; concepts of system and control volume; mass, momentum, and energy conservation principles; laminar and turbulent flows in conduits and channels; boundary layer theory; drag and lift; ideal fluid flow.

14:180:389. Fluid Mechanics Laboratory (1)
Corequisite: 14:180:387.
Experimental applications and demonstrations; measurement of fluid properties; applications of mass, energy, and momentum principles; energy losses; forces on immersed bodies; flow measurement devices.

14:180:402. Finite Element Methods in Civil Engineering (3)
Prerequisites: 14:180:243, 01:960:379 or equivalent.
Finite element method of analysis for problems in structures and solid, fluid, and soil mechanics. Fundamentals of the finite element method. Variational formulation of boundary value problems, Galerkin approximations, matrix equations, finite element interpolation, error estimates, computer program algorithms and codes.

14:180:406. Construction Engineering Management (3)
Prerequisite: 14:180:305.
Construction planning, scheduling, and control. Use of computer-based information systems for project management. Value engineering. Critical path method and PERT scheduling techniques. Computer-drawn scheduling networks. Schedule compression. Resource allocation leveling and optimization. Project organization and financial control. Decision making.

14:180:407. Construction Projects (4)
Prerequisites: 14:180:305, 406.
Application of skills and theories of construction engineering management to actual projects. Students assigned to a project and work with managers to budget, schedule, and control operations. Topics include project staffing, cost control and documentation, safety and health, and labor relations.

14:180:411. Reinforced Concrete (3)
Prerequisites: 14:180:318, 320.
Strength theories for the analysis and design of beams, slabs, columns, and floor systems in flexure, diagonal tension, torsion, serviceability, and load factors, including computer applications.

14:180:412. Behavior of Concrete Materials and Systems (3)
Prerequisites: 14:180:301, 411.
Material behavior under uniaxial, multiaxial, and time-dependent loading. Various methods of testing and computer aids for quality control. Analysis of structural members. Recent developments in cementitious composites.

14:180:413. Theory of Indeterminate Structures (3)
Prerequisite: 14:180:318.
Force method for solving simple indeterminate structures. Classical methods of slope-deflection and moment distribution. Formulation and algorithms for matrix method. Application of computers for analyzing indeterminate trusses and frames.

14:180:421. Reinforced Concrete Laboratory (1)
Lab. 3 hrs. Corequisite: 14:180:411.
Experimental stress analysis of concrete structures, including test to failure of beams, plates, and prestressed elements; control testing and design of concrete mixtures.

14:180:426. Structural Design (4)
Lec. 3 hrs., lab. 3 hrs. Prerequisites: 14:180:318, 320, 411, 421.
Design of steel or concrete structures; prestressed concrete design of beams and slabs. Design project with working drawings for a bridge or high-rise building. Economic and ethical considerations. Comprehensive report.

14:180:429. Water and Wastewater Engineering (3)
Prerequisites: 14:180:387, 389.
Design principles for water and wastewater engineering systems, water supply and distribution, wastewater collection and disposal, water treatment, and wastewater treatment.

14:180:430. Introduction to Transportation Planning (3)
Prerequisite: 14:180:364.
Various aspects of transportation demand forecasting problems. Solutions using some of the state-of-the-art transportation planning software packages, such as transplan, QRS2, and transcend. Case studies of transportation planning problems.

14:180:431. Design of Environmental Engineering Facilities (4)
Prerequisites: 14:180:387, 389, 429.
Analysis and design considerations for environmental engineering facilities, such as water supply and wastewater treatment plants; physical engineering management of solid and hazardous wastes; resource recovery; economic and ethical considerations. Comprehensive report.

14:180:438. Transportation Engineering II (4)
Lec. 3 hrs., lab. 3 hrs. Prerequisite: 14:180:364.
Studies in the design of transportation facilities, with emphasis on streets, highways, and airports. Earthworks, construction, pavement, and roadway design based on economic, stability, and durability considerations, and interface with the environment.

14:180:443. Advanced Hydraulics (3)
Prerequisite: 14:180:387.
Hydraulic engineering fundamentals—boundary layer, surface roughness, resistance in viscous flows; design of erodible and nonerodible canals; gradually varied flow, backwater analysis in rivers, computational methods; hydraulic jump; hydraulic applications in channel transitions and controls; flow over spillways; pollution problems in rivers and streams.

14:180:448. Elements of Hydrology (3)
Prerequisite: 14:180:387.
Hydrologic cycle; weather and hydrology; precipitation; evaporation and transpiration; stream flow and subsurface hydrology; stream flow hydrographs, unit hydrograph theory; stream flow routing, computer simulation of hydrologic processes; probability concepts in hydrology, models for frequency distribution of floods, time series analysis.

14:180:471. Elements of Environmental Geotechnology (3)
Prerequisite: 14:180:372.
Geotechnical aspects of analysis design and construction of waste containment systems.

14:180:473. Foundation Engineering (3)
Lec. 2 hrs., rec. 1 hr. Prerequisites: 14:180:372, 374.
Subsurface exploration; bearing capacity, settlement, and design of shallow foundations; design of rigid and flexible retaining structures; bearing capacity, settlement, and design of deep foundations.

14:180:474. Geotechnical Engineering Design (4)
Prerequisites: 14:180:372, 374, 473.
Subsurface investigation; construction dewatering; design concepts and procedures for shallow and deep foundations; application of numerical methods; safety and economy. Comprehensive report.

14:180:482. Professional Issues in Civil Engineering (1)
Prerequisite: Completion of all required courses through fall term of senior year.
Principles of design of civil engineering projects from the viewpoint of the whole; interactions between individual parts (subsystems) and the effect of each on the overall system; overview of design process, quality of design, risk and liability, ethics, and economic considerations; report writing.

14:180:491,492. Special Problems in Civil Engineering (BA,BA)
Open only to seniors with departmental permission.
Individual investigation in a branch of civil engineering of particular interest to the student.

14:180:493,494. Special Problems in Environmental Engineering (BA,BA)
Open only to seniors with departmental permission.
Individual investigation in a branch of environmental engineering of particular interest to the student.

14:180:496-497. Co-op Internship in Civil and Environmental Engineering (3,3)
Prerequisite: Permission of department. Graded Pass/No Credit.
Intended to provide a capstone experience to the student's undergraduate studies by integrating prior course work into a working civil and environmental engineering professional environment. Credits earned for the educational benefits of the experience and granted only for a continuous, six-month, full-time assignment.

ELECTRICAL AND COMPUTER ENGINEERING 332

14:332:202. Discrete Mathematics (3)
Prerequisite: 14:332:231.
Fundamentals of logic; functions; proofs; direct, contrapositive, and converse; induction; set theory, recursion and recursive equations; counting, combination, permutations; discrete probability; Euclidean algorithm; RSA encryption; polynomials; finite-field Fourier Transforms; finite-state automata; graph theory.

14:332:221-222. Principles of Electrical Engineering I,II (3,3)
Prerequisite: 01:640:152. Corequisites: 01:640:244, 251; 14:332:223-224.
Circuit elements, independent sources, dependent sources, circuit analysis in the DC and AC steady state, network theorems, operational amplifiers, transient analysis, Laplace Transforms, step and impulse response, active and passive filter circuits, two port networks, and introduction to 3-phase circuit. Introduction to Fourier series.

14:332:223-224. Principles of Electrical Engineering I,II Laboratory (1,1)
Corequisites: 14:332:221-222.

14:332:231. Digital Logic Design (3)
Prerequisite: 14:440:127. Corequisite: 14:332:233.
Binary arithmetic, Boolean algebra, K-maps. Combinational circuit synthesis, combinational MSI circuits. Sequential logic. Synchronous state machine design. Sequential MSI circuits.

14:332:233. Digital Logic Design Laboratory (1)
Corequisite: 14:332:231.

14:332:252. Programming Methodology I (3)
Prerequisite: 14:332:231.
Principles of block-structured languages and data systems. Syntax, semantics, and data types of C programming language. Structured programming. Arrays, structures, lists, queues, stacks, sets, and trees. Recursion and pointers. Searching, sorting, and hashing algorithms. Introduction to complexity analysis.

14:332:254. Programming Methodology I Laboratory (1)
Corequisite: 14:332:252.

14:332:303-304. Honors Candidacy Problems (0,0)
Prerequisite: Permission of department chairperson. Open to undergraduate students who wish to become James J. Slade Scholars.
Extensive reading and study in a particular problem area of electrical and computer engineering under the guidance of a faculty member in the Department of Electrical and Computer Engineering.

14:332:321. Probability and Random Processes (3)
Prerequisite: 14:332:222 or 50:750:234.
Probability and its axioms, conditional probability, independence, counting, random variables and distributions, functions of random variables, expectations, order statistics, central limit theorem, confidence intervals, hypothesis testing, estimation of random variables. Random processes and their characterization, autocorrelation function.

14:332:322. Principles of Communications Systems (3)
Prerequisites: 14:332:321, 345.
Amplitude modulation and demodulation, frequency modulation and demodulation, phase locked loops, stochastic processes, autocorrelation, power spectral density, noise analysis in analog systems, and digital communications.

14:332:331. Computer Architecture and Assembly Language (3)
Prerequisites: 14:332:231, 252. Corequisite: 14:332:333.
Principles of computer architecture. Principles of assembly language programming, data definitions, instruction sets, addressing modes, assembler directives, macros. Control structures, organization of microcontrol systems, microprogramming. Memory organization, physical and virtual memory, implementation of virtual and paging memory systems, DMA, caches. Bus organization, input/output handling, interfaces and asynchronous control.

14:332:333. Computer Architecture Laboratory (1)
Prerequisites: 14:332:231, 252. Corequisite: 14:332:331.
Assembly language programming for one of the standard commercial RISC microprocessors. Design and implementation of a simple microprocessor-based, single-user computer.

14:332:345. Linear Systems and Signals (3)
Prerequisites: 14:332:222, 01:640:244. Corequisite: 14:332:347.
Introduction to continuous- and discrete-time systems and signals, basis function representation of signals, convolution, Fourier Series, Fourier, Laplace, transforms theory, and state space variable.

14:332:346. Digital Signal Processing (3)
Prerequisites: 14:332:345, 01:640:244. Corequisite: 14:332:348.
Introduction to digital signal processing, sampling and quantization, A/D and D/A converters, review of discrete-time systems, convolution, Z-transforms, digital filter realizations, fast Fourier transforms, filter design, and digital audio applications.

14:332:347. Linear Systems and Signals Laboratory (1)
Corequisite: 14:332:345.

14:332:348. Digital Signal Processing Laboratory (1)
Corequisite: 14:332:346.

14:332:351. Programming Methodology II (3)
Prerequisite: 14:332:252.
In-depth analysis of algorithms using object-oriented techniques. Comparative algorithm analysis, sorting, graphs, NP completeness. Emphasis on programming and practical applications in electrical and computer engineering. Introduction to parallel programming. Programming project.

14:332:361. Electronic Devices (3)
Prerequisites: 14:332:221-222. Corequisite: 14:332:363.
Fundamentals of semiconductor devices and microelectronic circuits, characteristics of p-n, Zener and tunnel diodes, and analog diode circuits. Principles of JFET, MOSFET, and BJT operation; biasing and stabilization methods; and transistor analysis at low frequencies.

14:332:362. Analog Electronics (3)
Prerequisite: 14:332:361. Corequisite: 14:332:364.
Feedback amplifier analysis. Frequency response of BJT and FET amplifiers, frequency response with feedback stability, and power amplifiers.

14:332:363. Electronic Devices Laboratory (1)
Corequisite: 14:332:361.

14:332:364. Analog Electronics Laboratory (1)
Corequisite: 14:332:362.

14:332:366. Digital Electronics (3)
Prerequisite: 14:332:361. Corequisite: 14:332:368.
Transistor level circuit design theory for the digital logic gate families of CMOS, BiCMOS, nMOS, TTL, and ECL. Circuit delay, power, and noise analysis.

14:332:368. Digital Electronics Laboratory (1)
Corequisite: 14:332:366.

14:332:373. Elements of Electrical Engineering (3)
Prerequisites: 01:640:244, 01:750:227. Not open to electrical engineering students.
Survey course in electrical equipment and circuit solving.

14:332:375. Elements of Electrical Engineering Laboratory (1)
Corequisite: 14:332:373. Not open to electrical engineering students.

14:332:382. Electromagnetic Fields (3)
Prerequisites: 01:640:252 or 244, 01:750:227, 14:332:222.
Field theory of static, stationary, and moving charges explored. Basic laws of Coulomb, Gauss, Faraday, and Ampere discussed in the context of engineering applications. Knowledge of vector analysis assumed.

14:332:411. Electrical Energy Conversion (3)
Prerequisites: 14:332:221-222.
Principles of converting electrical energy into mechanical energy, and the reverse, via electromagnetic field interaction. Identification of different machines and their applications, understand machine-operating principles, and analyze key characteristics. Understanding of magnetic and thermal constraints.

14:332:415. Introduction to Automatic Control Theory (3)
Prerequisite: 14:332:345.
Theory of automatically controlled systems and their dynamic behavior.

14:332:417. Concepts in Control Systems Design (3)
Prerequisite: 14:332:345. Corequisite: 14:332:415.
Design methods for controllers of linear time-invariant systems using Bode diagrams, root locus, pole placement, and observer techniques. Linear-quadratic optimal controllers and Kalman filters. Design techniques for controllers of nonlinear systems based on linearization, first and second method of Lyapunov, describing function method. Observers for nonlinear systems and extended Kalman filter.

14:332:418. Capstone Design—Control Systems (3)
Prerequisite: 14:332:417.
Capstone design experience in control systems engineering. Focuses on team-oriented design projects involving linear-quadratic optimal regulators and nonlinear control systems. Students participate in a design process that incorporates realistic engineering constraints such as manufacturability and issues dealing with economics, safety, and ethics.

14:332:421. Communications Engineering (3)
Prerequisite: 14:332:322.
Quantization, analog signal coding, intersymbol interference, equalization, signal space and digital modulation, information theory, and coding.

14:332:423. Telecommunication Networks (3)
Prerequisite: 14:332:321.
Problems of network synthesis and analysis. Includes network architectures for telephony and data network, circuit and packet multiplexing / switching methods, network design / routing algorithms via elementary linear / dynamic programming, layered protocol architectures, protocol design and analysis methods, and performance analysis.

14:332:424. Introduction to Information and Network Security (3)
Prerequisite: 14:332:252.
Classical cryptosystems, modular arithmetic, Chinese Remainder Theorem, modular exponentiation, Fermat and Euler theorem, DES, modes of operation for block ciphers, breaking DES, Rijndael, public key cryptography, primality and prime testing, secret sharing schemes, Needham-Schroeder, Kerberos, public key infrastructure, password systems, Privacy Enhanced Mail (PEM), Pretty Good Privacy (PGP), SSL, IPSEC, and wireless network security.

14:332:426. Wireless Personal Communication Systems (3)
Prerequisites: 14:332:322, 421, 423.
Comparison of wireless and conventional communications, interference limited communications, channel reuse, capacity, spectrum efficiency, physical channels, systems, code division cellular system, low-tier personal communications systems, wireless data systems.

14:332:427. Concepts in Communication Systems Design (3)
Prerequisite: 14:332:322.
Design methods and laboratory experiments dealing with practical aspects of analog and digital communications schemes. Experiments involve component-level circuit construction, interconnection of modular subsystems, and use of interactive, graphics-based, system simulation software packages.

14:332:428. Capstone Design—Communication Systems (3)
Prerequisite: 14:332:427.
Capstone design experience in communications systems engineering. The course focuses on team-oriented design projects involving practical analog and digital communications systems. Students participate in a design process that incorporates realistic engineering constraints such as manufacturability and issues dealing with economics, safety, and ethics.

14:332:437. Concepts in Digital Systems Design (3)
Prerequisites: 14:332:231, 252, 331.
Design methodologies for combinational and sequential logic circuits. Characteristics of microprocessors, fault-tolerant computer design, and advanced state machine theory. Digital machine organization for testing and fault-tolerance. Hardware description using the VHDL language.

14:332:438. Capstone Design—Digital Systems (3)
Prerequisite: 14:332:437.
Capstone design experience in digital systems engineering. Focuses on team-oriented design projects involving a systematic approach to designing digital logic circuits for a variety of practical applications. Students participate in a design process that incorporates realistic engineering constraints such as manufacturability and issues dealing with economics, safety, and ethics.

14:332:447. Concepts in Digital Signal Processing Design (3)
Prerequisite: 14:332:346.
Digital signal processing systems design for applications including speech, audio, image, video, and data signals. Formulation of algorithms and structures for digital signal processing systems. Use of digital signal and systems simulation software.

14:332:448. Capstone Design—Digital Signal Processing (3)
Prerequisite: 14:332:447.
Capstone design experience in digital signal processing systems. Focuses on team-oriented design projects involving practical systems that process speech, image, audio, and discrete-time data signals. Students participate in a design process that incorporates realistic engineering constraints such as manufacturability and issues dealing with economics, safety, and ethics.

14:332:451. Introduction to Parallel and Distributed Programming (3)
Prerequisites: 14:332:331, 351.
Parallel and distributed architectures, fundamentals of parallel / distributed data-structures, algorithims, programming paradigms, introduction to parallel / distributed application development using current technologies.

14:332:452. Introduction to Software Engineering (3)
Prerequisite: 14:332:252.
Introduction to the concepts of software engineering. System planning, software requirements analysis, formal specification, testing, reliability, software maintenance, software cycle analysis and documentation.

14:332:460. Power Electronics (3)
Prerequisite: 14:332:361.
Electric power conversion is the central subject for this course. Emphasis is on basic power electronics devices, rectifier circuits and DC-DC conversion circuits (switch mode power supply) which find widespread applications in electronics systems. DC-AC inverter circuits which are responsible to drive most AC electric motors are also covered. Emerging power sources closely related to power conversion circuits including fuel cell, photovoltaic, and wind power are also introduced.

14:332:461. Pulse Circuits (3)
Prerequisite: 14:332:362. Corequisite: 14:332:463.
RC timing circuits used in waveform generating and shaping circuits.

14:332:462. Capstone Design—Electronic Circuits (3)
Prerequisite: 14:332:362.
Capstone design experience in electronic circuits. Focuses on team-oriented design projects involving circuits used for timing, waveform generation and shaping, logic, and memory. Students participate in a design process that incorporates realistic engineering constraints such as manufacturability and issues dealing with economics, safety, and ethics.

14:332:463. Pulse Circuits Laboratory (1)
Corequisite: 14:332:461.

14:332:464. Signal Integrity in High Speed Digital Circuits (3)
Prerequisite: 14:332:366.
Signal integrity in very-high performance digital circuit is the central subject for this course. Emphasis is on the common physical phenomena that lead to signal degradation in printed circuit board (PCB), multi-chip-modules (MCM), system-on-package (SoP), system-on-chip (SoC), and very-high performance integrated circuits (IC). Circuit signal integrity analysis using simulation tool will be employed.

14:332:465. Physical Electronics (3)
Prerequisite: 14:332:361.
Semiconductor fundamentals, p-n diodes, bipolar transistors, Schottky diodes, JFETs, MESFETs, and MOSFETs.

14:332:466. Optoelectronic Devices (3)
Prerequisites: 14:332:361, 382, 465.
Fiber optical waveguides, lasers, light-emitting diodes, photodetectors, modulators, and system application.

14:332:467. Concepts in Microelectronic Processing (3)
Prerequisite: 14:332:361. Corequisite: 14:332:465.
Overview of microelectronic processing technology, lithography, etching, oxidation, diffusion, implantation and annealing, film deposition, epitaxy growth, metallization, process integration, and simulation.

14:332:468. Capstone Design—Microelectronic Processing (3)
Prerequisite: 14:332:467.
Capstone design experience in microelectronic processing. Focuses on team-oriented design projects involving the fabrication of microelectronic devices. Students participate in a design process that incorporates realistic engineering constraints such as manufacturability and issues dealing with economics, safety, and ethics.

14:332:471. Concepts in Robotics and Computer Vision (3)
Prerequisites: 14:332:252, 345, 346.
Introduction to robotics. Robot arm kinematics and dynamics. Trajectories and control. Sensing and robot programming languages. Low-level vision, edge detection, and segmentation. Illumination strategies, 3-D.

14:332:472. Capstone Design—Robotics and Computer Vision (3)
Prerequisite: 14:332:471.
Capstone design experience in robotics and computer vision. Focuses on team-oriented design projects involving mobile robots to obtain and utilize real-world video data. Students participate in a design process that incorporates realistic engineering constraints such as manufacturability and issues dealing with economics, safety, and ethics.

14:332:474. Introduction to Computer Graphics (3)
Prerequisites: 14:332:231, 252.
Computer display systems, algorithms, and languages for interactive graphics. Vector, curve, and surface generation algorithms. Hidden-line and surface algorithms.

14:332:476. Virtual Reality (3)
Prerequisite: 14:332:252.
Introduction to VR, input / output devices, haptic interfaces, dedicated hardware, world modeling, human factors in VR simulations, applications, the future of VR.

14:332:478. Virtual Reality Laboratory (1)
Corequisite: 14:332:476.

14:332:479. Concepts in VLSI Design (3)
Prerequisites: 14:332:231, 331, 366.
Introductory digital VLSI chip design. CMOS technology, dynamic clocked logic, layout design rules, and analog MOSFET timing analysis.

14:332:480. Capstone Design—VLSI (3)
Prerequisite: 14:332:479.
Capstone design experience in digital VLSI chip design and testing. Focuses on team-oriented design projects involving the implementation of adders, counters, multipliers, memory, and arithmetic logic units. Students participate in a design process that incorporates realistic engineering constraints such as manufacturability and issues dealing with economics, safety, and ethics.

14:332:481. Electromagnetic Waves (3)
Prerequisite: 14:332:382.
Interaction of electromagnetic waves in various media presented, beginning with Maxwell's equations and the constitutive relations. Practical applications in optoelectronics, fiber optics, and communications presented throughout the course.

14:332:491,492. Special Problems: Independent Study (3,3)
Prerequisite: Permission of department.
Individual investigation in some branch of electrical and computer engineering of particular interest to the student. Topic selected for study must be approved and directed by a faculty member.

14:332:493,494. Topics in Electrical and Computer Engineering (3,3)
Topics of current interest and importance in electrical and computer engineering. Typically one topic per term is studied intensively.

14:332:496-497. Co-op Internship in Electrical and Computer Engineering (3,3)
Prerequisite: Permission of department. Graded Pass/No Credit.
Intended to provide a capstone experience to the student's undergraduate studies by integrating prior course work into a working electrical and computer engineering professional environment. Credits granted only for a continuous, six-month, full-time assignment.

GENERAL ENGINEERING 440

14:440:100. Engineering Orientation Lectures (1)
Graded Pass/No Credit.
Brief overview of each of the specific fields of engineering offered as degree programs at the college. Describes the major fields of study, as well as the engineering profession in general.

14:440:107. Methods of Inquiry for Engineers (E3)
Study skills. A system of thinking strategies and critical and analytical thinking skills applicable across the engineering curriculum.

14:440:127. Introduction to Computers for Engineers (3)
Prerequisite: Some prior programming experience is preferred.
Use of the higher-level languages MATLAB and ANSI_C to solve engineering-related problems. Emphasis on problem-solving skills and mathematical tools of importance in engineering.

14:440:191. Honors Introduction to Engineering (1)
Open only to honors program participants.
Covers the same material as 14:440:100 but in a more thorough and demanding fashion.

14:440:221. Engineering Mechanics: Statics (3)
Prerequisites: 01:640:151, 01:750:123.
Classification of systems of forces and their resultants; geometrical and analytical conditions for the equilibrium of force systems; frames and trusses; friction; parabolic and catenary cables; centers of gravity.

14:440:222. Engineering Mechanics: Dynamics (3)
Prerequisites: 14:440:221, 01:640:152, 01:750:124. Corequisite: 01:640:251.
Kinematics of particles and rigid bodies; rectangular, path, and polar descriptions. Relative motion. Kinetics of particles, particle systems, and rigid bodies; equations of motion, principles of work and energy, linear and angular impulse and momentum. Impact.

14:440:291. Honors Engineering Mechanics: Statics (3)
Open only to honors program participants.
Covers the same material as 14:440:221 but in a more thorough and demanding fashion.

14:440:292. Honors Engineering Mechanics: Dynamics (3)
Open only to honors program participants.
Covers the same material as 14:440:222 but in a more thorough and demanding fashion.

14:440:407. Mechanical Properties of Materials (3)
Prerequisites: 14:155:303, 14:180:243, 14:650:291, or equivalent.
Mechanical behavior of metals, ceramics, polymers, and composites. Elastic and plastic behavior. Theories of yielding, brittle fracture, time-dependent behavior, and fatigue. Relation of properties to structure.

INDUSTRIAL ENGINEERING 540

14:540:201. Work Design and Ergonomics (3)
Corequisite: 14:540:202.
Man-machine analysis, motion economy, time study, predetermined time systems, work sampling; introduction to robotics, facilities layout, material handling; introduction to ergonomics and anthropometric, biomechanical, and human-machine interface models.

14:540:202. Work Design and Ergonomics Laboratory (1)
Corequisite: 14:540:201.
Experiments in robotics, time study, work measurement, workplace design and the human-machine interface, facilities layout.

14:540:210. Engineering Probability (3)
Prerequisites: 01:640:152, 14:440:127.
Probability problems in engineering, conditional probability, discrete and continuous distributions, functions of random variables, interval estimates.

14:540:213. Industrial Engineering Laboratory (1)
Introduction to C programming; fundamental data types, flow control, and functions; arrays, pointers, and strings; algorithms and flow charts; application of dynamic memory allocation in simulation of queuing systems.

14:540:303. Manufacturing Processes (3)
Prerequisites: 14:180:243, 14:440:407. Corequisite: 14:540:304.
Properties of materials, phase diagrams, metal forming and cutting. Basic and computerized machine tools. Process planning. Control charts.

14:540:304. Manufacturing Processes Laboratory (1)
Corequisite: 14:540:303.
Experiments on machine tools: lathes, drilling machines, milling machines, and CNC milling machines; robot workplace design and computer control of machine tools.

14:540:305-306. Honors Candidacy Problems (0,0)
Prerequisite: Permission of departmental chairperson. Prerequisite for industrial engineering students who wish to be James J. Slade Scholars.
Extensive reading and study in a particular problem area of industrial engineering under the guidance of a faculty member.

14:540:311. Deterministic Models in Operations Research (3)
Prerequisite: 01:640:244.
Elements of modeling and problem solving. Use of a software package like LINDO, EXCEL to solve real life engineering problems. Linear programming, duality, sensitivity analysis, integer programming, transportation, and assignment problems.

14:540:338. Probability Models in Operations Research (3)
Prerequisite: 14:540:210.
Modeling and decision making under uncertainty, Markov chains, poisson processes, inventory models, queuing systems.

14:540:343. Engineering Economics (3)
Open only to junior and senior engineering students.
Economic decisions involving engineering alternatives; annual cost, present worth, rate of return, and benefit-to-cost; before and after tax replacement economy; organizational financing; break-even charts; unit and minimum-cost public sector studies.

14:540:382. Computer Control of Manufacturing Systems (3)
Corequisite: 14:540:383.
Programmable automation applied to manufacturing. Computer architecture, sensors and automatic data acquisition, computer control of actuators, continuous and discrete control of processes, computer integration, and local areas networks.

14:540:383. Computer Control of Manufacturing Systems Laboratory (1)
Corequisite: 14:540:382.
Use of microcomputers and industrial controllers in controlling machines and processes. Assembly language programming, ladder logic programming, and interfacing controllers to sensors and actuators. Experiments in manufacturing applications.

14:540:384. Simulation Models in Industrial Engineering (3)
Prerequisites: 14:540:210, 338.
Modeling and analysis of industrial and service systems using ARENA, simulation modeling perspectives, discrete event and continuous simulation, simulation languages, statistical aspects of simulation.

14:540:390. Manufacturing Processes and Materials for Engineers (3)
Properties of engineering materials, heat treating, welding, casting, forming, machining, and basic machine tool processes; experimental work, microscopic analysis of metals, chip formation, and tool life.

14:540:399. Design of Engineering Systems I (3)
Recommended pre- or corequisites: 14:540:303, 304.
Design principles, material selection, design for assembly, design for manufacturing, and effect of environmental issues on product design.

14:540:400. Design of Engineering Systems II (3)
Prerequisites: 14:540:303, 304, 382, 384, 399.
Team approach to the redesign of a "real life" product. Alternative engineering plans for improved designs developed and implemented. Both written and oral reports.

14:540:410. Linear Programming (3)
Prerequisite: 14:540:311. Open only to seniors and graduate students in engineering.
Methods and applications of linear programming, the Simplex method, the revised Simplex method, duality, transportation problems, postoptimality analysis, computer programs and solutions, decomposition and industrial application of linear programming.

14:540:421. Industrial Organization and Management (3)
Nature and purpose of organizing, types of organizations, functions of management, human problems in industrial management. Organizational design, staffing, and human resource management.

14:540:433. Quality Engineering and Statistics (3)
Prerequisite: 14:540:210. Corequisite: 14:540:434.
Statistical methods for monitoring and improving product quality and decreasing variation. Factorial experiments, variables and attribute control charts, acceptance sampling, on- and off-line process controls.

14:540:434. Quality Engineering Laboratory (1)
Corequisite: 14:540:433.
Practical application of quality engineering methodologies, statistical software, gage studies, online process control, design of experiments to improve product design, industrial manufacturing processes, and system design.

14:540:453. Production Planning and Control (3)
Prerequisites: 14:540:210, 311.
Coordination of activities of both manufacturing and service systems. Systems design; input and output; planning and scheduling. Decision-making problems employing mathematical techniques of linear programming. Sequencing jobs on machines and line balancing techniques.

14:540:461. Engineering Law (3)
Prerequisite: Permission of department. Open only to seniors and graduate students in engineering.
Legal and ethical aspects of engineering; bids, awards, and negotiated contracts. Liabilities to the public and to employees, contract labor law. Contracts, patents, copyrights, trademarks, and engineering specifications.

14:540:462. Facilities Layout and Materials Handling (3)
Prerequisites: 14:540:201, 303.
Fundamentals of the design, layout, and location of industrial and nonmanufacturing facilities. Selection of machines and material handling equipment and their efficient arrangement. Emphasis on quantitative methods. Warehouse layout. Facility location theory.

14:540:470,471. Industrial Engineering Seminar (1,1)
Broad aspects of current engineering practices. Individual investigation and reports by students. Participation by representatives from industry.

14:540:475. Introduction to Pharmaceutical Manufacturing (3)
Generic issues in pharmaceutical drug development and manufacturing processes, such as regulatory issues including safety requirements (OSHA); the Good Manufacturing Practice (FDA); and others such as validation, quality control, and automation. Sterile and nonsterile manufacturing operations and packaging applications studied. Design and performance analysis of pharmaceutical production systems emphasized using analytical as well as simulation techniques. Case studies emphasized.

14:540:484. Design of a Manufacturing Enterprise (3)
Open only to senior industrial engineering majors.
Senior-level capstone course. Students in small groups select product(s) to be manufactured and design and justify the enterprise.

14:540:485. Manufacturing Information Systems (3)
Design of information systems for integrated manufacturing. Modeling, specification, and implementation of factory information systems. Relational database model and structured query language. Methods of automatic data acquisition and integration of factory floor information with factory host database for production planning and control.

14:540:486. Automated Manufacturing Systems (3)
Corequisite: 14:540:487.
Introduction to computer-aided design and computer-aided manufacturing (CAD/CAM), numerical control, hardware and programming, robotics hardware and programming, and machine vision with applications in manufacturing.

14:540:487. Automated Manufacturing Systems Laboratory (1)
Corequisite: 14:540:486.
Use of CAD/CAM equipment to design and manufacture discrete parts. Experimentation with robotics with applications in manufacturing. Use of machine vision in manufacturing.

14:540:491,492. Special Problems (BA,BA)
Studies in phases of industrial engineering of special interest.

14:540:496-497. Co-op Internship in Industrial Engineering (3,3)
Prerequisite: Permission of department. Graded Pass/No Credit.
Intended to provide a capstone experience to the student's undergraduate studies by integrating prior course work into a working industrial engineering professional environment. Credits earned for the educational benefits of the experience and granted only for a continuous, six-month, full-time assignment.

MECHANICAL AND AEROSPACE ENGINEERING 650

14:650:215. Introduction to Computer-Aided Drafting and Machining (1)
Personal-computer-aided drafting, geometric construction techniques, orthographic projections, auxiliary views, sectional views, oblique and isometric views, library symbols, 3-D modeling and viewing.

14:650:231. Mechanical Engineering Computational Analysis and Design (3)
Prerequisite: 14:440:127. Open only to mechanical engineering majors.
Computational methods used in modeling mechanical engineering systems. Design project using the computer to judge engineering alternatives.

14:650:291. Introduction to Mechanics of Materials (3)
Prerequisite: 14:440:221. Corequisite: 01:640:244 or 251.
Stress and strain in elastic solids such as shafts and beams. Combined stresses; statically indeterminate beams.

14:650:312. Fluid Mechanics (3)
Prerequisite: 01:640:244.
Control volume concepts of mass, momentum, and energy transport. Hydrostatics, Euler's equations, potential flow, Navier Stokes equations, turbulence, and boundary layer theory.

14:650:342. Design of Mechanical Components (3)
Prerequisites: 14:650:291, 14:440:222.
Design philosophy; stress and deflection analysis; energy methods; theories of failure; fatigue; bearings; design of such mechanical elements as springs, weldments, and gears.

14:650:349. Mechanical Engineering Measurements Laboratory (1)
Corequisite: 14:650:350.
Laboratory experience in use of instrumentation.

14:650:350. Mechanical Engineering Measurements (3)
Pre- or corequisite: 14:332:373. Corequisite: 14:650:349.
Theory of instrumentation, selection, calibration, use of instruments. Error analysis. Sensors, signal conditioners, data acquisition, and processing systems. Design project.

14:650:351. Thermodynamics (3)
Prerequisites: 01:750:228, 01:640:244.
Fundamental concepts, First Law, reversibility, Second Law, entropy, properties of fluids and perfect gases, processes, cycles, general equations, and mixtures.

14:650:388. Computer-Aided Design in Mechanical Engineering (3)
Lec. 2 hrs., lab. 3 hrs. Prerequisites: 14:650:215, 231. Pre- or corequisite: 14:650:342.
Computer-aided design (CAD) applications of analysis, synthesis, and design. Automated drafting and higher-order programming languages. Development of general-purpose functions, components, and command files. Hands-on experience on CAD stations.

14:650:401. Mechanical Control Systems (3)
Prerequisites: 01:640:244, 14:650:231. Pre- or corequisite: 14:332:373.
Dynamic analysis of mechanical, electromechanical, thermal, hydraulic, and pneumatic feedback control systems.

14:650:431,432. Mechanical Engineering Laboratory I,II (1,1)
Lab. 3 hrs. Prerequisites: 14:650:312, 349, 350, 351.
Comprehensive experiments in fluid dynamics, acoustics, heat transfer, power systems, and dynamic mechanical systems. Preparation of test procedure, data analysis, presentation of results and conclusions.

14:650:433. Aerospace Engineering Laboratory (1)
Lab. 3 hrs. Prerequisites: 14:650:312, 349, 350. Corequisite: 14:650:481. Open only to students enrolled in aerospace option.
Comprehensive experiments in fluid dynamics, heat transfer, acoustics, power system, and dynamic mechanical systems. Preparation of test procedure, data analysis, and presentation of reports and conclusion.

14:650:434. Biomechanics Engineering Laboratory (1)
Lab. 3 hrs. Prerequisites: 14:650:312, 342, 349, 350, 351. Open only to students enrolled in the biomechanical option.
Course gives students the opportunity to test theoretical knowledge of biomechanics, biofluids, and bioheat transfer with experiments, and to deliver a technical presentation on laboratory results to their classmates in a formal manner.

14:650:443. Vibrations and Controls (3)
Prerequisite: 14:650:342.
Mechanical vibration, vibration isolation, and critical speeds. Balancing of rotating and reciprocating machinery. Feedback control systems.

14:650:447. Probabilistic Models in Mechanical and Aerospace Systems (3)
Prerequisite: 14:332:321 or 14:540:210 or 01:640:477 or 01:960:379.
Probabilistic concepts and modeling in mechanical design and analysis. Reliability of mechanical systems. Introduction to turbulence modeling. Introduction to computational aspects. Design project.

14:650:449. Introduction to Mechanics of Composite Materials (3)
Prerequisite: 14:650:291.
Particle and fiber-reinforced composites, stress-strain relations of anisotropic materials, tensor transformation, derivation of effective moduli of composites from those of the constituents, cross-ply / angle-ply laminates, symmetric / antisymmetric laminates, and engineering applications.

14:650:451. Vehicle Dynamics (3)
Performance: 14:440:222. Corequisite: 14:650:312.
Performance, handling, and ride of ground vehicles. Tires, slip and traction, braking, aerodynamic effects, and steering.

14:650:455. Design of Mechanisms (3)
Prerequisite: 14:440:222.
Motion analysis. Centrodes, analytical representation of plane motion, Euler-Savary equation, Bobillier's theorem. Linkages and cams. Two- and three-position syntheses, Freudenstein's method, and optimal methods. Design project.

14:650:458. Aerospace Structures (3)
Prerequisite: 14:650:291.
Load factors, stresses and deformations in thin-walled members, shear center, torsion of single-cell and multicell structures, analysis of aircraft components.

14:650:459. Aerospace Propulsion (3)
Prerequisites: 14:650:312, 351.
Theory of air-breathing and rocket engines. Propulsion performance parameters and mission requirements. Operation of diffusers, combustors, rockets, and jet engines. Design project.

14:650:460. Aerodynamics (3)
Prerequisites: 14:650:312, 351.
Circulation and lift, Kutta-Joukowski theorem, thin airfoil theory, finite wing theory, induced drag, static and dynamic longitudinal and lateral stability and control. Design project.

14:650:461. Internal Combustion Engines (3)
Prerequisite: 14:650:351.
Thorough analysis of reciprocating engines and gas turbine. Fuel characteristics. Pollutant formation and control. Combustion and lubrication.

14:650:462. Power Plants (3)
Prerequisite: 14:650:351.
Current theory and practice of cycles and design of equipment for the generation of power in central stations and industrial power plants. Design projects.

14:650:463. Compressible Fluid Dynamics (3)
Prerequisites: 14:650:312, 351.
Integral form of conservation laws. One dimensional compressible flow with friction and heat. Normal and oblique shock waves. Prandtl-Meyer expansion. Differential form of conservation laws. Unsteady wave motion. 2-D subsonic, supersonic, and hypersonic flow.

14:650:465. Orbital Mechanics (3)
Open only to senior mechanical engineering majors.
Rocket principle and performance; staging; trajectories in central force field; orbit transfer; reentry dynamics and heating.

14:650:467-468. Engineering Projects Laboratory I,II (1.5,1.5)
Open only to senior mechanical engineering majors.
Application of both analytical and experimental skills to an engineering research project. Individual work with weekly consultations with a faculty adviser.

14:650:471. Introduction to Musculoskeletal Mechanics (3)
Open only to junior or senior engineering majors.
Introduction to motion-actuating, force-generating, and load-supporting mechanisms in musculoskeletal system, as explained from basic engineering principles. Elucidation of function-structure relationships from both ultrastructural and mechanical analyses. Experimental and analytical approaches to solve realistic orthopedic and recreational problems.

14:650:472. Biofluid Mechanics (3)
Prerequisite: 14:650:312 or 14:125:303 or 14:155:303.
Basic introduction to fluid mechanics and heat and mass transport in biological systems. Emphasis on the study of models and applications of biofluid flows in physiological processes occurring in human blood circulation and underlying physical mechanisms from an engineering perspective, and on chemical and physical transport processes with applications toward the development of drug delivery systems, bioartificial organs, and tissue engineering.

14:650:473. Design of Assistive Devices (3)
Open only to junior or senior engineering majors.
Overview of assistive devises; mechanism design; actuator, sensor, and computer technology; human-machine interface and control; human factors; clinical considerations.

14:650:474. Solar Thermal Energy Collection and Storage (3)
Open only to senior engineering or physical sciences majors.
Introduction to the design and theory of systems that employ solar thermal energy as a replacement for fossil fuel energy used in buildings and homes. Design project.

14:650:477. Environmental Control of Buildings (3)
Prerequisite: 14:650:351. Pre- or corequisite: 14:650:481.
Methods of controlling temperature and humidity in buildings and homes. Load calculations. Use of DOE-2.1 or other computer simulation in HVAC design project.

14:650:478. Mechanical Engineering Aspects of Electronic Packaging (3)
Corequisite: 14:650:481.
Packaging of integrated circuits, printed circuit boards, and electronic equipment from consumer electronics and personal computers to large mainframe computers and telephone switching systems. Thermal analysis and design, stress analysis, shock and vibration, electrical analysis and design, materials, reliability, and failure mode analysis.

14:650:481. Heat Transfer (3)
Prerequisites: 14:650:312, 351; 01:640:421.
Theory of heat transfer by steady and transient conduction. Heat transfer by radiation. Convection of heat by fluid motion in external and internal flow. Combined heat transfer calculations.

14:650:485. Topics in Mechanical Engineering (3)
Open only to senior mechanical engineering majors.
One or two topics of current importance and interest studied intensively. Topic examples: acoustics, combustion, energy conversion, refrigeration, urban engineering, and propulsion.

14:650:486-487. Design of Mechanical Systems I,II (3,3)
Lec. 2 hrs., lab. 3 hrs. Open only to senior mechanical engineering majors.
Allows students to use knowledge acquired in the curriculum on solving open-ended, multicriteria engineering problems. Emphasis placed on teamwork, project management, conceptualization, detailed design, analysis, and manufacturing.

14:650:491,492. Special Problems (3,3)
Prerequisite: Permission of department.
Studies of special interest in aspects of mechanical and aerospace engineering.

14:650:495. Internship in Mechanical and Aerospace Engineering (3)
Prerequisite: Permission of department; open to MAE students only. Graded Pass/No Credit.
Provides students with opportunity to practice and / or apply knowledge and skills in various mechanical engineering professional environments.

14:650:496-497. Co-op Internship in Mechanical and Aerospace Engineering (3,3)
Prerequisite: Permission of department. Graded Pass/No Credit.
Intended to provide a capstone experience to the student's undergraduate studies by integrating prior course work into a working mechanical and aerospace engineering professional environment. Credits earned for the educational benefits of the experience and granted only for a continuous, six-month, full-time assignment.

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