General Information

The mission of the School of Engineering and Applied Science is to achieve international prominence as a student-focused school of engineering and applied science that educates men and women to be leaders in technology and society and that contributes to the well-being of our citizens through the creation and transfer of knowledge.

Engineers and applied scientists use the knowledge of mathematics, the sciences, and computer science to design and build physical devices, processes, structures, and systems that satisfy society's growing dependence on technology for health, safety, and prosperity. Today's graduates will spend their careers in an evolving global market filled with unprecedented challenges and opportunities. The School of Engineering and Applied Science therefore seeks to prepare and motivate its students to excel in their chosen endeavors by instilling in them the necessary attributes of knowledge, creativity, inquisitiveness, leadership, confidence, awareness, and ethical values.

Graduates must have a firm understanding of the fundamental principles of their discipline, the knowledge to design a system, component, or process to meet desired ends, and the ability to adapt innovative, ethical solutions to the problems of society. Because engineering and applied science graduates enjoy a broad range of career opportunities, it is also important that they understand research methods, have the ability to integrate broad interdisciplinary considerations, and have the confidence to pursue new professional activities. They must be capable of working in teams and leading them. In addition, they must be skilled in oral and written communication and in the use of computer tools and laboratory instruments appropriate to the discipline. Above all, they should acquire self-study habits in order to enjoy a rich, life-long learning experience.

While most graduates move directly into professional careers in industry and government, many others seek further academic preparation for careers as Ph.D. researchers or university faculty in engineering and applied science. Some use the degree to prepare for graduate programs in other areas, such as business, law, and medicine. The Office of the Dean welcomes inquiries, via phone or letter, from prospective applicants who have questions about career possibilities, program options, high school preparation, and other concerns.

Engineering at Virginia

The University of Virginia takes pride in its continued development of modern engineering education and research. For over one hundred fifty years, the University has offered regular study in engineering, coinciding with the industrial development of the nation and paralleling the rise of the engineering profession itself.

The infusion of applied science into the learned professions was anticipated in the founding of the University. As early as 1825, the Rector and Visitors formally indicated that instruction in military and civil architecture would be a part of the education program of the University. Such courses were offered starting in 1827. Notable members of the early engineering staff were Charles Bonycastle, trained in military engineering in England, and William Barton Rogers, later co-founder of the Massachusetts Institute of Technology. Engineering instruction was not sought widely by young men in the predominantly agricultural south, however, and by 1850, it was announced that the engineering program would be discontinued.

A new and more successful beginning was made in 1865 under the direction of Professor Charles Scott Venable, and by 1869 the University awarded its first degrees in engineering. Instruction was offered in civil and mining engineering until the 1881-1882 session, when engineering became a professional department. William Mynn Thornton became the first dean of Engineering in 1905. Under his leadership, three new degree programs were added: mechanical engineering in 1891, electrical engineering in 1897, and chemical engineering in 1908.

Between World War I and World War II, the engineering curricula were revised and strengthened to provide a broader program of studies, including the humanities. During both wars the school offered engineering instruction to members of the armed forces, and ROTC programs for the Navy, Army, and Air Force were introduced during and after World War II.

Reorganization following World War II led again to an extensive revision of all curricula and to the graduate studies now offered. In 1955, two new branches of engineering study were recognized by degrees: aeronautical and nuclear engineering. In the same year, the first doctoral programs were instituted in chemical engineering and in engineering physics.

In 1962, the name of the school was changed to the School of Engineering and Applied Science in anticipation of the establishment of the Department of Materials Science (1963), the Department of Applied Mathematics and Computer Science (1964), and the Department of Biomedical Engineering (1967). The Department of Systems Engineering was established in 1975, and in 1984, applied mathematics and computer science became separate departments. Further reorganization has led to the present school academic structure with its Departments of Biomedical Engineering; Chemical Engineering; Civil Engineering; Computer Science; Electrical and Computer Engineering; Materials Science and Engineering; Mechanical and Aerospace Engineering; Systems and Information Engineering; and Science, Technology, and Society.

The undergraduate program in engineering science and the graduate program in engineering physics are administered by the Department of Materials Science and Engineering.

Address

School of Engineering and Applied Science
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University of Virginia
P.O. Box 400233
Charlottesville, VA 22904-4233
(434) 924-3164
www.seas.virginia.edu

Facilities and Services

The School of Engineering and Applied Science is located in a complex of buildings, the main one being Thornton Hall, named after the first dean of engineering. Thornton Hall houses the school's administrative offices, the Departments of Civil Engineering, Electrical and Computer Engineering, and Science, Technology, and Society; and assorted research laboratories. South of Thornton Hall is Olsson Hall, which houses the Departments of Computer Science and Systems Engineering. Adjacent to these buildings are three buildings housing the Departments of Mechanical and Aerospace Engineering, Materials Science and Engineering, and Chemical Engineering. The Department of Biomedical Engineering is located in MR-5, which is part of the Health Sciences Center. The Aerospace Research Laboratory is located on Mount Jefferson.

The Charles L. Brown Science and Engineering Library is located in Clark Hall. It includes books and bound journals, current scientific periodicals and technical serials, and files of graduate and undergraduate theses and dissertations. Reference service is available to all parts of the University, to other educational institutions, and to industry by the library staff and, occasionally, by others on the professional staff of the School of Engineering and Applied Science. Close cooperation is maintained with the other University libraries, whose total resources of more than four million volumes are open to engineering students and faculty members.

The Center for Diversity in Engineering, established in the School of Engineering and Applied Science in 1986, is available to help our diverse student body by providing academic support, motivational activities, and financial assistance. The office provides counseling and other special services for both undergraduate and graduate students.

The Office of Engineering Career Development is available to help engineering students...
establish their career goals and develop strategies to achieve those objectives. The office provides resource material on career fields, job search strategies, interviewing techniques, and employment opportunities. It also coordinates on-Grounds interviews in conjunction with University Career Services, manages the Co-operative Education Program, and develops a broad range of summer job opportunities.

Computers
The School of Engineering and Applied Science (SEAS), the Department of Information Technology and Communication (ITC), and the University Library provide a wide range of modern facilities and services to support student computing. Students use the facilities primarily for coursework, projects, capstone design, and thesis research.

SEAS and the University invest heavily in computer labs and multimedia facilities for student use. Nearly all students bring their own computers, although there is no computer ownership requirement. All dormitory rooms have been wired with network connections. For further information on personally owned machines, please see “Computing and Communications Guide for Students” available at www.itc.virginia.edu/pubs/docs/Handbook.

A high-speed network (hardwired and wireless) provides access to all areas of the University, as well as the Internet, while supporting public computing labs, which contain over 700 networked PCs with fully configured software. The labs, available to all students, are located throughout the Engineering School and other on-Grounds locations. Public labs with access to Linux & UNIX supercomputers are also available.

These facilities are open 24 hours a day, seven days a week. Many are staffed with student consultants during the afternoons and evenings, while the help desk provides support by telephone (434-924-3731), e-mail (consult@virginia.edu), and in person (Dynamics Building) as well provided. In addition to this technical support, ITC offers numerous training workshops and short courses. Other centralized services, including e-mail, disk storage and web publishing are provided to all students, High speed laser printing in the public labs is a pay-for-print system.

Some classrooms at the Engineering School are technology-equipped and have computers at students’ desks. These computers permit students to learn by working a problem in the classroom, individually or as part of a team, and facilitate interaction between faculty and students. There are over 100 computers located in classrooms of this type throughout the University, in addition to the training rooms, media labs, and other centers containing specialized equipment and services.

SEAS also maintains computer facilities, teaching labs, and design labs specifically for engineering and applied science students. These departmental labs contain over 250 PCs and Macs, and a number of UNIX workstations and X-terminals. They provide access to discipline-specific software, high-end workstations, and a variety of peripheral devices. Specialized studios, such as our Internet Teaching Lab, allow hands-on experience with networking hardware, software, and related leading-edge technologies.

For more information about computing facilities and services, please visit www.seas.virginia.edu/admin/inftech.php.

Research and Development
The School of Engineering and Applied Science currently conducts a thriving and diversified $35 million annual research program under the sponsorship of various federal agencies and private companies. Over 450 active research projects support faculty, professional researchers, and students. These projects span a variety of engineering disciplines and include biotechnology and nanotechnology, microelectronics, advanced materials, biomedical engineering, information technology and environmental engineering. These programs provide an excellent opportunity for undergraduate and graduate training.

Under the School of Engineering and Applied Science, research has led to the creation of special laboratories in areas of particular interest, including the Advanced Materials and Structures Laboratory; Aerospace Research Laboratory; Applied Electrophysics Laboratory; Injury Prevention Program; Center for Bioprocess Development; Communications, Control, and Signal Processing Laboratory; Composite Mechanics Laboratory; Center for Advanced Computational Technology; Small Center for Computer Aided Engineering; Center for Electrochemical Science and Engineering; Center for High Temperature Composites; Intelligent Processing of Materials Laboratory; Internet Technology Innovation Center; Legion Meta-Computing Project; Light Aerospace Alloy and Structure Technology Program; Light Metals Center; Center for Magnetic Bearings; Mathematical-Computational Modeling Laboratory; Next-Generation Real-Time Systems Laboratory; Institute for Technology in Medicine; Networking Multimedia; Institute for Parallel Computation; Center for Risk Management of Engineering Systems; Rotating Machinery and Controls Industrial Program; Center for Semiconductors Integrated Systems; Center for Survivable Information Systems; Center for Transportation Studies; Center for Engineering of Wound Prevention and Repair; Center for Genetic Engineering Targeting Vascular Disease; Institute for Microelectronics; the Virginia Laboratory for Engineering and Automated Design; and the Center for Applied Biomechanics.

Activities and Organizations
Engineering Council The Engineering Council serves as the student government within the School of Engineering and Applied Science. It is headed by a president, vice president, treasurer, and secretary and has representatives elected from each class and department. Members from Student Council, the Judiciary Committee, and the Executive Committee also have seats on the council.

The Engineering Council primarily serves as a liaison between students and faculty, coordinates student activities within the school, advises on matters of curricula, and promotes social activities.

Student Branches of Professional Societies Represented in the school are the American Institute of Aeronautics and Astronautics (AIAA), the American Institute of Chemical Engineers (AIChE), Alpha Chi Sigma (AXE), the American Society of Civil Engineers (ASCE), the Institute of Electrical and Electronics Engineers (IEEE), the American Society for Engineering Management (ASEM), the American Society of Heating Refrigeration and Air Conditioning Engineering (ASHRAE), the American Society of Mechanical Engineers (ASME), the Association for Computing Machinery (ACM), the Association for Computing Machinery for Women (ACM-W), and the Computing Research Association (CRA).

Tau Beta Pi, the national engineering honorary fraternity, recognizes high scholastic achievement and honorable character in engineering students. Other honorary fraternities include Chi Epsilon (civil engineering), Eta Kappa Nu (electrical engineering), Omega Rho (systems engineering), Pi Tau Sigma (mechanical engineering) and Sigma Gamma Tau (aerospace engineering).

Theta Tau Professional Engineering Fraternity, founded in 1904, is the University’s only national, professional, engineering fraternity. Since its establishment at the University of Virginia in 1922, Theta Tau has been bringing its members closer together through social service and professional activities. Theta Tau is a coed fraternity that strives for a diverse and enthusiastic membership.

Trigon Engineering Society takes pride in its members being well-rounded engineers. Trigon sponsors numerous service projects each semester, takes part in intramural sports, and sponsors many social events. Membership in Trigon is open to any undergraduate in the Engineering School.

The Omicron Xi Engineering Society, founded on January 21, 1987, is a service and social organization dedicated to promoting brotherhood between the engineering disciplines and performing good works within the school, the University, and the community. The society builds upon the University tradition of meaningful social interaction, sponsoring events for the University community in addition to a variety of intra-society affairs.

The Society of Women Engineers is a non-profit, educational, professional service organization dedicated to communicating the need for women engineers and encouraging young women to consider an engineering education.

The National Society of Black Engineer’s (NSBE) mission is to increase the number of culturally responsible African-
American engineers who excel academically, succeed professionally and positively impact the community. UVA’s Chapter is recognized nationally for its accomplishments which include an academic excellence program, tutorial programs, group-study sessions, technical seminars and workshops lead by professional engineers, and very active outreach programs. NSBE’s Pre-College Initiative Program (PCI) is highly dedicated to encouraging and mentoring area youth in pursuit of higher education. Nationally, the NSBE organization has a communications network, two national magazines, a host of professional newsletters, and sponsors annual national conventions, conferences, and career fairs.

The Society of Hispanic Professional Engineers (SHPE) is the leading social-technical organization whose function is to achieve educational excellence, economic opportunity and social equity for Hispanics in engineering, math, and science. The SHPE chapter at UVA provides a network for Hispanic students to participate in regional and national conferences, technical seminars, and career fairs. SHPE members visit high schools and invite students on grounds to experience academic and social life at UVA in an effort to encourage them to pursue a higher education in engineering, math, or science.

Honors, Awards, and Scholarships

The Rodman Scholars Program, named for Walter S. Rodman, dean of the School of Engineering and Applied Science from 1933 to 1946, is for talented, well-rounded students with a strong interest in the school’s curricula. Rodman scholars are selected from the entering class on the basis of superior academic credentials and indications that the student can benefit from, and contribute to, the program; participation is by invitation only. Several courses have been set up for Rodman scholars, from physics, humanities, and design in the first year, to a special seminar in conjunction with the Rodman Eminent Scholars Series later in the curriculum. During their first year, Rodman scholars live in a selected dormitory with Echols scholars from the College of Arts and Sciences.

The Virginia Engineering Outstanding Student Award is made annually and given to a current SEAS undergraduate student who, has demonstrated outstanding academic performance, leadership, and service.

The Mac Wade Award is presented in memory of Freeman McMillan Wade, Class of 1952, who was killed in action in the Korean War. It is awarded annually to the group, faculty member, or student who has rendered outstanding service to the School of Engineering and Applied Science.

Scholarships There are no scholarships for which newly admitted students can apply. Students who qualify for financial aid are automatically considered for certain scholarships as part of their aid package.

A limited number of endowed merit-based scholarships are awarded to incoming Rodman scholars. Selections are made prior to the offer of admission to the University, and the award offers are extended at the time students are invited to join the Rodman Scholars Program. Prospective students do not apply for either the program or the scholarship.

Regardless of financial need status, enrolled students who can demonstrate satisfactory progress toward their degrees have the opportunity to apply for a number of industrial or endowed scholarships. These have specific restrictions, such as GPA, major field, academic level, intended area of employment, geographic location, and demonstrated leadership. The scholarships are publicized to the student body in early spring for submission to the committee after the spring recess, usually around the third week of March.

Dean’s List Full-time students who demonstrate academic excellence while taking a minimum of 15 credits of graded course work are eligible for the Dean’s List of Distinguished Students at the end of each semester. Courses taken on a CR/NC basis may not be counted toward the 15-credit minimum. A current minimum grade point average of 3.400 is necessary to be eligible for the dean’s list. Any student receiving an F, NC, or NG during the semester is not eligible to be on the dean’s list.

Intermediate Honors A certificate of intermediate honors is awarded to the top twenty percent of those students in the School of Engineering and Applied Science who enter the University directly from high school or preparatory school and earn at least 60 credits of course work in their first four regular semesters. The computation is based upon the cumulative grade point average at the end of the fourth semester. No more than twelve of the 60 required credits may be earned on a CR/NC or S/U basis. Advanced placement and transfer credits do not count toward the required credits.

Theses and Commencement Honors Students who have demonstrated high academic achievement in pursuit of their bachelor’s degree are eligible for commencement honors.

Diplomas inscribed “with distinction” are awarded to graduates who have earned a cumulative grade point average of at least 3.400.

Diplomas inscribed “with high distinction” are awarded to graduates who have earned a cumulative grade point average of at least 3.600.

Diplomas inscribed “with highest distinction” are awarded to graduates who have earned a cumulative grade point average of at least 3.800.

All students in the School of Engineering and Applied Science, whether or not they satisfy the requirements for commencement honors, are required to complete a senior thesis and take STS 401 and 402, the six-credit thesis course.

Degree Programs

Admission Inquiries regarding admission to the School of Engineering and Applied Science should be addressed to the Dean of Admissions, University of Virginia, P.O. Box 400160, Charlottesville, VA 22904-4160 or by e-mail at undergrad-admission@virginia.edu.

Requirements The first and second years of study at the engineering school are spent gaining a solid background in the sciences and mathematics. The student takes courses in chemistry, physics, computer programming, mathematics, and various courses in engineering science, as well as social science and humanities courses.

During the first year, students declare a major in one of ten programs in engineering or applied science. The last three years are spent specializing in a chosen area and taking further courses in the general field of engineering. Successful graduates can expect a wide range of career opportunities in engineering, business, law, and medicine.

In the event a particular major is oversubscribed, admission may be limited. Admission to such programs is based on space availability, academic performance, a personal essay, and extra-curricular activities. At present, systems engineering, biomedical engineering, computer engineering, and computer science are limited-admission programs.

Bachelor’s-Master’s Program Outstanding students may be admitted to the combined Bachelor’s-Master’s Program at the end of their third year. After admission, students take a mixture of graduate and undergraduate courses and work on a sponsored research project in the summer and academic year. This program encourages the best and brightest students to enter into research in the various engineering and applied science fields.

Graduate Degrees are offered in all of the school’s areas of specialization. For information on these programs and inquiries regarding admission, contact the Office of Graduate Programs, School of Engineering and Applied Science, P.O. Box 400242, Charlottesville, VA 22904-0242.

Admission As a Special Student In certain circumstances, individuals may be permitted to enroll in a maximum of two School of Engineering and Applied Science courses through Continuing Education.

Special students who wish to become degree candidates must apply through the University Office of Admission for undergraduate admission or through the School of Engineering and Applied Science for graduate admission.

Advisory System Faculty members and upper class students in the School of Engineering and Applied Science aid entering students in the transition to college life and in furthering their academic and career interests. Each first-year student consults with his or her faculty advisor about course and major selection, and other academic requirements.

Toward the end of the second semester, the student selects a major field of engineer-
The petitioner will be notified by letter of the action taken by the Committee on Rules and Courses.

Course Load

Normal: The normal undergraduate course load is 15-18 graded credits, unless the student is on probation, in which case a course load of 12 to 15 credits is recommended. Any program of study requires the advisor's approval.

Overload: An overload of 19 or 20 credits may be approved by a faculty advisor for a student who has achieved a grade point average of 3.000 or higher.

A proposed overload amounting to 21 or more credits must also be reviewed and approved by the Office of the Dean. Demonstrated superior academic performance and clear career planning will be the major criteria for approval, including a grade point average of 3.600 or higher.

Underload: A semester load of fewer than 15 credits (not counting CR/NC courses) must be approved by the advisor and the dean's office.

Attendance: Regular attendance in classes is a vital part of the educational process. At the University of Virginia, each student is expected to attend all lectures, laboratories, quizzes, and practical exercises, subject to absence penalties specified by the instructor.

Absences traditionally excused are those that occur because of illness or death in a student's family, important religious holidays, or authorized University activities, such as field trips or University-sponsored events.

Students who anticipate absence for cause should obtain permission from the instructor in advance of the absence; unforeseen absences resulting from sickness or other circumstances considered to be emergencies may be excused by the instructor, and arrangements may be made with the instructor to complete the assignments missed.

The term of the first suspension is one year. A second suspension is final and the student is not allowed to return.

Appeal of Academic Regulations: In circumstances not covered by specific regulations, or in difficulties that cannot be resolved by the dean or the instructor concerned, a student has the right to petition the Committee on Rules and Courses for redress of his or her grievance. The action by the committee on the petition is final inasmuch as it acts for the full faculty in these matters.

The petition must be signed and dated by the student and submitted to the Office of the Assistant Dean for undergraduate programs. The petition must contain:

1. the name of the student's academic department (except first-year students);
2. a clear and concise statement of the variance requested;
3. adequate supporting evidence to enable the committee to render fair and proper judgment;
4. a signed acknowledgement by the student's academic advisor.

Dropping a Course: With the approval of the student's advisor, a student may drop and void registration in a course any time up to the official drop date, unless such action reduces the number of graded credits for which the student is registered to fewer than 15. Permission to take less than 15 credits a semester must be obtained from the Office of the Dean.

Withdrawing from a Course: After the drop date, a student must petition the Office of the Dean to withdraw from a course. Students will be granted one withdrawal for personal reasons. Subsequent requests to withdraw will be granted only when there are extenuating circumstances beyond a student's control. A student who is permitted to withdraw from a particular course will receive a W for the course. Petitions must be signed by the course instructor and faculty advisor, and approved by the Office of the Dean.

Extension of a Course: After the withdrawal date (two weeks before the end of the semester), a student can no longer withdraw from a course. If there are extenuating circumstances, and if it is feasible, a student may petition for a course extension. If approved, all work must be completed by the end of the next academic term and preferably before the start of the next term. Feasibility is determined after a review of the outstanding work, the availability of the instructor, the accessibility of laboratory facilities, and other practical considerations.

Enforced Withdrawal From a Course: With the approval of the dean, faculty may enforce withdrawal with a grade of F as a penalty for habitual delinquency in class, habitual idleness, or any other fault that prevents the student from fulfilling the purposes implied by registration in the University.

Enforced withdrawal may also be imposed for failure to take the physical examination required of all entering students, or for failure to obtain medical leave or medical withdrawal from the Department of Student Health in the case of repeated or prolonged absence from class as a result of illness.

Laboratory Courses: To register for or attend any laboratory course, a student must be registered or have credit for the associated lecture course. If the associated courses are taken concurrently and the lecture course is dropped, the laboratory course may be continued for credit only with permission of the laboratory instructor or the dean.

Completion of Prerequisite Courses: The sequences of required courses leading to various engineering degrees are carefully arranged to ensure that a student who enters any course may be expected to receive maximum benefit from the course. A student who failed a course may not normally enroll for any course that lists the failed course as a prerequisite before satisfactorily completing that course. Under unusual circumstances, exceptions may be made. Exceptions require written permission from the instructor of the failed course, all instructors of the subsequent course, and approval by the dean.
Students are expected to consult with their advisor to arrive at an acceptable overall program of electives. All electives should be chosen to meet an objective rather than at random. This program, signed by the department head or advisor, must be filed in the dean’s office.

Absence From Examinations Unexcused absence from an examination incurs an automatic failure in the course with a grade of F. Absence from a final examination for any course offered in the School of Engineering and Applied Science may be excused only by the dean, and then only when accompanied by evidence of arrangement with the instructor for a deferred examination, to be taken within ten days after the regular examination. An emergency that justifies extension of this period will be considered only when supported by satisfactory documentation submitted immediately after the period of emergency. After the ten day period, or its extension if granted by the dean, the temporary grade of IN (incomplete) will officially become a grade of F unless the deferred examination has been completed. Absences are excused only for sickness on the day of the examination or for other providential cause acceptable to the dean. An excused absence may be absolved by taking a special examination at a time mutually satisfactory to the instructor and the student concerned. Special examinations are not granted for reasons other than those stated above.

Degree Requirements To qualify for a baccalaureate degree, a student must have received credit for all required and elective courses included in their program. In addition, the student must have maintained a cumulative grade point average of at least 2.000. Students must complete degree applications in September of their final year.

Regular programs leading to the various degrees are described under the departmental listings. The student should become familiar with the requirements of his or her chosen area of study. Students are expected to declare a major area of study at the end of the second semester but may change majors at a later date.

Course Enrollment Except for students in extended programs or for special arrangements approved by the dean, each student in the School of Engineering and Applied Science must enroll for all courses required by the curriculum of the department in which he or she is enrolled. Substitutions of courses completed elsewhere by students entering with advanced standing must be approved by the dean (in consultation with the departmental faculty concerned when necessary). Students making normal progress toward their degree may graduate under the curriculum in force at the time they entered the school. However, because curricula change to keep pace with evolving technologies and new disciplines, students may be required to substitute courses that the faculty designates as equivalent.

Each student is responsible for the selection of his or her own program, the fulfillment of prerequisites, and the scheduling of all courses required by his or her curriculum. The dean and faculty will assist, but the duty of enrolling in and completing the full degree requirements rests primarily with the student.

Accuracy of Students’ Records It is the student’s responsibility to check the accuracy of his or her enrollment records each semester and to call any error to the attention of the instructor and assistant dean for undergraduate programs. After one semester has lapsed, the student’s record is considered permanent.

Residence Requirements A recipient of a degree in engineering or applied science must have been in residence for two academic years in this University, and registered in the School of Engineering and Applied Science during the semester in which he or she receives a degree.

ROTC Programs The regular curricula can be supplemented to include Air, Military, or Naval Science courses. Depending on the ROTC branch and degree program, such a curriculum may take more than eight semesters to complete.

Minors The School of Engineering and Applied Science offers minors in aerospace engineering; applied mathematics; biomedical engineering; chemical engineering; civil engineering; computer science; electrical engineering; engineering business; materials science and engineering; mechanical engineering; systems engineering; the history of science and technology; and technology and the environment. Minors in specific engineering disciplines are described below in the appropriate department listing; interdisciplinary minors are described in the Department of Science, Technology, and Society listing. Minors in these areas, or in areas offered by other academic units of the University, are not required for any of the Engineering degree programs.

Major/Minor in the College Engineering students may earn a major or a minor in the College of Arts and Sciences. Prior admission must be obtained from the chair or director of undergraduate programs of the College or department in which a student is seeking the major or minor.

In pursuing the above, students will not receive two degrees from the University. They receive a B.S. from Engineering and a major (or minor) appearing as degree information on the official transcript.

Students are responsible for completing the major or minor form (available in the College departments) and for obtaining the signature of the chair or director of the undergraduate programs. Forms are submitted to the SEAS Undergraduate Office, which monitors the satisfactory completion of requirements.

Curricula

For inquiries concerning curricula and courses, contact the Office of the Assistant Dean for Undergraduate Programs, School of Engineering and Applied Science, P.O. Box 400233, Charlottesville, VA 22904-4233. Additional information may also be available on the school’s Web site at www.seas.virginia.edu.

The degree of Bachelor of Science is granted with the following majors:
- Aerospace Engineering
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Computer Science
- Electrical Engineering
- Engineering Science
- Mechanical Engineering
- Systems Engineering

The curriculum leading to these degrees are arranged to prepare a graduate to enter directly into employment or to continue graduate studies in either scientific or engineering fields. The baccalaureate degrees include required and elective courses in technical subjects and applied mathematics; required and elective courses in the physical sciences; and elective mathematics, humanities, and social science courses. The aim of these curricula is to provide the student with a strong foundation in methods of engineering analysis, design, and synthesis, and to ensure a firm grasp of fundamental principles in science, mathematics, and the humanities.

All the curricula are accredited by the Southern Association of Colleges and Schools, and the professional engineering programs in aerospace, chemical, civil, computer, electrical, mechanical, and systems engineering are accredited by the Accreditation Board for Engineering and Technology (ABET), the accepted national agency for accrediting curricula in engineering.

The curricula that follow have been developed on the principle that instruction in engineering and applied science should prepare the graduate for professional practice as it has currently evolved and provide a firm foundation in the physical sciences and mathematics that will encourage an imaginative and flexible approach to the problems of engineering and applied science of the future. Included in the student’s first four semesters’ work are elective courses in the humanities taught by the College of Arts and Sciences and a required Science, Technology, and Society (STS) course in the School of Engineering and Applied Science. The elective College courses broaden the students’ interests in fields outside of their technical program, and thus prepare them for a balanced and culturally rich life in the community. The School of Engineering and Applied Science STS courses aim to encourage effective oral and written communication in both technical and non-technical pursuits, and to develop an appreciation for the interactions of technology and society students will encounter in both their professional lives and as responsible citizens.

The curriculum of the school does not require premature specialization. A non-departmental core program covering most of the first two years is administered jointly by all departments. Most curricula have some requirements in the second-year program, and students should consult with their advisors and exercise judicious selection of electives to avail themselves of two or more options among major fields until the beginning of the third year.

**Aerospace Engineering**

Aerospace engineering is concerned with the science and technology underlying the behavior and design of vehicles and systems that operate within the atmosphere and in space. It requires knowledge of a wide range of subject areas, including the basic sciences, mathematics, and engineering sciences as well as specialized studies in aerodynamics, propulsion systems, structures, materials, flight dynamics, astronautics, planetary atmospheres, and computational methods. This broad background qualifies the graduating engineer not only to handle problems that are special to the aerospace field, but also to meet challenges of an interdisciplinary nature facing society, such as those involving the environment, transportation, and energy resources.

With the changing climate in industry and educational units, increasing pressure is being placed on academic institutions to prepare students properly for the future workplace. Students need different experiences than they did ten years ago in order to be competitive in the changing industrial atmosphere. Rapidly expanding, global industries no longer have the resources for extensive “on the job” training. As indicated by discussions with recruiters and industry leaders, graduating students are now expected to have some practical and/or unique experience that they will be able to apply in an industry in the near term. These experiences may come from either laboratory work at the University, from a co-operative education (co-op) program or from summer jobs or internships with industry.

The Department of Mechanical and Aerospace Engineering implemented a co-op program in 1996 that is currently placing students with 40 industries. This program builds self-confidence, helps define career goals. The co-op experience often helps students obtain senior thesis topics through industrial projects, eases transition to the industrial world, and enhances the student’s marketability. Salaries for co-op students are typically two-thirds of those for B.S. level engineers. It takes four and one-half years to complete the co-op program, including one extended stay (summer plus semester) in industry, with one or more summers possible. Requirements include third year academic standing and a grade point average of at least 2.000. Participation is optional and non-credit; details can be obtained from the school or department.

**Program Objectives**

1. Apply knowledge of mathematics, science, engineering, and the principles of engineering design to the professional practice of their discipline in modern industry.
2. Identify and formulate engineering problems in and related to their discipline, and to solve them using modern engineering tools and techniques, through the inspection and analysis of data obtained from the design and execution of experiments, or from the application of theoretical or computational analysis.
3. Pursue continuous, lifelong learning and professional renewal, including undertaking graduate studies. Possess the tools and motivation for continuous learning, scholarship and self-directed research.
4. Understand the nature of engineering knowledge and the social context of engineering; appreciate the impact of engineering solutions in a contemporary, global, societal and environmental context; exhibit professionalism, understand and adhere to professional ethics and standards.
5. Communicate effectively, take leadership positions, and function on multi-disciplinary teams. Understand the importance of diversity in the workplace and of the ethical practice of their profession.

**Minor**

A minor in aerospace engineering is comprised of five courses and requires MAE 201 and two courses from List A and two courses from List B.

**Curriculum (128 credits)**

**First Semester**

- APMA 111 Single Variable Calculus ..........4
- CHEM 151 Introductory Chemistry for Engineers .................3
- CHEM 151L Intro Chemistry Lab ..............1
- ENGR 162 Intro to Engineering ...............4
- STS 101 Engineering, Technology, & Society ..........3

**Second Semester**

- APMA 212 Multivariate Calculus ..............4
- PHYS 142E General Physics I ..................3
- PHYS 142W Physics Workshop .................1
- CS 101 Intro. to Programming ...............3

**Third Semester**

- MAE 200L Mechanics Familiarity Lab ..........1
- MAE 201 Intro to Aerospace Engineering .............3
- MATH 231 Statistics .........................3
- PHYS 241E General Physics II ...............3
- PHYS 241L General Physics Lab I ...........3

Minor A minor in aerospace engineering is comprised of five courses and requires MAE 201 and two courses from List A and two courses from List B. List A: MAE 210, 230, 231, 232, and 321. List B: 301, 322, 331, 342, 352, 373, 382, 412, and 413.

Additional information may also be obtained from the school or department.

For inquiries concerning curricula and courses, contact the Office of the Assistant Dean for Undergraduate Programs, School of Engineering and Applied Science, P.O. Box 400233, Charlottesville, VA 22904-4233. Additional information may also be available on the school’s Web site at www.seas.virginia.edu.
Fourth Semester
APMA 213 Ordinary Differential Eq. ..........3
MAE 210 Thermodynamics ..................3
MAE 210L Fluid/Thermal Fam Lab ..........1
MAE 231 Strength of Materials ...............3
MAE 232 Dynamics ................................3
STS ___ STS 2xx/3xx elective ..................3

Fifth Semester
APMA 314 Applied Partial Differential Equations ..........3
MAE 321 Fluid Mechanics ...................3
MAE 332 Engineering Materials ...........3
MAE 381 Experimental Methods Lab ..2
MAE 301 Astronautics ........................3
Unrestricted elective(1)............3

Sixth Semester
MAE 322 Adv. Fluid Mechanics ...............3
MAE 331 Aerospace Structures ...............3
MAE 382 Aerodynamics Lab ..................3
Unrestricted elective(2) ..........3

Seventh Semester
MAE 373 Flight Vehicle Dynamics ..........3
MAE 412 Air Breathing Propulsion ...........3
MAE 495 Aerospace Design I .................3
STS 401 Western Technology and Culture........................3
HSS elective(3) ................3

Eighth Semester
MAE 466 Aerospace Design II .................3
Technical elective(4) ................3
Technical elective(4) ................3
STS 402 The Engineer, Ethics, and Society ...........................................3
Unrestricted elective(2) ..........3

Minor
A minor in applied mathematics consists of five courses at the 300 level or above. These courses must include at least two courses from APMA 308, 310, and 314. Courses may be selected from APMA offerings, as well as offerings in MATH and/or STAT in the College of Arts and Sciences which are not substantial duplicates of SEAS courses taken.

Biomedical Engineering
Program Objective
Our objective is to impart the knowledge and skills students need to excel during graduate training in biomedical engineering, medicine, law, business, or other disciplines; establish a fulfilling career in industry; contribute in areas that rely on their unique integrative abilities; and ultimately become society's leaders.

Program Description
Biomedical engineering is built upon the premise that the tools and methods of engineering can be used to improve human health and enhance our understanding of the biological world. Biomedical engineering education integrates mathematics, science, engineering methodology, and engineering design to train individuals who are uniquely prepared for the collaborative challenges of this field. The end result of this type of training is knowledge, devices, materials, techniques and treatments to enhance human health. The foundation for these applications is the steady stream of discovery emerging from our nation's academic and industrial research programs.

The Department of Biomedical Engineering (BME) has offered degrees at the master's and doctoral level since 1967. BME introduced a new bachelor's of science degree in biomedical engineering in 2003. The major begins with an early, sound underpinning in the life sciences via two semesters of quantitative mammalian physiology and one semester of cell and molecular biology. Engineering fundamentals follow, taught in the context of biomedical engineering examples in systems analysis, biomechanics and biotransport, and computational systems. In the 3rd year BME majors complete a two-semester IDEAS Lab, integrating concepts and skills from prior BME and other engineering course work. The BME major culminates in the 4th year with a capstone design project where students undertake a year-long "design-and-build" or "design-of-experiment" project. Throughout all four years, electives offer additional breadth and depth.

Exceptionally prepared students can graduate in five years with both a B.S. and an M.S. in biomedical engineering. These students should plan early to design a senior thesis topic that can continue on to a master's or science thesis. Students interested in this option are strongly urged to plan early in their 3rd year and discuss this plan with appropriate faculty in biomedical engineering.

The department encourages students to participate in research and inquiry-based learning above and beyond what is required by the curriculum. In the past students have pursued paid or volunteer positions in research labs, "for-credit" independent research projects, and industry or research internships. Research areas in the department include tissue engineering and genetic engineering targeting vascular disease; adhesion biomolecules, molecular bioengineering, cellular mechanics, and vascular remodeling; cellular mechanisms of wound healing; biomechanics; bioelectricity; biotransport; cardiovascular, respiratory, orthopedic, and neurological systems; and medical imaging, particularly ultrasound, X-ray, and MR imaging. Interdepartmental research collaboration links BME with most other School of Engineering and Applied Science departments and many clinical and basic science departments in the School of Medicine and the College of Arts and Sciences.

Biomedical engineers contribute to society from positions in universities, hospitals, government, the medical device and pharmaceutical industries, and a broad range of research enterprises. As the discipline grows, BME graduates are finding that their broad education provides an excellent platform from which to launch rewarding careers; begin graduate studies in biomedical engineering, biotechnology, or biophysics; or pursue advanced degrees in medicine, law, and business.

Because of the great demand for the biomedical engineering major and the need to maintain an excellent laboratory experience for each student, enrollment in the program is limited to 60 students per year. Admission is based on space availability, academic performance, a personal essay, and diversity. Application forms are available in the department office (Room 2010) in the Biomedical Engineering and Medical Science Building (MR3) in the School of Medicine, on the department website, and in the Office of the Associate Dean for Undergraduate Programs (Room A-122) of Thornton Hall.

Minor
The department also offers an undergraduate minor in conjunction with any of the majors in the School of Engineering and Applied Science. The 18-credit minor in biomedical engineering consists of BIOM 201 and 204, plus 4 approved electives that may include BIOM 310, 315, 322, 406, 411, 428, 441, 483, 484, 490, 495, 496, CHE 347, and MSE 512. One elective may be chosen from BIOM 202 or BIOL 301, 309, 417, 465, or 501.

Biomedical Engineering Curriculum (126 credits)
First Semester
APMA 111 Single Variable Calculus ........4
CHEM 151 Introductory Chemistry for Engineers .................................3
CHEM 151L Intro Chemistry Lab ..........1
ENGR 162 Intro to Engineering ...........4
STS 101 Engineering, Technology, & Society ........................................3

1. Chosen from: BIOL 201, 202; CHEM 152; ECE 200; PHYS 252; and MSE 209.
2. Chosen from the approved list available in A122 Thornton Hall.
(3) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean's office, located in A122 Thornton Hall. APMA 109 counts as a three-credit unrestricted elective.
4. Chosen from the MAE Department's approved Technical Electives List except for MAE courses required for the degree.
5. APMA 311 will satisfy the requirements of MAE 209 for the degree.

Applied Mathematics
The program in Applied Mathematics coordinates and administers mathematics instruction through its APMA courses to students in all departments of the School of Engineering and Applied Science. The mathematical tools and expertise developed are essential to the professional development of the future engineer and applied scientist. This instruction forms the core of the analytical-mathematical component of an engineering education and lays the foundation for ongoing professional development.
## Second Semester

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>APMA 212</td>
<td>Multivariate Calculus</td>
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<tr>
<td>PHYS 142E</td>
<td>General Physics I</td>
</tr>
<tr>
<td>PHYS 142W</td>
<td>Physics Workshop</td>
</tr>
<tr>
<td>CS 101</td>
<td>Intro. to Programming</td>
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<tr>
<td>Science elective I(1)</td>
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<tr>
<td>APMA elective(2)</td>
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17 credits

## Third Semester

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<tr>
<th>Course</th>
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<tbody>
<tr>
<td>APMA 213</td>
<td>Ordinary Differential Equations</td>
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<tr>
<td>PHYS 241E</td>
<td>General Physics II</td>
</tr>
<tr>
<td>PHYS 241L</td>
<td>General Physics Lab I</td>
</tr>
<tr>
<td>BIOM 200</td>
<td>Intro to BME Design &amp; Discovery</td>
</tr>
<tr>
<td>BIOM 201</td>
<td>Physiology I</td>
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<tr>
<td>Unrestricted elective(3)</td>
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17 credits

## Fourth Semester

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<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>BIOM 202</td>
<td>Physiology II</td>
</tr>
<tr>
<td>BIOM 204</td>
<td>Cell and Molecular Biology</td>
</tr>
<tr>
<td>BIOM 322</td>
<td>Biomechanics &amp; Biorobotics</td>
</tr>
<tr>
<td>APMA 311</td>
<td>Applied Statistics &amp; Probability</td>
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<tr>
<td>STS ____</td>
<td>STS 2xx, 3xx elective</td>
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15 credits

## Fifth Semester

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<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>BIOM 310</td>
<td>Systems Analysis &amp; Design</td>
</tr>
<tr>
<td>BIOM 380</td>
<td>IDEAS Laboratory I</td>
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<tr>
<td>HSS elective(3)</td>
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<tr>
<td>Engineering elective(3)</td>
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<td>Technical elective(3)</td>
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16 credits

## Sixth Semester

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<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>BIOM 390</td>
<td>IDEAS Laboratory II</td>
</tr>
<tr>
<td>BIOM 315</td>
<td>Computational BME</td>
</tr>
<tr>
<td>Unrestricted elective(3)</td>
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<td>Engineering elective(3)</td>
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<td>Technical elective(3)</td>
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16 credits

## Seventh Semester

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<th>Course</th>
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<tbody>
<tr>
<td>BIOM 463</td>
<td>BME Capstone Design I</td>
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<tr>
<td>STS 401</td>
<td>Western Tech &amp; Culture</td>
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<tr>
<td>HSS elective(3)</td>
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<tr>
<td>Unrestricted elective(3)</td>
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<tr>
<td>BIOM elective(3)</td>
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15 credits

## Eighth Semester

<table>
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<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>STS 402</td>
<td>The Engineer, Ethics, and Society</td>
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<tr>
<td>BIOM 464</td>
<td>BME Capstone Design II</td>
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<tr>
<td>Unrestricted elective(3)</td>
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<tr>
<td>BIOM elective(3)</td>
<td></td>
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<tr>
<td>Bioengineering elective(3)</td>
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</tbody>
</table>

15 credits

(1) Chosen from: BIOL 201, BIOL 202 (if premed), CHEM 152, ECR 200, & MSE 209.
(2) Chosen from the approved list available in AI 222 Thornton Hall.
(3) Chosen from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any intro programming course. APMA 109 counts as a 3-credit unrestricted elective.
(4) 200-level or higher engineering courses in a single area of concentration. One course is usually, but not always, a prerequisite for the other. A list of suggested course sequences is available in MRJ 2010 (BME main office).
(5) Chosen from any 200-level or higher science, math, or engineering course, unless it is a course for non-science majors, it duplicates required BME class work, or it is a "research-for-credit" or "capstone design" course. Only 3 credits from the BIOL 201-202 (or AP credit) sequence will count as a tech elective.
(6) Chosen from any 300-level or higher BIOM elective, except BIOM 411. Only 3 credits of BIOM 453, 454 will count as either a BIOM or Bioengineering elective.
(7) Chosen from an approved list of engineering electives, 300-level or higher, with a substantial bioengineering component. Typically chosen from MSE 312, CHE 347, CHE 448, or any 300-level or higher BIOM elective, except BIOM 411. Only 3 credits of BIOM 453, 454 will count as either a BIOM or Bioengineering elective.

## Chemical Engineering

Chemical engineering applies physical, chemical, and engineering principles to the processing and utilization of such varied products as fuels, drugs, foods, plastics, metals, and basic chemicals. Given the broad applications of chemical engineering, our program has the following two objectives: (1) Graduates demonstrate technical competency, communication skills and breadth of knowledge in serving effectively in the chemical engineering profession and in becoming technical leaders in industry, government or academia.
(2) Graduates engage successfully in advanced study in engineering and applied sciences and in professions such as law, business, and medicine.

Many chemical engineers serve in the traditional chemical process industries of petroleum, chemicals, paper, pharmaceuticals, and plastics. Some develop new products or processes through research, while others carry out the pilot studies and design work to bring innovations from the laboratory into manufacturing operations. Many are engaged in the operation and management of process plants. Others are in marketing, developing new applications for, or solving problems arising from, the use of products. Often a chemical engineer moves from one function to another. Chemical engineers have long aided in energy and materials production from oil, gas, and coal. They are involved in the research, development, and production of energy from alternative energy resources. Similarly, their chemical expertise and broad knowledge of processes are valuable in the identification and control of environmental problems, in health care and pharmaceuticals, and in areas such as electronic materials production. A chemical engineer's career path is varied and rewarding, allowing individual talents to grow and be fully utilized.

In preparation for these opportunities, undergraduate studies for the B.S. ChE degree are very broad in both science and engineering. The curriculum progresses from basic sciences and mathematics (with an emphasis on chemistry), through engineering sciences, to applications in chemical process analysis, and culminates in a capstone design project. Computer methods, laboratory techniques, open-ended problem solving, team approaches, and effective written and oral communication are emphasized throughout the UVa program of study. Elective courses permit minors or concentrations in diverse technical and non-technical areas; recent students have minored in all other engineering disciplines, the sciences and many different humanities and liberal arts programs, including languages. Throughout, students are expected not only to develop in technical capability, but also to learn to consider the ethical, environmental, cultural, and economic impacts of technological activities.

## First-Year and Second-Year Program

Chemical engineering students take a two-semester sequence of general chemistry with the standard first-year program. Because of individual long term goals and the various options available for students in the chemical engineering program, consultation with a ChE advisor in the first semester of studies is strongly recommended. For example, the second semester chemistry course and laboratory are required for ChE majors and should be taken in the second semester. Further, those planning on medical school must schedule a full year of organic chemistry as well as the biology requirements.

## Concentration in Biotechnology and Biochemical Engineering

A concentration in Biotechnology and Biochemical Engineering prepares chemical engineering students for careers with biotechnology and pharmaceutical companies and for further graduate work in these areas. The concentration includes three required courses (CHE 246-Introduction to Biotechnology, CHE 347-Biochemical Engineering, CHE 448-Bioseparations Engineering) as well as two elective bio-science or bioengineering courses taken from a list available in the department.

## Minor

A minor in chemical engineering consists of CHE 215, 316, 318, 321, and 322.

## Chemical Engineering Curriculum (128 Credits)

### First Semester

<table>
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<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>APMA 111</td>
<td>Single Variable Calculus</td>
</tr>
<tr>
<td>CHEM 151</td>
<td>Introductory Chemistry for Engineers</td>
</tr>
<tr>
<td>CHEM 151L</td>
<td>Intro Chemistry Lab</td>
</tr>
<tr>
<td>ENGR 162</td>
<td>Intro to Engineering</td>
</tr>
<tr>
<td>STS 101</td>
<td>Engineering, Technology, &amp; Society</td>
</tr>
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</table>

15 credits

### Second Semester

<table>
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<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>APMA 212</td>
<td>Multivariate Calculus</td>
</tr>
<tr>
<td>PHYS 142E</td>
<td>General Physics I</td>
</tr>
<tr>
<td>PHYS 142W</td>
<td>Physics Workshop</td>
</tr>
<tr>
<td>CS 101</td>
<td>Intro to Programming</td>
</tr>
<tr>
<td>BIOM 215</td>
<td>Material and Energy Balance</td>
</tr>
<tr>
<td>ENGR elective(3)</td>
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<td>HSS elective(3)</td>
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17 credits

### Third Semester

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<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>APMA 213</td>
<td>Ordinary Differential Eq.</td>
</tr>
<tr>
<td>PHYS 241E</td>
<td>General Physics II</td>
</tr>
<tr>
<td>PHYS 241W</td>
<td>General Physics Wkshp.</td>
</tr>
<tr>
<td>CHE 215</td>
<td>CHEM 246</td>
</tr>
</tbody>
</table>

17 credits
Fourth Semester

APMA 311 Applied Statistics & Probability ...................... 3
CHEM 212 Organic Chemistry .................................. 3
CHEM 212L Organic Chem. Lab .................................. 1
CHEM 202 Thermodynamics ................................. 3
CHE 216 Modeling & Simulation in ChE .................................. 3
STS 2XX/3XX Elective ................................................. 3

Fifth Semester

CHE 316 Chem. Thermodynamics .................................. 3
CHE 321 Transport Processes I .................................. 4
CHEM 361 Physical Chemistry .................................. 3
CHEM 371 Physical Chemical Experimentation .................. 3
Unrestricted elective(6) ................................................. 2

Sixth Semester

CHE 318 Chemical Reaction Engineering .................. 3
CHE 322 Transport Processes II .................................. 4
CHE 398 Chem. Engineering Lab I .................................. 3
Technical elective(6) ................................................. 3
HSS elective(3) ......................................................... 3

Seventh Semester

STS 401 Western Technology and Culture .................. 3
CHE 438 Process Modeling, Dynamics, and Control ............ 3
CHE 491 Chemical Engr. Lab II ................................. 3
CHEM/SCI elective(8) ................................................. 4
Unrestricted elective(6) ................................................. 3

Eighth Semester

STS 402 The Engineer, Ethics, and Society .................... 3
CHE 476 Chem. Engineering Design .......................... 3
CHE elective(6) ......................................................... 3
Technical elective(6) ................................................. 3
Unrestricted elective(6) ................................................. 3

Civil Engineering

Civil engineering is the application of science and technology to the planning, design, analysis, construction, operation, and maintenance of the physical facilities required by society. It is the broadest of all engineering professions, encompassing activities from aerospace to urban planning. Civil engineers are the fabricators of modern society and the protectors of our environment. They deal with people and their management, materials and their use, designs and their application, and the problems of interweaving these factors to serve society. Typical civil engineering projects include environmental facilities, such as systems for water quality control, toxic and hazardous waste control and stormwater networks; structures, such as high-rise buildings, bridges, off-shore platforms, shuttle launch pads, and dams; and transportation facilities, such as Intelligent Transportation Systems, airports, highways, and railways. Civil engineering has a long history and a bright future serving the basic needs of society.

Civil engineering graduates with a BS degree may opt for employment with high technology consulting firms; local, state, or federal governments; contractors or construction firms; public utilities; or industrial corporations. Another option is graduate school, where students pursue an area of specialty within civil engineering. Such studies open up more advanced employment opportunities in government, consulting, construction, or industry, and introduce new choices, including research and teaching. A civil engineering degree also provides a good background for professional training in law, business administration, or medicine.

Detailed degree requirements are posted on the Civil Engineering web site, www.ce.virginia.edu.

Advanced Materials and Structures Laboratory conducts thermomechanical testing with an emphasis on multi-scale approaches that establish connections between size-scale and thermomechanical performance of materials and structures. Together with conventional macroscale materials testing, this facility has a state-of-the-art nano-indentation system that allows mechanical testing on length-scales spanning from nanometers to millimeters. This system has force resolution on the order of one billionth of a Newton, and displacement resolution on the order of an angstrom—a unique capability is an environmental temperature chamber, which enables testing in the range of -50°C to 100°C. Current research is directed towards establishing connections between nanoscale material features and thermomechanical stability in thin films and MEMS, with an emphasis on compliant materials such as nano-porous ceramics and polymers.

Center for Transportation Studies focuses on issues and problems related to the development, operation, and maintenance of a safe, efficient intermodal transportation system for the Commonwealth of Virginia and the nation. The Center's research program is noted for being responsive to emerging challenges from the transportation sector and for continually probing into new areas of transportation-related research, like intelligent transportation systems, traffic simulation studies, applications of geographic information systems in facilitating transportation planning and management, and decision support systems using artificial intelligence.

Smart Travel Lab is a state-of-the-art facility of the Center for Transportation Studies that supports research and education in the rapidly emerging area of intelligent transportation systems (ITS). Using the latest information technologies and analysis and modeling techniques, researchers in the lab are developing prototype systems and applications that promise to improve the effectiveness of ITS. The distinguishing characteristic of the lab is the direct connection established between the lab and transportation management systems operated throughout the Commonwealth of Virginia. This connection provides researchers with direct access to real ITS data and systems.

Program Objectives

1. To provide graduates with the technical competencies and insight necessary to practice civil engineering and have an impact on the profession.
2. To provide a solid foundation for successful study at leading graduate and professional institutions.
3. To promote a breadth of abilities and knowledge, including quantitative and analytical skills, communication skills and social insight, to allow graduates to pursue careers in a diversity of fields including engineering, business, management, and information technology.
4. To prepare graduates for a lifetime of learning, for leadership, and for service to the profession and society.

Minor Completion of five Civil Engineering courses, with no more than two at the 200 level.

Civil Engineering Curriculum (128 Credits)

Civil Engineering Proficiency Areas - Minimum Number Required for Graduation (see below)

First Semester

APMA 111 Calculus II ................................................. 4
CHEM 151 Intro. Chemistry for Engrs. .......................... 3
CHEM 151L Intro. Chemistry Lab .................................. 1
ENGR 162 Introduction to Engineering .................... 4
STS 101 Engineering, Technology, & Society .................. 3
Second Semester
APMA 211 Multivariate Calculus ..........4
PHYS 142E General Physics I ..........4
CS 101 Intro. to Programming ...........3
Science elective(a) .......................3
HSS elective(a) .........................3
17

Third Semester
APMA 308 Linear Algebra ................3
PHYS 241E General Physics II ........3
PHYS 241L General Physics II Lab ..........1
CE 201 Civil Engr. Techniques ..........3
CE 230 Statics ....................................3
HSS elective(a) .........................3
16

Fourth Semester
APMA 213 Ordinary Diff. Equations ....4
CE 231 Strength of Materials ..........3
CE 205 Intro to Env. Eng. ..................3
CE 315/365 Fluid Mechanics/Lab ..........4
STS — STS 2xx/3xx elective ........3
17

Fifth Semester
APMA 311 Applied Statistics & Probability ........3
CE 319 Structural Mechanics ..........3
CE 323/363 Properties & Behavior of Materials/Lab ..........4
CE 336 Water Resources Eng. ..........3
Unrestricted elective(a) ................3
16

Sixth Semester
CE 316/316L Intro. to Geotech. Eng./Lab .4
CE 326 Design of Concrete Str. ..........3
CE 344 Trans. Facilities Design ..........3
HSS elective(a) .........................3
Science/Eng elective(a) .................3
16

Seventh Semester
CE 490 CE Design and Practice ..........4
STS 401 Western Tech. & Culture ..........3
Civil Eng elective(a) .................3
Civil Eng elective(a) .................3
Unrestricted elective(a) .................3
15

Eighth Semester
STS 402 Engineer, Ethics & Society ..........3
Civil Eng elective(a) .................3
Civil Eng elective(a) .................3
Engineering elective(a) .................3
Unrestricted elective(a) .................3
15

128 credits, four Civil Engineering proficiency areas, and one design elective - minimum required for graduation.

(1) Science elective: chose from: BIOL 201, 202; CHEM 152; ECE 200; MISE 209; and PHYS 252.
(2) Humanities and Social Sciences (HSS) elective: chose from the approved list available in Thornton A122.
(3) Science/Engineering elective: chose from: BIOL 201, 202; CHEM 152, 212; EVSC 280; PHYS 252; all 200-level SEAS courses (with the exception of STS courses) and any course meeting the requirements of the Engineering elective (Item (5) below).
(4) Civil engineering elective: chose from all 300- and 400-level Civil Engineering courses. With guidance of advisor, student must select Civil Engineering electives to allow for the completion of one of the following proficiency areas: environmental engineering, transportation engineering or infrastructure engineering and management; and include at least one design elective.
(5) Engineering elective: chose from all 300- and 400-level SEAS courses (with the exception of STS courses, ENGR 488, and TMP 352) plus other approved technical courses.
(6) Unrestricted electives: chose from any graded course in the University except mathematics courses below MATH 131 and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean’s office, located in Thornton Hall, Room A122. APMA 109 counts as a three-credit unrestricted elective.

Civil Engineering Proficiency Areas
To complete a proficiency area, at least two courses must be completed within that area. All students will satisfy the first three areas through required courses; one of the last three areas must also be completed. Each student must complete at least one design elective: Civil Engineering Materials, Structural Engineering, Water Resources Engineering, Transportation Engineering, Environmental Engineering, Infrastructure Engineering and Management

Computer Engineering (CPE)
Computer Engineering is an exciting field that spans topics in both electrical engineering and computer science. Students learn and practice the design and analysis of computer systems, including both hardware and software aspects and their integration. Careers in computer engineering are as wide and varied as computer systems themselves, which range from embedded systems found in consumer products or medical devices, to control systems for automobiles, aircraft, and trains, to more wide-ranging applications in telecommunications, financial transactions, and information systems.

A recent Bureau of Labor Statistics Occupational Outlook Handbook states that “very favorable opportunities” (more numerous job openings compared to job seekers) can be expected for college graduates with at least a bachelor’s degree in computer engineering. It also projects an employment increase of over 21% by 2010 for occupations available to graduates with a bachelor’s degree in computer engineering. More details can be obtained from www.bls.gov/oco.

Program Objectives
Graduates of the Computer Engineering program at the University of Virginia will have the knowledge, skills and attitudes that will allow them to make tangible contributions, meet new technical challenges, contribute effectively as team members, and be innovators in computer hardware, software, design, analysis and applications. They will communicate effectively and interact responsibly with colleagues, clients, employers and society.

Faculties from the Computer Science and Electrical & Computer Engineering departments jointly administer the computer engineering undergraduate degree program at the University of Virginia.

In order to major in computer engineering, a formal application must be submitted and approved by the Computer Engineering Curriculum Committee. An application form and a description of acceptance policies can be found at www.cpe.virginia.edu.

Computer engineering majors must maintain a C average or better in their computer science and electrical engineering courses.

Computer Engineering Curriculum (128 credits)

First Semester
APMA 111 Single Variable Calculus ..........4
CHEM 151 Chem for Engineers ..........3
CHEM 151L Chem for Engineers Lab ..........1
ENGR 162 Intro to Engineering ..........4
STS 101 Engineering, Technology, & Society ..........3
15

Second Semester
APMA 212 Multivariate Calculus ..........4
PHYS 142E General Physics I ..........3
PHYS 142W Physics Workshop ..........1
CS 101 Intro. to Programming ..........3
Science elective(a) ..................3
HSS elective(a) ..................3
17

Third Semester
APMA 213 Ordinary differential Equations ..........3
CE 201 Intro to Env. Eng. ..........3
CE 316/316L Intro to Geotech. Eng./Lab ..........4
CE 326 Design of Concrete Str. ..........3
CE 344 Trans. Facilities Design ..........3
HSS elective(a) ..................3
Science/Eng elective(a) .................3
16

Fourth Semester
CS 216 Program and Data Representation ..........3
ECE 204 Electronics I ..........4
CS/ECE 230 Digital Logic Design ..........3
CS/ECE elective(4)(6) ..................3
STS elective ..........3
16

Fifth Semester
APMA 310 Probability ..................3
ECE 323 Signals and Systems ..........3
CS/ECE 333 Computer Architecture ..........3
PHYS 241E Physics II ..........3
PHYS 241W Physics Workshop ..........1
Unrestricted elective(5) .................3
16

Sixth Semester
CS 340 Advanced Software Development Techniques ..........3
CS 414 Operating Systems ..........3
CS/ECE 457 Computer Networks ..........3
ECE 435 ECE Computer Design ..........4.5
CS/ECE elective(4)(6) ..................3
Unrestricted elective(5) .................3
16.5

Seventh Semester
STS 401 Western Technology and Culture ..........3
CS/ECE 457 Computer Networks ..........3
CS/ECE 435 ECE Computer Design ..........4.5
CS/ECE elective(4)(6) ..................3
Unrestricted elective(5) .................3
16.5
Eighth Semester

STS 402 The Engineer, Ethics, and Society .........................3
ECE 436 Advanced Digital Design .........................4.5
CS/ECE elective(a) ........................................3
Technical elective(b) ........................................3
Unrestricted elective(b) ........................................3
16.5

(a) Chosen from the approved list available in A122 Thornton Hall.

(b) Chosen from: among BIOL 201, 202; CHEM 152;
ECE 200; MSE 209; and PHYS 252.

Computer Science

Through the development of sophisticated computer systems, processors, and embedded applications, computer scientists have the opportunity to change society in ways unimaginable several years ago. A major goal of the Department is the education and training of a diverse body of students who can lead the current information technology revolution. To this end, the computer science program builds students toward the pragmatic aspects of computer science. Good engineering is rooted in solid mathematics and science, and grounding in these fundamentals is essential. Provided in the context of the practice of computing, this early grounding forms the basis for an education that outstandingly prepares students for a computing career.

As a discipline, computer science has seen many dramatic changes in its brief history. Traditional programming instruction emphasizes writing short programs from scratch in a dead language. This emphasis contrasts with the skills needed by contemporary computing professionals. With funding from the National Science Foundation, the Department of Computer Science has designed, developed, and is currently disseminating a curriculum focused on the practice of computing, yet grounded in the mathematical and scientific fundamentals of computer science. The curriculum is structured around the introduction of modern software development techniques in the very beginning courses and is supported by a coordinated set of "closed laboratories."

In order to provide an environment appropriate to our courses, the department has established several laboratories with more than 150 workstations. These machines have high-resolution graphics and are connected to large file handlers, as well as to the University network. The lab courses expose students to many commercial software tools and systems and are currently introducing modern software development techniques via object-oriented design and implementation in C++ and Java.

The Department of Computer Science offers, with the Department of Electrical and Computer Engineering, a degree in Computer Engineering.

To major in computer science or computer engineering, a formal application must be submitted to, and approved by, the Department of Computer Science. An application form and a description of acceptance policies can be found at www.cs.virginia.edu. Applications are normally considered at the end of the spring semester.

Program Objectives

Graduates of the Computer Science program at the University of Virginia will have the knowledge, skills and attitudes that will allow them to make tangible contributions, meet new technical challenges, contribute effectively as team members, and be innovators in the design, analysis and application of computer systems.

Grading Policy

Majors and minors are required to maintain a C average or better in their CS courses.

Transfer

Students in the College of Arts and Sciences with an interest in obtaining a degree in computer science may transfer to the School of Engineering and Applied Science. Like other SEAS students, transfer students must formally apply to, and be approved by, the Department of Computer Science to take the Computer Science program of study. To minimize loss of credit upon transfer, College students must take a rigorous program in mathematics and the sciences. The School of Engineering and Applied Science expects a minimum of 63 credits in the first two years, instead of the 60-credit minimum that is customary in the College of Arts and Sciences. (The additional credits are often completed through summer courses.)

Detailed information on curriculum requirements may be obtained from the Office of the Dean of the School of Engineering and Applied Science.

Minor

The 18-credit computer science minor consists of CS 101, 201, 202, and 216. In addition, two other computer science courses from a prescribed list must be taken. Complete details can be found at the computer science Web site, www.cs.virginia.edu.

Computer Science Curriculum (125.5 credits)

First Semester

APMA 111 Single Variable Calculus .......................4
CHEM 151 Introductory Chemistry for Engineers .................3
CHEM 151L Intro to Chemistry Lab .....................1
ENGR 162 Intro to Engineering ........................4
STS 101 Engineering, Technology, & Society .................3
15

Second Semester

APMA 212 Multivariate Calculus .......................4
PHYS 142E General Physics I ..........................3
PHYS 142W Physics Workshop .........................1
CS 101 Intro. to Programming ........................3
Science elective(c) ........................................3
HSS elective(d) ........................................3

Third Semester

APMA APMA 310 or APMA electives(e) ................3
PHYS 241E General Physics II ........................3
PHYS 241W Physics Workshop .........................1
CS 201 Software Devel. Methods ...................3
CS 202 Discrete Mathematics I ....................3
HSS elective(d) ........................................3
16

Fourth Semester

CS 216 Program and Data Representation ................3
CS/ECE 230 Digital Logic Design ......................3
CS 290 CS Seminar ....................................1
CS 302 Discrete Mathematics II .....................3
Technical elective(e) ........................................3
STS STS 2xx/3xx elective ..............................3
16

Fifth Semester

CS/ECE 333 Computer Architecture ....................3
CS 432 Algorithms .......................................3
APMA APMA 310 or APMA electives(e) ................3
Gen. Ed. elective(e) ........................................3
HSS elective(e) ........................................3
15

Sixth Semester

CS 340 Advanced Software Development Tech. ........3
CS 414 Operating Systems ............................3
APMA APMA 310 or APMA electives(e) ................3
Gen. Ed. elective(e) ........................................3
HSS elective(e) ........................................3
16

Seventh Semester

STS 401 Western Technology and Culture ................3
ECE 435 Computer Organization and Design .................4.5
CS CS elective ........................................3
CS CS elective ........................................3
Gen. Ed. elective(e) ........................................3
16.5

Eighth Semester

STS 402 The Engineer, Ethics, and Society .................3
CS CS elective ........................................3
CS CS elective ........................................3
Technical elective(e) ........................................3
Gen Ed elective(e) ........................................3
15

(a) Chosen from: BIOL 201, 202; CHEM 152; ECE 200;
ECE 209; and PHYS 252.

(b) Chosen from the approved list available in A122
Thornton Hall.

(c) Technical electives are courses whose major
emphasis is mathematics, science, or engineering.
One of the technical electives can be at the 2xx level.
The other electives must be at the 3xx level.

(d) Unrestricted electives may be chosen from any
graded course in the University except mathematics
courses below MATH 131 and courses that substi-
tially duplicate any others offered for the degree,
including PHYS 201, 202; CS 110, 120; or any intro-
duction to mathematics, or science at the 200 level or above.

(e) Students interested in selected advanced CS elec-
tives should take CS 302. Students interested in
selected advanced ECE electives should delay this
elective until the sixth semester and take a technical
elective instead.

(f) Chosen from CS/ECE course at the 300 level or
higher. Two CS/ECE electives must be 400-level or above.
should get the approval of their advisor and the dean’s office, located in A122 Thornton Hall. APMA 109 counts as a three-credit unrestricted elective.

(5) Electives must be chosen from APMA 213, 308, or 312.

(6) Gen Ed electives include all those allowed for HSS electives and other non-technical courses that broaden one’s education. See list of approved courses at www.cs.virginia.edu.

**Electrical Engineering**

Electrical engineering is a rapidly expanding field, and includes such areas as communications, microelectronics, control systems, and computer system design. New and exciting areas are continually being developed, and more traditional areas are finding new applications. Because of the rapidly-changing nature of the field, this program is designed to provide a strong preparation in traditional electrical engineering, while providing maximum flexibility to accommodate student interests and current technological developments. The objectives of the undergraduate Electrical Engineering program are: Graduates of the Electrical Engineering program at the University of Virginia will have the knowledge, skills and attitudes that will allow them to make tangible contributions, meet new technical challenges, contribute effectively as team members, and be innovators in the analysis, design and implementation of electrical and electronic devices and systems. They will communicate effectively and interact responsibly with colleagues, clients, employers and society.

Students can use the flexibility available in the elective program to focus their study on an area of particular interest within electrical engineering, including communication systems, digital system design, control systems, applied electrophysics, and microelectronics. In addition, with careful planning, students can use technical electives for interdisciplinary studies; for example, computer engineering, biomedical engineering, or materials science, perhaps even earning a minor in a related field. Specific suggestions for study in several areas are available from the office of the Department of Electrical and Computer Engineering.

**Program Objectives**

Graduates of the Electrical Engineering program at the University of Virginia will have the knowledge, skills and attitudes that will allow them to make tangible contributions, meet new technical challenges, contribute effectively as team members, and be innovators in the analysis, design and implementation of electrical and electronic devices and systems. They will communicate effectively and interact responsibly with colleagues, clients, employers and society.

**Minor**

The 19-credit minor consists of ECE 203, 204, and 230, as well as 3 electives (with at least one course at the 400 level or above). The electives are selected from a list of courses available in the Office of the Department of Electrical and Computer Engineering.

**Electrical Engineering Curriculum (128 credits)**

### First Semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>APMA 111 Single Variable Calculus</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 151 Introductory Chemistry for Engineers</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 151L Intro Chemistry Lab</td>
<td>1</td>
</tr>
<tr>
<td>ENGR 162 Intro to Engineering</td>
<td>4</td>
</tr>
<tr>
<td>STS 101 Engineering, Technology, &amp; Society</td>
<td>3</td>
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### Second Semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>APMA 212 Multivariate Calculus</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 142E General Physics I</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 142W Physics Workshop</td>
<td>1</td>
</tr>
<tr>
<td>ECE 203 Intro to Programming</td>
<td>3</td>
</tr>
<tr>
<td>SC 201 Software Devel. Methods</td>
<td>3</td>
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</table>

### Third Semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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<tbody>
<tr>
<td>APMA 213 Ordinary Differential Eq.</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 241E General Physics II</td>
<td>3</td>
</tr>
<tr>
<td>PHYS 241W Physics Workshop</td>
<td>1</td>
</tr>
<tr>
<td>ECE 203 Intro Circuit Analysis</td>
<td>3</td>
</tr>
<tr>
<td>ECE 204 Electronics</td>
<td>3</td>
</tr>
<tr>
<td>ECE 320 Digital Logic Design</td>
<td>3</td>
</tr>
<tr>
<td>ECE 435 and 436 each count as one course</td>
<td>3</td>
</tr>
<tr>
<td>STS 301 Software Devel. Methods</td>
<td>3</td>
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### Fourth Semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ECE 309 Electromagnetic Fields</td>
<td>3</td>
</tr>
<tr>
<td>ECE 323 Signals and Systems</td>
<td>3</td>
</tr>
<tr>
<td>ECE 435 and 436 each count as one course</td>
<td>3</td>
</tr>
<tr>
<td>ECE 436 and 437 each count as one course</td>
<td>3</td>
</tr>
<tr>
<td>Unrestricted elective</td>
<td>3</td>
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</table>

### Fifth Semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>ECE 309 Electromagnetic Fields</td>
<td>3</td>
</tr>
<tr>
<td>ECE 323 Signals and Systems</td>
<td>3</td>
</tr>
<tr>
<td>ECE 324 Technical elective</td>
<td>3</td>
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<tr>
<td>HSS elective</td>
<td>3</td>
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### Sixth Semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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<tbody>
<tr>
<td>APMA 310 Probability</td>
<td>3</td>
</tr>
<tr>
<td>ECE 333 Computer Architecture</td>
<td>3</td>
</tr>
<tr>
<td>ECE 435 Technical elective</td>
<td>3</td>
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<tr>
<td>HSS elective</td>
<td>3</td>
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### Seventh Semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>STS 401 Western Technology and Culture</td>
<td>3</td>
</tr>
<tr>
<td>ECE 435 Technical elective</td>
<td>3</td>
</tr>
<tr>
<td>ECE 436 Technical elective</td>
<td>1.5</td>
</tr>
<tr>
<td>ECE 437 Technical elective</td>
<td>3</td>
</tr>
<tr>
<td>Unrestricted elective</td>
<td>3</td>
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</table>

### Eighth Semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS 402 The Engineer, Ethics, and Society</td>
<td>3</td>
</tr>
<tr>
<td>ECE 435 Technical elective</td>
<td>3</td>
</tr>
<tr>
<td>ECE 436 Technical elective</td>
<td>1.5</td>
</tr>
<tr>
<td>ECE 437 Technical elective</td>
<td>3</td>
</tr>
</tbody>
</table>

(1) A technical elective is defined as a course in engineering (may be ECE), mathematics, or science (intended for science majors) at the 200 level or above. Of the four technical electives, two must be at the 300 level or above. Any course appearing on the approved list of HSS electives may not be used as a technical elective.

(5) ECE 435 and 436 each count as one course and one lab if chosen as electives. One of the ECE electives must be the Major Design Experience Course. At least two courses and one lab must fall within a single area of concentration. The five areas of concentration are applied electrophysics, communications and signal processing, digital systems, control, and microelectronics. A list of electives that fulfill the requirements of each concentration is included in the Electrical Engineering Undergraduate Handbook.

(6) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131, including STAT 110 and STAT 112, and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202, CS 110, 120, or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean’s office, located in A122 Thornton Hall. APMA 109 counts as a three-credit unrestricted elective.

(7) ECE 230 is offered in both fall and spring semesters; it can be taken in the third semester.

(8) ECE 333 is offered in both fall and spring semesters; it can be taken in the third semester.

**Engineering Science**

Engineering Science is a flexible undergraduate engineering program. It offers imaginative students in the School of Engineering and Applied Sciences the opportunity to design a course of studies that appeals to their special academic interests and prepares them for graduate school. This flexibility allows students to develop expertise in topical areas in the biological, environmental, mathematical, and physical sciences. Students typically select engineering science to prepare for a career in applied mathematics, engineering physics, materials science, or medicine, all of which have strong graduate programs at the University of Virginia but do not have undergraduate programs. Alternatively, some students seek to obtain a broad engineering/science background as preparation for work in non-engineering fields, such as teaching.

Engineering science students, in collaboration with their advisors, define their program of studies. The study plan for each student must show direction by including an approved minor in the School of Engineering and Applied Science. The equivalent of a minor in a science area is also strongly encouraged. The advanced project course in the fourth year, which supplements the senior thesis, allows the student to complete an in-depth research project. Minors in Materials Science and Engineering (MSE), Applied Mathematics and Biomedical Engineering are common choices, but any minor in SEAS is allowed. The MSE option in Engineering Science is excellent preparation for either graduate school in MSE or obtaining a position in the materials industry. The courses required for the minor are listed under the relevant departments. Students using Engineering Science as preparation for medicine, business or law should also consult the office of the preprofessional advisor for undergraduates in Bryant Hall.
(3) Chosen from: 2xx courses in SEAS approved by advisor.
(4) Math elective I: 200-level or higher course in mathematics. Advanced math/CS elective II: Two advanced mathematics courses, 300-level or higher, in SEAS or CLAS, or one advanced-level mathematics and one 200-level or higher computer science course. Mathematical modeling courses in the various departments of SEAS may be used, as approved by the advisor.
(5) Chosen from 200-level or higher courses in astronomy, biology, chemistry, environmental sciences, or physics for science majors. Should have a science, mathematics or computer science pre-requisite. Chosen from: ASTR 211, 212; BIOL 201, 202, 203, 204; CHEM 152, 212, 222, 241, 241L, 242, 242L, 252, 281, 281L, 282, 282L; EVSC 280, 280L; MSE 209; PHYS 252, 252L; and PSYC 221. The four-course sequence for science majors (CHEM 181/181L, 182/182L, 281/281L, 282/282L) may be taken to replace CHEM 151/151L, two science electives, and the 2xx technical elective. The course sequence for science majors (PHYS 151, 152, 251, 252, and labs PHYS 221, 222) may replace PHYS 142E, 241E/241W, and two science electives.
(6) Advanced sciences are 300-level or above courses in astronomy, biology, chemistry, environmental sciences, or physics. The course must have mathematics or science prerequisites. For students with minors in engineering other than the materials science minor, 300-level courses in materials science may be used. Two credits of advanced laboratory work should be included. The science elective and technical electives can be used to obtain the equivalent of a science minor.
(7) Advanced technical electives should be chosen from 300- to 400-level science, mathematics, or engineering courses for science and engineering majors (i.e., courses not open to non-science majors). At least two of the technical electives must be 400-level or higher SEAS courses. The technical electives must be chosen to include an advanced minor in SEAS.
(8) Students are expected to define a research project to be completed in the fourth year. The advanced project courses are graded research courses supplementing the student’s thesis work.
(9) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 131, including STAT 110 and STAT 122, and courses that substantially duplicate others used for the student’s degree.
(10) Chosen from: BIOL 201, 202; CHEM152; MSE 209; ECE 200; and PHYS 252.
(11) Chosen from the approved list available in A122 Thornton Hall.

Materials Science and Engineering
The Department of Materials Science and Engineering offers a selection of undergraduate courses with the objective of providing students with a fundamental background in the structure, properties, processing, and performance of materials. This background is essential to engineers or scientists in understanding the selection of materials for various applications. A minor in Materials Science and Engineering is available to all engineering majors in SEAS. The purpose of the minor is to provide instruction on how the processing, structure, and properties of materials affect and complement your major field of study. Additionally, a materials science and engineering concentration is available to the undergraduate student within the framework of the Engineering Science Program.

A broad background in materials science and engineering is available by selecting MSE 209 (Introduction to the Science and Engineering of Materials), which develops the terminology and scientific foundation necessary for understanding the behavior of metals, polymers, and ceramics. More advanced courses (300-500) are available to introduce the student to structure-property relationships for various classes of materials, such as alloys and polymers, as well as modern and classical aspects of corrosion. Students are introduced to the typical experimental techniques for characterizing materials and their properties through laboratory demonstrations in the courses. Qualified students may also take 600-level graduate courses in materials science and engineering with the approval of the instructor. Research opportunities exist for undergraduate students interested in working with faculty on project areas identified in the Graduate Record. A general materials course, MSE 201 (EVSC 201), emphasizing the relationship of materials technology to modern society, is offered each semester for students of all disciplines throughout the university.

Minor Five courses constitute a minor: MSE 209 (MAE 352 may substitute); two of the following: MSE 305, 306, or 567; and two of the following: MSE 301, 304, 305, 306, 357, 512, 524, 532, 567, and special topics (491, 492, 500).

Finally, a minor advisor must be assigned, who can help guide course selection to best match the student’s major and career objectives. Minoring students who are interested in focused laboratory experience, and perhaps graduate school, are encouraged to enroll in MSE 451 or 452. For more information, consult the department website, www.virginia.edu/ms.

Mechanical Engineering
Mechanical engineering is the broadest of the engineering disciplines, providing opportunities for employment in industry, business, government, research, and education. The mechanical engineer is concerned with the development of machines and systems for diverse applications in our modern technological society. Talents and interests of a graduate M.E. include those required to plan, analyze, design, and improve components and systems. The practice of mechanical engineering is applied to manufacturing, energy conversion, transportation, construction, and environmental control. In the future, mechanical engineers must provide leadership in developing new sources of power and new systems to accommodate societal demands.

The curriculum begins with the study of chemistry, physics, mathematics, computer science, and general engineering courses. As students progress, they take advanced analytic, design, and laboratory courses related to mechanical and thermal systems. One-fourth of the program is devoted to the humanities and social sciences, which broaden the student’s education and assist in developing communication and leadership skills.

Young engineers need relevant experiences to be competitive in the global economy. As indicated by discussions with recruiters and industry leaders, graduating students are now expected to have some prac-
tical and/or unique experience that they will be able to apply in an industry in the near term. These experiences may come from laboratory work, projects at the University, or a co-operative education (co-op) program.

The Department of Mechanical and Aerospace Engineering implemented a co-op program in 1996 that is currently placing students with 40 industries. This program builds self-confidence, helps define career goals. The co-op experience often helps students obtain senior thesis topics through industrial projects, eases transition to the industrial world, and enhances the student's marketability. Salaries for co-op students are typically two-thirds of those for B.S. level engineers. It takes four and one-half years to complete the co-op program, including one extended stay (summer plus semester) in industry, with one or more summers possible. Requirements include third year academic standing and a grade point average of at least 2.000. Participation is optional and non-credit; details can be obtained from the school or department.

Program Objectives

1. Apply knowledge of mathematics, science, engineering, and the principles of engineering design to the professional practice of the discipline in modern industry.
2. Identify and formulate engineering problems in related to the discipline, and to solve them using modern engineering tools and techniques, through the inspection and analysis of data obtained from the design and execution of experiments, or from the application of theoretical or computational analysis.
3. Pursue continuous, lifelong learning and professional renewal, including undertaking graduate studies. Possess the tools and motivation for continuous learning, scholarship and self-directed research.
4. Understand the nature of engineering knowledge and the social context of engineering; appreciate the impact of engineering solutions in a contemporary, global, societal and environmental context; exhibit professionalism, understand and adhere to professional ethics and standards.
5. Communicate effectively, take leadership positions, and function in multi-disciplinary teams. Understand the importance of diversity in the workplace and of the ethical practice of their profession.

Minor A minor in mechanical engineering is comprised of five courses and one lab, and requires MAE 200 and either MAE 200L or MAE 210L, as well as two courses from List A and two courses from List B. List A: MAE 210, MAE 230, MAE 231, MAE 232, MAE 321. List B: MAE 312, MAE 314, MAE 362, MAE 371, MAE 471, MAE 473, MAE 474, MAE 476.

Mechanical Engineering Curriculum (128 credits)

First Semester

APMA 111 Single Variable Calculus ........4
CHEM 151 Introductory Chemistry for Engineers ..............3

Second Semester

MAE 152 Intro to Engineering ...............4
STS 101 Engineering, Technology, & Society ..............3

Third Semester

MAE 200 Intro to Mechanical Engr. ........2
MAE 200L Mechanics Familiarity Lab ...1
MAE 311 Applied Probability and Statistics(1) ..............3
MAE 230 Statics ..................................3
PHYS 241E General Physics I ..............3
PHYS 241W Physics Workshop .................1
STS 200 STS 2xx/3xx elective ..................2

Fourth Semester

APMA 213 Ordinary Differential Eq. ..........4
MAE 210 Thermodynamics ..................3
MAE 210L Fluid/Thermal Fam Lab ........1
MAE 231 Strength of Materials ..........3
MAE 232 Dynamcis ..................3
STS 210 STS 2xx/3xx elective ..................2

Fifth Semester

MAE 321 Fluid Mechanics ..................3
MAE 371 Mechanical Sys. Modeling ..........3
MAE 381 Experimental Methods Lab ........2
Math/Science II elective(2) ........3
Technical elective(3) ..................3
Unrestricted elective(3) ........3

Sixth Semester

MAE 314 Elements of Heat & Mass Transfer ..................3
MAE 362 Machine Elements and Fatigue in Design ..........4
MAE 384 Mech Engr Lab ..........2
Technical elective(3) ..................3
HSS elective(3) ..................3

Seventh Semester

MAE 461/463 Design I elective ..............3
STS 401 Western Technology & Culture ..............3
MAE 471 Mechatronics ..................4
Technical elective(3) ..................3
Unrestricted elective(3) ........3

Eighth Semester

MAE 462/464 Design II elective .........3
Technical elective(3) ..................3
STS 402 The Engineer, Ethics, and Society ..........3
Technical elective(3) ..................3
Unrestricted elective(3) ........3

(1) Chosen from: BIOL 201, 202; CHEM 152; ECE 200; a PHYS 252, and MSE 209.
(2) Chosen from the approved list available in A122 Thornton Hall.
(3) Chosen from the MAE Department’s Math Science Elective II approved list or the Science Elective I list. See Department’s web site.

Department of Science, Technology, and Society

The Department of Science, Technology, and Society (STS) provides instruction in subjects that are essential to the education of professional engineers. This instruction forms the core of a liberal education and lays the foundation for ongoing professional development. All STS courses emphasize the relationships among science, technology, and society; ethics; and oral and written communication.

In addition to the first- and fourth-year courses (STS 101 and 401-402), required of all Engineering undergraduates, the department offers an array of 200-level courses from which each student must choose at least one. Additional elective courses are offered at the 300 level. Drawing on disciplines in the humanities and social sciences, these courses provide a variety of perspectives—social, historical, esthetic, ethical, religious—on engineering, science, and technology. They also help students develop written and oral communication skills.

In their senior year, all engineering undergraduates undertake a senior thesis project. Students work with a faculty member in their major and with an STS faculty member teaching STS 401-402; the thesis work includes integration of the technical subject matter with its ethical and social context. STS courses supplement the student’s general education (furthered by course work in the College of Arts and Sciences) and connect the humanities and social sciences to engineering knowledge and practice. The STS component of the UVA engineering degree ensures that students will have seriously considered the moral and social aspects of their future life’s work.

Minor in Engineering Business This minor offers engineering students the opportunity to study how technology and business interact. Through coursework in Commerce and Economics, students gain an overview of business enterprise and study how new products are developed and marketed. In contrast to the STP minor, which explores the role of technology in the larger realms of policy-making and political economy, the engineering business minor focuses on decision-making within a company or organization. Overall, the minor serves to develop the student's
potential as a leader and decision-maker in technology-driven industries.

Requirements The six-course minor requires COMM 180, ECON 201, and TMP 351. The other three courses are selected from a list of electives available from the course coordinator or in A122 Thornton Hall. The program is administered by a coordinator and committee appointed by the dean of the school. For further information, contact the EB Minor Coordinator, Department of Science, Technology, and Society, Thornton Hall, P.O. Box 400744, Charlottesville, VA 22904-4744; (434) 924-6113.

Minor in the History of Science and Technology In conjunction with the History Department, the Department of Science, Technology, and Society offers a minor in the history of technology and science. Open to all undergraduates, this minor provides students with an opportunity to become familiar with humanistic perspectives of technology and science. For the engineering student, the minor offers an occasion for placing his or her professional education in a larger social and intellectual context; likewise, it provides the liberal arts student with a better understanding of science and technology as key components in human culture.

Requirements The minor consists of 18 credits. College students may include the non-College courses as general electives upon completion of the requirements for the minor. The list of eligible courses and requirements can be obtained from the HST Minor Coordinator, Department of Science, Technology, and Society, Thornton Hall, P.O. Box 400744, Charlottesville, VA 22904-4744; (434) 924-6113.

Minor in Science and Technology Policy Science, technology, engineering, and government are intertwined. Federal, state, local, and foreign governments shape science and technology in a variety of ways, including through grants, contracts, regulations, and foreign policy. Science and engineering reshape governments in turn by supplying tools and expertise and, indirectly, by transforming social and economic structures.

This minor equips students with the basic skills to understand those interactions. Along with two courses in politics and economics, all students take a course in science and technology policy designed for this minor. Three electives—from fields such as history, philosophy, and planning as well as politics and economics—deepen and broaden students’ education.

Students completing this minor will gain a deeper understanding of the interdependence of science, technology, engineering, and policy. They will also prepare themselves to lead organizations inside and outside of government, including those in industry, consulting, law, and medicine.

Students interested in this minor should contact the Science, Technology, and Society Department in Thornton A-237.

Minor in Technology and the Environment The increasing prevalence of technology has affected the environment in complex and often unforeseen ways. Society is now demanding that all disciplines of engineering be environmentally aware. Furthermore, those that use and distribute technology need to appreciate its far-ranging impacts. For a more sophisticated understanding of the relationships between technology and the environment, engineers, managers, and historians require interdisciplinary expertise.

This minor, open to all undergraduates, addresses these concerns with an interdisciplinary course of studies. A cornerstone of the minor is a basic knowledge of the technologies that directly impact environmental systems. This technological foundation allows students to build a more sophisticated understanding of how technology and the environment are inter-related. In addition to the technological courses, complementary interdisciplinary courses are selected to complete the minor.

Requirements The minor consists of six courses (18 credits), with no more than two courses taken in the student’s major department. Each student must complete at least two courses related to environmental technology, including either CE 205 or EVSC 148. In addition, each student must choose an emphasis by completing at least three courses in one of three areas: environmental planning and policy, history of technology and the environment, or management and economics.

A full description of suitable course work for this minor is available from the TE Minor Coordinator, Department of Science, Technology, and Society, Thornton Hall, P.O. Box 400744, Charlottesville, VA 22904-4744; (434) 924-6375.

Science and Technology Policy Internships Second- and third-year undergraduates in SEAS are eligible to participate in the school’s Washington, D.C., Internship Program in Science and Technology Policy. The program places interns in executive agencies on Capitol Hill and in think tanks to work on science and technology policy for about 10 weeks each summer. Admission is competitive and takes place during fall term. Those selected take a preparatory course during spring term. The program provides shared dormitory housing and a stipend during the summer. In Washington, the program merges with a similar endeavor at the Massachusetts Institute of Technology. Interns from the two schools share dormitory rooms, attend a speaker series, carry out service projects, and socialize together.

Systems Engineering The undergraduate program in Systems Engineering prepares graduates to engage in development, implementation, and optimization of systems that include humans, data and information, hardware, software, and natural and technology resources; embark on sustainable, productive careers in systems engineering, applied science, and technology management; excel in the practices of analytical modeling and integrative systems engineering; seek and succeed in lifelong professional education that includes advanced schooling and mentoring; and contribute to the profession of systems engineering and to human welfare through professional societies, public service, and civic activities.

The program in Systems Engineering is designed for students interested in bringing people and technologies together to improve the productivity and effectiveness of organizations and address complex, multidimensional problems in society and industry. Students receive exposure to a wide range of topics, including the economic, political, managerial, environmental, and technical aspects of large scale systems design and implementation. Students are provided with diverse opportunities for hands-on experience with real-world situations and problems.

The Systems Engineering curriculum is more flexible than many traditional engineering programs. In addition to the courses specifically required in the curriculum, students are able to take nine credits of unrestricted electives, nine credits of electives tailored to an application area, and six credits of technical electives.

The curriculum allows students to pursue a specific area of interest within the broad framework of systems engineering. The following areas are available as application sequences: biomedical systems, communication systems, computer and information systems, control systems, economic systems, energy and environmental systems, financial systems, human factors, intelligent transportation systems, management systems, and mathematical systems. Appropriate ROTC courses may be counted as an application sequence in military systems. Additionally, there are opportunities for students with special interests and abilities to design their own unique application sequences.

The program culminates in a capstone design project, spanning both the fall and spring semesters of the fourth year. Students working in small teams under the direction of a faculty advisor are matched with a client from the public or private sector. Each team is assigned an open-ended design problem, and they apply the perspectives, methods, and tools of systems engineering that they learn in the classroom to the resolution of a problem for a client.

A degree in Systems Engineering from UVA confers employability in a wide range of industries, governmental agencies, and nonprofits. It offers students a variety of career choices in engineering and management, and also provides excellent pre-med, pre-business, and pre-law preparation. The award-winning program is one of the largest systems engineering programs in the United States, and the graduates of the program consistently receive higher salary offers than the national average for other systems programs and other engineering disciplines. The program is accredited by the Accreditation Board for Engineering and Technology and received the first award of the Board for Curricular Innovation. The program also received the outstanding Educator Award from the Boeing Company, which recognized the Department of Systems and Information Engineering for
its potential to “develop leaders prepared to shape the future.” An award from the U.S. Department of State enables a select group of fourth year Systems Engineering students to study in Brazil with their capstone team for a semester.

Admission to the program is based on space availability, academic performance, and extracurricular activities. Application forms and further information are available in the department office in Olsson 114.

Minor Students who wish to minor in systems engineering must complete APMA 310 and 312, and four courses from SYS 201, 204, 257, 321, and 360 with a cumulative grade point average of 2.000. Students who wish to pursue a minor in systems engineering must complete APMA 310 and APMA 308, and four courses from SYS 201, 204, 257, 321, and 360.

Minor Declaration Form. The forms may be obtained in the SEAS Undergraduate Office, A122 Thornton.

Systems Engineering Curriculum (128 credits)

First Semester

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<tr>
<td>APMA 111</td>
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<td>CHEM 151</td>
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<td>CHEM 151L</td>
<td>3</td>
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<td>ENGR 162</td>
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<td>STS 101</td>
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<tr>
<td>SS/TECH 101</td>
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Second Semester

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Third Semester

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<td>SYS 355</td>
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Eighth Semester

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<td>STS 402</td>
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<td>SYS 454</td>
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<td>SYS elective(1)</td>
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</table>

(1) Chosen from: BIOL 201, 202; CHEM 152; ECE 200; MIE 209; and PHYS 252.

(2) Chosen from the list of SIE approved science elective II courses, as well as from any 200 to 400-level science or mathematics course approved for science majors.

(3) Chosen from the approved list available in the Undergraduate Office, A212 Thornton Hall.

(4) Nine credits of applications electives should be selected in a related applications area of systems engineering. Appropriate sequences include biomedical systems, communications systems, computer and information systems, control systems, economic systems, energy and environmental systems, financial systems, human factors, intelligent transportation systems, management systems, mathematical systems, and military systems (ROTC). Students may define alternative application sequences with the advice and consent of their academic advisor.

(5) Chosen from 200-level (or higher) courses in SEAS, other than STS.

(6) Unrestricted electives may be chosen from any graded course in the University except mathematics courses below MATH 111, including STAT 110 and STAT 112, and courses that substantially duplicate any others offered for the degree, including PHYS 201, 202; CS 110, 120; or any introductory programming course. Students in doubt as to what is acceptable to satisfy a degree requirement should get the approval of their advisor and the dean’s office, located in A 122 Thornton Hall. APMA 109 counts as a three-credit unrestricted elective.

Course Descriptions

Some courses included in the engineering and applied science curricula are taught by the College of Arts and Sciences faculty and are listed in the course offerings of that school. These include physics (PHYS), chemistry (CHEM), and college mathematics (MATH).

Note: Courses at the 600 level and above are listed in the course offerings of that school. Some courses included in the engineering and applied science curricula are taught by the College of Arts and Sciences faculty and are listed in the course offerings of that school.

### Applied Mathematics

**APMA 109 - 4 (Y)**

**Calculus I**

The concepts of differential and integral calculus are developed and applied to the elementary functions of a single variable. Applications are made to problems in analytic geometry and elementary physics. For students with no exposure to high school calculus.

**APMA 111 - 4 (Y)**

**Calculus II**

Prerequisite: APMA 109 or equivalent. Includes the concepts of differential and integral calculus and applications to problems in geometry and elementary physics, including indeterminate forms; techniques of integration; polar coordinates; and infinite series.

**APMA 202 - 3 (S)**

**Discrete Mathematics I**

Prerequisite: APMA 111 and CS 101, or equivalent. Introduces discrete mathematics and proof techniques involving first order predicate logic and induction. Application areas include sets (finite and infinite, such as sets of strings over a finite alphabet), elementary combinatorial problems, and finite state automata. Develops tools and mechanisms for reasoning about discrete problems. Cross-listed as CS 202.

**APMA 212 - 4 (S)**

**Multivariate Calculus**

Prerequisite: APMA 111. Topics include vectors in three-space and vector valued functions and multivariable calculus, including partial differentiation, multiple integrals, line and surface integrals, Green’s Theorem, the divergence theorem, and Stokes’s Theorem.

**APMA 213 - 4 (S)**

**Ordinary Differential Equations**

Prerequisite: APMA 111 or equivalent. First order differential equations, second order and higher order linear differential equations, Laplace transforms, linear systems of first order differential equations and the associated matrix theory, and applications.

**APMA 302 - 3 (Y)**

**Discrete Mathematics II**

Prerequisite: APMA/CS 202 or equivalent. A continuation of APMA 202, consisting of topics in combinatorics, including recurrence relations and generating functions. An introduction to graph theory, including connectivity properties; and Eulerian and Hamiltonian graphs, spanning trees and shortest path problems. Cross-listed as CS 302.

**APMA 308 - 3 (S)**

**Linear Algebra**

Prerequisite: APMA 212 or equivalent. Analyzes the systems of linear equations; vector spaces; linear dependence; bases; dimension; linear mappings; matrices; determinants; quadratic forms; eigenvalues; orthogonal reduction to diagonal form; and geometric applications.

**APMA 310 - 3 (S)**

**Probability**

Prerequisite: APMA 212 or equivalent. A calculus-based introduction to probability theory and its applications in engineering and applied science. Includes counting techniques, conditional probability, independence, discrete and continuous random variables, expected value and variance, joint distributions, covariance, correlation, Central Limit theorem, an introduction to statistical inference.

**APMA 311 - 3 (S)**

**Applied Statistics and Probability**

Prerequisite: APMA 212 or equivalent. Examines variability and its impact on deci-
APMA 312 - (3) (S)
Statistics
Prerequisite: APMA 310 or equivalent.
Includes confidence interval and point estimation methods, hypothesis testing for single samples, inference procedures for single-sample and two-sample studies, and multifactor analysis of variance techniques. Linear and non-linear regression and correlation, and using Minitab for large data sets. Students cannot receive credit for both this course and APMA 311.

APMA 314 - (3) (S)
Applied Partial Differential Equations
Prerequisites: APMA 212 and 213 or equivalents.
Partial differential equations that govern physical phenomena in science and engineering. Separation of variables, superposition, Fourier series, Sturm-Liouville eigenvalue problems, Green's function expansion techniques. Particular focus on the heat, wave, and Laplace equations in rectangular, cylindrical, and spherical coordinates.

APMA 334 - (3) (S)
Complex Variables with Applications
Prerequisite: APMA 212 or equivalent.
Topics include analytic functions, Cauchy formulas, power series, residue theorem, conformal mapping, and Laplace transforms.

APMA 495, 496 - (3) (Y)
Independent Reading and Research
Prerequisite: Fourth-year standing. Reading and research under the direction of a faculty member.

APMA 507 - (3) (SI)
Numerical Methods
Prerequisite: Two years of college mathematics, including some linear algebra and differential equations, and the ability to write computer programs in any language. Introduces techniques used in obtaining numerical solutions, emphasizing error estimation. Includes approximation and integration of functions, and solution of algebraic and differential equations.

Biomedical Engineering

BIOM 200 - (3) (Y)
Biomedical Engineering Design and Discovery
Prerequisite: CS 101, PHYS 142, and ENGR 162, or instructor permission. Provides overview of the BME discipline and major sub-disciplines (biomechanics, genetic engineering, tissue engineering, bioelectricity, imaging, cellular engineering, computational systems biology), covers conceptual and detail design processes, and introduces quantitative tools utilized throughout the BIOM curriculum. A major focus of the class will be formulation and execution of a design project.

BIOM 201 - (3) (Y)
Physiology I
Prerequisite: CHEM 151 and PHYS 241E, or instructor permission.
Studies how excitable tissue, nerves and muscle, and the cardiovascular and respiratory systems work. Focuses on understanding mechanisms, and includes an introduction to structure, an emphasis on quantitative functions, and integration of hormonal and neural regulation and control.

BIOM 202 - (3) (Y)
Physiology II
Prerequisite: BIOM 201 or instructor permission.
Introduces the physiology of the kidney, salt and water balance, gastrointestinal system, endocrine system, and central nervous system, with reference to diseases and their pathophysiology. (Circulation and respiration are covered in the fall semester course, BIOM 201).

BIOM 204 - (3) (Y)
Cell and Molecular Biology for Engineers
Prerequisite: CHEM 151 or instructor permission.
Introduces the fundamentals of cell structure and function, emphasizing the techniques and technologies available for the study of cell biology. A problem-based approach is used to motivate each topic. Divided into three general sections: cell structure and function includes cell chemistry, organelles, enzymes, membranes, membrane transport, intracellular compartments and adhesion structures; energy flow in cells concentrates on the pathways of glycolysis and aerobic respiration; information flow in cells focuses on modern molecular biology and genetic engineering, and includes DNA replication, the cell cycle, gene expression, gene regulation, and protein synthesis. Also presents specific cell functions, including movement, the cytoskeleton and signal transduction.

BIOM 310 - (3) (Y)
Biomedical Systems Analysis and Design
Prerequisite: APMA 213, CS 101, and PHYS 142, or instructor permission.
Presents the analytical tools used to model signals and linear systems. Specific biomedical engineering examples include multioperator modeling of drug delivery, modeling of dynamic biomechanical systems, and electrical circuit models of excitable cells. Major topics include terminology for signals and systems, convolution, continuous time Fourier transforms, Laplace transforms, electrical circuits with applications to bioinstrumentation and biosystems modeling, and applications of linear system theory. Students cannot receive credit for both this course and ECE 323.

BIOM 315 - (3) (Y)
Computational Biomedical Engineering
Prerequisite: BIOM 201, BIOM 204, or CHE 246, BIOM 310, and BIOM 322, or instructor permission.
Introduces techniques for constructing predictive or analytical engineering models for biological processes. Teaches modeling approaches using example problems in transport, mechanics, bioelectricity, molecular dynamics, tissue assembly, and imaging. Problem sets will include (1) linear systems and filtering, (2) compartmental modeling, (3) numerical techniques, (4) finite element/finite difference models, and (5) computational automata models.

BIOM 322 - (3) (Y)
Biomechanics/Biotransport
Prerequisite: APMA 212, APMA 213, and BIOM 201, or instructor permission. MAE 231 is helpful.
Introduces the principles of continuum mechanics of biological tissues and systems. Topics include (1) review of selected results from statics and strength of materials, continuum mechanics, free-body diagrams, constitutive equations of biological materials, viscoelastic models, and fundamental concepts of fluid mechanics and mass transport; (2) properties of living tissue; (3) mechanical basis and effects of pathology and trauma, (4) introduction to mechanotransduction, circulatory transport, growth and remodeling, and tissue-engineered materials, and (5) low Reynolds number flows in vivo and in microsystems.

BIOM 380 - (4) (Y)
Biomedical Engineering Integrated Design and Experimental Analysis (IDEAS) Laboratory I
Prerequisite: APMA 212, APMA 213, APMA 311, BIOM 201, BIOM 204, and BIOM 322, or instructor permission. Corequisite: BIOM 310 or instructor permission. First half of a year-long course to integrate concepts and skills from prior courses in order to formulate and solve problems in biomedical systems, including experimental design, performance, and analysis. Lab modules include testing in tissues/cells and manipulation of molecular constituents of living systems to determine their structural and functional characteristics for design of therapeutic or measurement systems. Methods include biochemical, physiological, cell biology, mechanical, electrical and computer systems, chemical, imaging, and other approaches.

BIOM 390 - (4) (Y)
Biomedical Engineering Integrated Design and Experimental Analysis (IDEAS) Laboratory II
Prerequisite: BIOM 380 or instructor permission.
Second half of a year-long course to integrate concepts and skills from prior courses in order to formulate and solve problems in biomedical systems, including experimental design, performance, and analysis. Lab mod-
ules include testing in tissues/cells and manipulation of molecular constituents of living systems to determine their structural and functional characteristics and to design measurement or therapeutic systems. Methods include biochemical, physiological, cell biology, mechanical, electrical and computer, systems, chemical, imaging, and other approaches.

BIOM 406 - (3) (SI)
Biomedical Applications of Genetic Engineering
Prerequisite: BIOM 201, 202, and 204 or CHE 246, and third- or fourth-year standing, or instructor permission.
Provides a grounding in molecular biology and a working knowledge of recombinant DNA technology, thus establishing a basis for the evaluation and application of genetic engineering in whole animal systems. Beginning with the basic principles of genetics, this course examines the use of molecular methods to study gene expression, deliver viral and non-viral vectors, and its critical role in health and disease.

BIOM 411 - (3) (Y)
Bioinstrumentation and Design
Prerequisite: BIOM 310 or ECE 203, or instructor permission.
Introduces transducers and instrumentation systems used in measuring biological variables. Discusses the physical, electromagnetic, and chemical principles of measurement, effects of interfaces between biological systems and sensors, and design tradeoffs. Surveys major electronic circuits and signal conditioning systems for biological and medical monitoring. Laboratory experiments involve construction and characterization of simple transducers, imaging systems, and signal conditioning equipment for biological variables, such as blood pressure, displacement, force, temperature, flow, and biopotentials. Exercises cover conceptual design to detailed design specifications for selected biomedical instrumentation systems.

BIOM 428 - (3) (SI)
Motion Biomechanics
Prerequisite: BIOM 201, 322, or instructor permission.
Focuses on the study of forces (and their effects) that act on the musculoskeletal structures of the human body. Based on the foundations of functional anatomy and engineering mechanics (rigid body and deformable approaches); students are exposed to clinical problems in orthopedics and rehabilitation.

BIOM 441 - (3) (SI)
Bioelectricity
Prerequisite: BIOM 310 or ECE 203, BIOM 201, or instructor permission.
Studies the biophysical mechanisms governing production and transmission of bioelectric signals, measurement of these signals and their analysis in basic and clinical electrophysiology. Introduces the principles of design and operation of therapeutic medical devices used in the cardiovascular and nervous systems. Includes membrane potential, action potentials, channels and synaptic transmission, electrodes, electroencephalography, electromyography, electrocardiography, pacemakers, defibrillators, and neural assist devices.

BIOM 453-454 - (3) (Y)
Biomedical Engineering Advanced Projects
Prerequisite: third- or fourth-year standing, and instructor permission.
A year-long research project in biomedical engineering conducted in consultation with a department faculty advisor; usually related to ongoing faculty research. Includes the design, execution, and analysis of experimental laboratory work and computational or theoretical computer analysis of a problem. Requires a comprehensive report of the results.

BIOM 463, 464 - (3) (Y)
Biomedical Engineering Capstone Design I & II
Prerequisite: APMA 212, 213, 311, BIOM 201, 204, 310, 380, fourth-year standing in BME major, or instructor permission.
A year-long design project in biomedical engineering required for BME majors. Students select, formulate, and solve a design problem - either for a device or system "design & build" project or a "design of experiment" research project. Projects use conceptual design, skills obtained in the integrated lab, and substantial literature and patent reviews. Projects may be sponsored by BME faculty, medical doctors, and/or companies. Students may work on their own with outside team members when appropriate or with other SEAS students in integrative teams.

BIOM 483 - (3) (Y)
Medical Image Modalities
Prerequisite: BIOM 310 or ECE 323, or instructor permission.
An overview of modern medical imaging modalities with regard to the physical basis of image acquisition and methods of image reconstruction. Topics cover the basic engineering and physical principles underlying the major medical imaging modalities: x-ray (plain film, mammography, and computed tomography (CT)), nuclear medicine (positron-emission tomography (PET) and single-photo-emission computed tomography (SPECT)), ultrasound, and magnetic resonance imaging (MRI). Taught concurrent with BIOM 783.

BIOM 484 - (4) (SI)
Medical Image Analysis
Prerequisite: BIOM 310, ECE 323, or instructor permission.
Introduces the fundamental principles of medical image analysis and visualization. Focuses on the processing and analysis of ultrasound, MR, and X-ray images for the purpose of quantitation and visualization to increase the usefulness of modern medical image data. Includes image perception and enhancement, 2-D Fourier transform, spatial filters, segmentation, and pattern recognition. A weekly lab develops skill in computer image analysis with the KHOROS system.

BIOM 490 - (4) (SI)
Molecular Bioengineering
Prerequisite: BIOM 204 or CHE 246, BIOM 322, fourth-year standing, or instructor permission; CHE 321 is also recommended as a prerequisite or corequisite.
Uses a problem-based approach to examine a number of current bioengineering technologies applicable to tissue engineering, wound healing, drug delivery, and gene delivery. Special topics include microfluidics and low Reynolds number hydrodynamics, molecular mechanics related to cell and microparticle sorting, and micropatterning surfaces for cell and tissue engineering.

BIOM 495, 496 - (3) (SI)
Special Topics in Biomedical Engineering
Prerequisite: third- or fourth-year standing and instructor permission.
Applies engineering science, design methods, and system analysis to developing areas and current problems in biomedical engineering. Topics vary by semester. Recent topics include tissue engineering and biomedical imaging systems theory.

BIOM 499 - (1-3) (S)
Independent Study
Prerequisite: instructor permission.
In-depth study of a biomedical engineering area by an individual student in close collaboration with a departmental faculty member. Requires advanced analysis of a specialized topic in biomedical engineering that is not covered by current offerings. Requires faculty contact time and assignments comparable to regular course offerings.

Chemical Engineering

CHE 202 - (3) (S)
Thermodynamics
Corequisite: APMA 212.
Includes the formulation and analysis of the first and second laws of thermodynamics; energy conservation; concepts of equilibrium, temperature, energy, and entropy; equations of state; processes involving energy transfer as work and heat; reversibility and irreversibility; and closed and open systems and cyclic processes. Cross-listed as MAE 210.

CHE 215 - (3) (Y)
Material and Energy Balances
Prerequisite: CHEM 151, APMA 111.
Introduces the field of chemical engineering, including material and energy balances applied to chemical processes, physical and thermodynamic properties of multicomponent systems. Three lecture and one discussion hour.

CHE 216 - (3) (Y)
Modeling and Simulation in Chemical Engineering
Prerequisite: CS 101, CHE 213, 215.
Mathematical and computational tools for the analysis and simulation of chemical processes and physicochemical phenomena. Mathematical and numerical methods. Three lecture and one laboratory hour.
CHE 246 - (3) (Y)
Introduction to Biotechnology
Prerequisite: CHEM 151.
Introduction to the fundamentals of biochemistry and molecular and cell biology emphasizing their relevance to industrial applications of biotechnology. Three lecture hours.

CHE 316 - (3) (Y)
Chemical Thermodynamics
Prerequisite: CHE 202, 215, or equivalent.
Principles of chemical thermodynamics further developed and applied. Emphasizes phase and chemical equilibria calculations. Three lecture hours.

CHE 318 - (3) (Y)
Chemical Reaction Engineering
Prerequisite: CHE 216, 316; corequisite: CHE 322.
Determination of rate equations for chemical reactions from experimental data. Use of kinetics and transport relations in the design of both batch and continuous reactors; homogeneous, heterogeneous, uncatalyzed and catalyzed reactions. Three lecture hours.

CHE 321 - (4) (Y)
Transport Processes I: Momentum and Heat Transfer
Prerequisite: CHE 215, 216.
Development and application of the concepts of momentum and heat transfer to chemical processing operations, emphasizing continuous operations. Four lecture hours.

CHE 322 - (4) (Y)
Transport Processes II: Mass Transfer and Separations
Prerequisite: CHE 216, 316, and 321.
Fundamental concepts of diffusion and mass transfer. Application to continuous contactin in separation devices. Material and energy conservation calculations for equilibrium stage processes, including multistage, multi-component calculations as involved in distillation, absorption, and extraction systems. Four lecture hours.

CHE 347 - (3) (Y)
Biochemical Engineering
Prerequisite: CHE 246, CHE 321, or instructor permission; corequisite: CHE 322 or instructor permission.
Quantitative engineering aspects of industrial applications of biology including the microbial synthesis of commercial products, environmental biotechnology, and the manufacture of biopharmaceuticals through recombinant microorganisms, transgenic animals, and plants. Three lecture hours.

CHE 398 - (3) (Y)
Chemical Engineering Laboratory I
Prerequisite: CHE 215 and 321.
Experimental study of selected operations and phenomena in fluid mechanics and heat transfer. Students plan experiments, analyze data, calculate results and prepare written and/or oral planning and final technical reports. One hour discussion, four laboratory hours.

CHE 438 - (3) (Y)
Process Modeling, Dynamics, and Control
Prerequisite: CHE 318 and 322.
Introduction to the dynamics and control of process systems, controller, sensors, and final control elements. Time and frequency domain characterization of these subsystems are developed and employed in stability analysis of closed control loops. Design of simple process control systems. Three lecture hours.

CHE 442 - (3) (Y)
Applied Surface Chemistry
Prerequisite: Instructor permission.
Factors underlying interfacial phenomena, emphasizing thermodynamics of surfaces, structural aspects, and electrical phenomena. Application to areas such as emulsification, foaming, detergency, sedimentation, fluidization, nucleation, wetting, adhesion, flotation, and electrophoresis. Three lecture hours.

CHE 448 - (3) (Y)
Bioseparations Engineering
Prerequisite: CHE 322 or instructor permission.
Principles of bioseparations engineering, including specialized unit operations not normally covered in regular chemical engineering courses. Processing operations down-stream of the initial manufacture of biotechnology products, including product recovery, separations, purification, and ancillary operations such as sterile processing, clean-in-place and regulatory aspects. Three lecture hours.

CHE 449 - (3) (Y)
Polymer Chemistry and Engineering
Prerequisite: CHE 321 or instructor permission.
Analyzes the mechanisms and kinetics of various polymerization reactions; relations between the molecular structure and polymer properties, and how these properties can be influenced by the polymerization process; fundamental concepts of polymer solution and melt rheology. Applications to polymer processing operations, such as extrusion, molding, and fiber spinning. Three lecture hours.

CHE 461, 462 - (3) (SI)
Special Topics in Chemical Engineering
Prerequisite: Fourth-year standing and instructor permission.
Applications engineering science, design methods, and system analysis to developing areas and current problems in chemical engineering. Topics are announced at registration.

CHE 476 - (3) (Y)
Chemical Engineering Design
Prerequisite: CHE 216, 318, and 322.
Application of academically acquired skills to the practice of chemical engineering in an industrial environment: industrial economics; process synthesis and selection; flow sheet development; equipment sizing; plant layout and cost estimation. Report preparation and oral presentations. Use of commercial process simulation software. Two lecture hours, two discussion hours, and design laboratory.

CHE 491 - (3) (Y)
Chemical Engineering Laboratory II
Prerequisite: CHE 318, 322, and 398.
Continuation of CHE 398; emphasizes separations, chemical reaction, and process dynamics and control. One discussion and four laboratory hours.

CHE 495, 496 - (1-3) (S)
Chemical Engineering Research
Prerequisite: Instructor permission.
Library and laboratory study of an engineering or manufacturing problem conducted in close consultation with a departmental faculty member, often including the design, construction, and operation of laboratory scale equipment. Requires progress reports and a comprehensive written report.

Chemistry

CHEM 151, 152 - (3) (Y)
Introductory Chemistry for Engineers
Corequisite: CHEM 151L and 152L, or CHEM 181L and 182L.
Develops the principles and applications of chemistry. Topics include stoichiometry, chemical equations and reactions, chemical bonding, states of matter, thermodynamics, chemical kinetics, equilibrium, acids and bases, electrochemistry, nuclear chemistry, and descriptive chemistry of the elements. Designed for engineering students and may be used as a prerequisite for further courses in chemistry. Three class hours.

CHEM 151L, 152L - (1) (Y)
Introductory Chemistry for Engineers Laboratory
Corequisite: CHEM 151 and 152.
Investigates the practice of chemistry as an experimental science; the development of skills in laboratory manipulation; laboratory safety; observation, measurement, and data analysis; separation and purification techniques; and qualitative and quantitative analysis. Three and one-half laboratory hours. Meets every other week.

CHEM 212 - (3) (Y)
Introduction to Organic Chemistry
Prerequisite: One semester of general chemistry; corequisite: CHEM 212L.
Introduces the nomenclature, structure, reactivity, and applications of organic compounds, including those of importance in the chemical industry. Three lecture hours.

CHEM 212L - (1) (Y)
Introduction to Organic Chemistry Laboratory
Corequisite: CHEM 212.
Six-to-seven four-hour laboratory sessions and an equal number of one-hour laboratory lectures to accompany CHEM 212.

Civil Engineering

CE 201 - (3) (Y)
Civil Engineering Techniques
Prerequisite: ENGR 162 and Civil Engineering major.
This course will introduce and familiarize students with fundamental knowledge and skills
necessary for civil engineering project design and development. The focus is on: engineering economics, surveying, and engineering graphics. Particular emphasis is placed on providing hands-on experience with the latest equipment and technology used in the profession. The course serves as a foundation for higher-level civil engineering design courses and as the cornerstone of the Infrastructure Management proficiency area.

CE 205 - (3) (Y)
Introduction to Environmental Engineering
Prerequisite: College chemistry.
Focuses on society’s interaction with water, air, and soil systems. Management of these major environmental components is examined, considering health and ecological needs and technical limitations. This course may stand alone as introduction to the current environmental challenges that we face, or as the foundation for further study in the field of environmental engineering.

CE 230 - (3) (Y)
Statics
Prerequisite: PHYS 142E.
Basic concepts of mechanics: systems of forces and couples; equilibrium of particles and rigid bodies; analysis of structures: trusses, frames, machines; internal forces, shear and bending moment diagrams; distributed forces; friction, centroids and moments of inertia; principle of virtual work; and computer applications. Cross-listed as MAF 230.

CE 231 - (4) (Y)
Strength of Materials
Prerequisite: CE 230, APMA 212.
Stress and strain definitions: Normal stress and strain, thermal strain, shear stress, shear strain; transformations of stress and strain; Mohr’s circle for plane stress and strain; stresses due to combined loading; axially loaded members; torsion of circular and thin-walled closed sections; deformation, strains and stresses in beams; deflections of beams; stability of columns; and energy concepts in mechanics. Cross-listed as MAF 231.

CE 232 - (3) (Y)
Dynamics
Prerequisite: PHYS 142E and CE 230.
Reviews kinematics and kinetics of particles and the kinematics of rigid bodies, including translation and fixed-axis rotation relative to translating axes; general planar motion; fixed point rotation; and general motion and the kinetics of rigid bodies, specifically center of mass, mass moment of inertia, product of inertia, principal-axes, parallel axis theorems, planar motion, and the work-energy method. Cross-listed as MAF 232.

CE 235 - (3) (Y)
Fluid Mechanics
Prerequisite: CE 230 or equivalent.
Studies the statics and dynamics of incompressible fluids, primarily water. The basic principles of fluid flow, energy equation, and momentum equation, are presented and applied to closed conduit flow, open channel flow, and problems of flow measurement pertinent to civil engineering practices.

CE 316 - (4) (Y)
Introduction to Geotechnical Engineering
Prerequisite: CE 231.
Introduces the fundamental principles of particulate mechanics with an emphasis on soil strength, consolidation behavior, and fluid flow. Concepts of theoretical soil mechanics and soil physics combined with laboratory investigation of soil behavior. Three lecture and three laboratory hours.

CE 319 - (3) (Y)
Structural Mechanics
Prerequisite: CE 231.

CE 323 - (3) (Y)
Properties and Behavior of Materials
Prerequisite: CE 231.
Studies the properties and behavior of engineering materials, emphasizing construction materials, including metals, concrete, wood, and composites. Considers service conditions and underlying scientific principles related to applications and performance of materials.

CE 326 - (3) (Y)
Design of Concrete Structures
Prerequisite: CE 319.
Introduces physical properties of concrete and reinforcing steel. Design and analysis of basic structural elements of reinforced concrete including beams, slabs, columns, and footings. Consideration of construction practices and building codes.

CE 330 - (3) (SI)
Water for the World
This course examines complex issues associated with providing potable water to the world’s population. Topics include the use of surface and ground water as potable water supplies, the fundamentals of water chemistry, the science and engineering principles used in the design of modern water and wastewater treatment and distribution systems, and the problems associated with providing potable water in economically disadvantaged communities, refugee camps, and developing and underdeveloped countries, including shortages of resources, lack of government support, inadequate institutional structures, and lack of local interest/acceptance.

CE 336 - (3) (Y)
Water Resources Engineering
Prerequisite: CE 315.
Principles of fluid mechanics and hydrology, including open channel and groundwater flow, rainfall, evaporation, and surface runoff applied to water resources development and management. Applications include water supply, drainage, flood control, and water control, emphasizing computer simulation tools.

CME 341 - (3) (IR)
Civil Engineering Systems Analysis
Introduces the tools of operations research and engineering economy as applied to civil engineering problems; problem formulation, linear programming, economic analysis, and decision analysis; optimization, minimum cost and utility methods; and application to structural optimization, traffic flow, resource allocation and environmental design.

CE 344 - (3) (Y)
Transportation Infrastructure Design
Prerequisite: Third-year standing in Civil Engineering or instructor permission. Analyzes the characteristics of the driver, pedestrian, vehicle, and road; highway surveys and locations; geometric design, horizontal and vertical alignment of highway cross sections, highway drainage and drainage structures; and highway pavement design.

CE 363 - (1) (Y)
Materials Laboratory
Corequisite: CE 351.
Laboratory study of the macroscopic mechanical, thermal, and time-dependent properties and behaviors of typical civil engineering construction materials (metals, concrete, wood, plastics). Students plan and conduct experiments, and prepare written reports.

CE 365 - (1) (Y)
Fluid Mechanics Laboratory
Corequisite: CE 315.
Laboratory study of the flow of fluids. Uses laboratory data to quantify hydrostatic forces, flow rates in pipes and open channels, forces due to impact, and flow regimes in open channels. Student conduct experiments and prepare written reports.

CE 401 - (3) (Y)
Design of Metal Structures I
Prerequisite: CE 231, 319, or instructor permission.
Introduction to the design/construction process in the context of a real civil engineering project; provides the opportunity for the students to work in multidisciplinary teams and demonstrate teamwork and leadership; application of practical civil engineering design methods; consideration of environmental and transportation concerns of civil engineering projects; illustrates professional practice and ethical issues associated with engineering projects; and introduces and applies modern technology for document preparation and engineering graphics. The course culminates in a project plan for a specific site.

CE 402 - (3) (Y)
Design of Metal Structures II
Prerequisite: CE 401.
Analyzes the behavior and design of continuous beams, plate girders, composite steel-concrete members, members subjected to combined bending and compression, and eccentric connections using LRFD design approach; and torsion and torsional stability of structural members.
provide the theoretical background that pertains directly to the laboratory for that week. Topics covered are relevant to water and wastewater treatment operations, ground- and surface-water hydrology, and the fate and transport of pollutants in the environment.

CE 426 - (3) (Y)
Environmental Systems Management
Prerequisite: CE 315.
Emphasizes the formulation of environmental management issues as optimization problems. Simulation models are presented and combined with optimization algorithms. Environmental systems addressed include stream quality, air quality, water supply, waste management, groundwater remediation, and reservoir operations. Optimization techniques presented include linear, integer, and separable programming, dynamic programming, nonlinear programming and genetic algorithms.

CE 430 - (3) (Y)
Environmental Engineering
Prerequisite: CE 316. Analyzes the design of unit processes used to treat and manage water and wastewater associated with people and the environment. Process considerations include pump systems, mixing, sedimentation, filtration, precipitation, coagulation, disinfection, and biological oxidation. Presents principles of design and design practices used in physical, chemical, and biological treatment are presented.

CE 431 - (4) (Y)
Foundations Engineering
Prerequisite: CE 316 and 325. Analyzes the methods and purposes of subsurface exploration; control of ground water; excavations; sheeting and bracing design; shallow foundations; bearing capacity and settlement analyses; deep foundation—piers, piles, caissons and cofferdams; underpinning; and the legal aspects of foundation engineering.

CE 432 - (3) (Y)
Advanced Reinforced Concrete Design
Prerequisite: CE 326.
Design of building and bridge components, including floor systems, rigid frames, retaining walls, and tanks. Introduction to prestressed concrete.

CE 434 - (3) (Y)
Construction Engineering and Economics
Prerequisite: CE 322 or equivalent.
Lectures alternate between hands-on-laboratory, field, and computer experiments, and demonstrations of advanced analytical instrumentation or field sampling procedures. Weekly lectures provide the theoretical background that pertains directly to the laboratory for that week. Topics covered are relevant to water and wastewater treatment operations, ground- and surface-water hydrology, and the fate and transport of pollutants in the environment.

CE 435 - (3) (Y)
Environmental Systems Management
Prerequisite: CE 326.
Emphasizes the formulation of environmental management issues as optimization problems. Simulation models are presented and combined with optimization algorithms. Environmental systems addressed include stream quality, air quality, water supply, waste management, groundwater remediation, and reservoir operations. Optimization techniques presented include linear, integer, and separable programming, dynamic programming, nonlinear programming and genetic algorithms.

CE 440 - (3) (Y)
Groundwater Hydrology
Prerequisite: CE 315, 336, or equivalent.
Topics include Darcy’s Law, fluid potential, hydraulic conductivity, heterogeneity and anisotropy, the unsaturated zone, compressibility, transmissivity and storativity, the 3-D equation of groundwater flow, steady-state and transient regional groundwater flow, and well hydraulics, including discussions involving Theis’ Inverse Method, Jacob’s Method, slug test analyses, and the principle of superposition. Ground-water contamination and remediation techniques are introduced.

CE 441 - (3) (Y)
Traffic Operations
Prerequisite: CE 344 or instructor permission.
Analyzes traffic characteristics: the road user, the vehicle and roadway; traffic engineering studies: speed, volume, and delay; and intersection control, capacity, and level of service.

CE 444 - (3) (Y)
Introduction to Transportation Planning
Prerequisite: CE 344 or instructor permission.
Framework and principles of urban transportation planning; transportation decision making; transportation data and information systems; analysis and evaluation of alternatives; forecasts of population and socioeconomic activity; small area land use allocation; introduction to supply-demand equilibrium, trip generation, trip distribution, modal choice, traffic assignment; quick response model applications.

CE 445 - (3) (Y)
Information Systems
Prerequisite: CE 446 or instructor permission.
Introduces engineering problem-solving using geographic information systems (GIS). GIS has proven to be an effective tool in Civil Engineering applications that include a significant spatial component. Focuses on the fundamental concepts of GIS, the top-down process required to effectively use advanced information technology tools, and the acquisition of hands-on experience in GIS problem-solving using the Arc GIS package. Provides experience with the GIS application process, rather than expertise in a particular GIS software package.

CE 451, 452 - (3) (SI)
Special Topics in Civil Engineering
Prerequisite: Fourth-year standing and instructor permission.
Applies basic engineering principles, analytical procedures and design methodology to
special problems of current interest in civil engineering. Topic(s) for each semester are announced at the time of course enrollment.

CE 455 - (3) (IR) Mechanics of Composite Materials
Prerequisite: CE 231.
Introduces engineering properties and advantages of advanced fibrous composites; anisotropic, thermo-mechanical constitutive theory for plane stress analysis; thermal-mechanical stress analysis of laminates subjected to inplane and bending loads; engineering properties of laminates; test methods and material response (in the laboratory); designing with composites; computer implementation. Cross-listed as MAE 454.

CE 456 - (3) (IR) Environmental Systems Management
Prerequisite: Fourth-year standing.
Emphasizes the formulation of environmental management issues as optimization problems. Simulation models are presented and then combined with optimization algorithms. Environmental systems addressed include stream quality, air quality, water supply, waste management, groundwater remediation, and reservoir operations. Optimization techniques presented include linear, integer, and separable programming, dynamic programming, nonlinear programming and genetic algorithms.

CE 461 - (3) (IR) Computer Applications in Civil Engineering
Prerequisite: Fourth-year standing.
Studies civil engineering problems and their solutions in a numerical context, using the digital computer; the formulation of these problems using various computational procedures; the development of typical algorithms; utilization of microcomputers, including structured programming with graphics. Emphasizes construction of numerical models for applications and the solution of representative multidimensional problems from all areas of civil engineering.

CE 462 - (3) (IR) Advanced Structural Analysis
Prerequisite: CE 319.
The general methods of analyzing indeterminate structures; fundamentals of structural theory, including virtual work and energy theorems; introduction to concepts of stiffness and flexibility; force and displacement methods of analysis, methods of consistent deformation, slope-deflection, moment distribution; and an introduction to matrix formulation.

CE 471 - (3) (Y) Introduction to Finite Element Methods
Prerequisite: CE 319.
Review of matrix operations. Introduces basic concepts of finite element analysis. Weighted residual (Galerkin) approach and variational (Rayleigh-Ritz) approach. One-dimensional and two-dimensional formulations; local vs. global coordinate systems; shape functions. Computational implementation and applications in the areas of structural analysis, steady-state fluid flow, and heat transfer.

CE 490 - (4) (Y) Civil Engineering Design and Practice
Prerequisite: Fourth-year standing.
This course will broaden a student's exposure to professional practice issues, including project planning and management, financial and contractual relationships. The major focus of the course will be providing practical civil engineering design experience. Students will participate in one or more multi-disciplinary team design projects requiring integration of technical skills from multiple sub-areas of civil engineering (structural, environmental and transportation systems) and application of managerial skills. Extension of design projects to undergraduate thesis projects is encouraged.

CE 495, 496 - (1-3) (SI) Civil Engineering Research
Prerequisite: Fourth-year standing.
Study of a civil engineering problem in depth by each student using library, computer, or laboratory facilities. The project is conducted in close consultation with departmental faculty and involves survey, analysis, or project development. Progress reports and a comprehensive written report are required. May be repeated if necessary.

Computer Science

CS 101 - (3) (S) Introduction to Programming
Prerequisite: Fourth-year standing.
Introduces the basic principles and concepts of object-oriented programming through a study of algorithms, data structures and software development methods in Java. Emphasizes both synthesis and analysis of computer programs.

CS 110 - (3) (S) Introduction to Information Technology
Prerequisite: CS 101 and 102 with grades of C-.
Provides exposure to a variety of issues in information technology, such as computing ethics and copyright. Introduces and provides experience with various computer applications, including e-mail, newsgroups, library search tools, word processing, Internet search engines, and HTML. Not intended for students expecting to do further work in CS. Cannot be taken for credit by students in SEAS or Commerce.

CS 120 - (3) (S) Introduction to Business Computing
Prerequisite: Second-year CS or CPE major.
Overview of modern computer systems and introduction to programming in Visual Basic, emphasizing development of programming skills for business applications. Intended primarily for pre-commerce students. May not be taken for credit by students in SEAS.

CS 201 - (3) (S) Software Development Methods
Prerequisite: CS 101 with a grade of C- or higher.
A continuation of CS 101, emphasizing modern software development methods. An introduction to the software development life cycle and processes. Topics include requirements analysis, specification, design, implementation, and verification. Emphasizes the role of the individual programmer in large software development projects.

CS 202 - (3) (S) Discrete Mathematics I
Prerequisite: CS 101 with grade of C- or higher.
Introduces discrete mathematics and proof techniques involving first order predicate logic and induction. Application areas include sets (finite and infinite), elementary combinatorial problems, and finite state automata. Development of tools and mechanisms for reasoning about discrete problems. Cross-listed as APMA 202.

CS 216 - (3) (S) Program and Data Representation
Prerequisite: CS 201 and 202 with grades of C- or higher.
Introduces programs and data representation at the machine level. Data structuring techniques and the representation of data structures during program execution. Operations and control structures and their representation during program execution. Representations of numbers, arithmetic operations, arrays, records, recursion, hashing, stacks, queues, trees, graphs, and related concepts.

CS 230 - (3) (S) Digital Logic Design
Prerequisite: CE 231.
Includes number systems and conversion; Boolean algebra and logic gates; minimization of switching functions; combinational network design; flip-flops; sequential network design; arithmetic networks. Introduces computer organization and assembly language. Cross-listed as ECE 230.

CS 290 - (1) (Y) Computer Science Seminar I
Prerequisite: Second-year CS or CPE major.
Provides cultural capstone to the undergraduate experience. Students make presentations based on topics not covered in the traditional curriculum. Emphasizes learning the mechanisms by which researchers and practicing computer scientists can access information relevant to their discipline, and on the professional computer scientist’s responsibility in society.

CS 302 - (3) (Y) Discrete Mathematics II
Prerequisite: CS 201 and 202 with grades of C-.
Introduces computation theory including grammars, finite state machines and Turing machines; and graph theory. Also demonstrates the importance of these topics through several software projects. Cross-listed as APMA 302.

CS 305 - (3) (Y) HCI in Software Development
Prerequisite: CS 201 with a grade of C- or higher.
Human-computer interaction and user-centered design in the context of software engineering. Examines the fundamental principles of human-computer interaction. Includes evaluating a system’s usability based on well-defined criteria; user and task analysis, as well as conceptual models and metaphors;
the use of prototyping for evaluating design alternatives; and physical design of software user-interfaces, including windows, menus, and commands.

**CS 333 - (3) (S)**
**Computer Architecture**
*Prerequisite:* CS 201 and ECE/CS 230 with grades of C- or higher.
Includes the organization and architecture of computer systems hardware; instruction set architectures; addressing modes; register transfer notation; processor design and computer arithmetic; memory systems; hardware implementations of virtual memory, and input/output control and devices. Cross-listed as ECE 333.

**CS 340 - (3) (Y)**
**Advanced Software Development Techniques**
*Prerequisite:* CS 216 with a grade of C- or higher.
Introduces artificial intelligence. Covers fundamental concepts of programming languages and techniques; and large project management approaches; project planning, scheduling, resource management, accounting, configuration control, and documentation.

**CS 414 - (3) (Y)**
**Operating Systems**
*Prerequisite:* CS 216 and CS 333 with grades of C- or higher.
Investigates techniques for designing and analyzing dependable computer-based systems. Topics include fault models and effects; fault avoidance techniques; hardware redundancy; error detecting and correcting codes; time redundancy, software redundancy, combinatorial reliability modeling; Markov reliability modeling; availability modeling, maintainability, safety modeling; trade-off analysis; design for testability; and the testing of redundant digital systems. Cross-listed as ECE 434.

**CS 415 - (3) (Y)**
**Programming Languages**
*Prerequisite:* CS 216 and CS 333 with grades of C- or higher.
Prresents the fundamental concepts of programming language design and implementation. Emphasizes language paradigms and implementation issues. Develops working programs in languages representing different language paradigms. Many programs oriented toward language implementation issues.

**CS 416 - (3) (Y)**
**Artificial Intelligence**
*Prerequisite:* CS 201, 202, and 216 with grades of C- or higher (programming experience at the CS 216 level can satisfy the 216 requirement).
Introduces artificial intelligence. Covers fundamental concepts and techniques and surveys selected application areas. Core material includes state space search, logic, and resolution theorem proving. Application areas may include expert systems, natural language understanding, planning, machine learning, or machine perception. Provides exposure to AI implementation methods, emphasizing programming in Common LISP.

**CS 432 - (3) (Y)**
**Algorithms**
*Prerequisite:* CS 216 and 302 with grades of C- or higher.
Introduces the analysis of algorithms and the effects of data structures on them. Algorithms selected from areas such as sorting, searching, shortest paths, greedy algorithms, backtracking, divide and conquer, and dynamic programming. Data structures include heaps and search, splay, and spanning trees. Analytic techniques include asymptotic worst case, expected time, amortized analysis, and reductions between problems.

**CS 434 - (3) (Y)**
**Fault-tolerant Computing**
*Prerequisite:* CS 333, APMA 213, APMA 310, with grades of C- or higher.
Investigates techniques for designing and analyzing dependable computer-based systems. Topics include fault models and effects; fault avoidance techniques; hardware redundancy; error detecting and correcting codes; time redundancy, software redundancy, combinatorial reliability modeling; Markov reliability modeling; availability modeling, maintainability, safety modeling, trade-off analysis; design for testability; and the testing of redundant digital systems. Cross-listed as ECE 434.

**CS 445 - (3) (Y)**
**Introduction to Computer Graphics**
*Prerequisites:* CS 216 with a grade of C-.
Introduces the fundamentals of three-dimensional computer graphics: rendering, modeling, and animation. Students learn how to represent three-dimensional objects (modeling) and the movement of those objects over time (animation). Students learn and implement the standard rendering pipeline, defined as the stages of turning a three-dimensional model into a shaded, lit, texture-mapped two-dimensional image.

**CS 446 - (3) (Y)**
**Real Time Rendering**
*Prerequisite:* Grade of C- or better in CS 445 or equivalent working knowledge.
Examines real-time rendering of high-quality interactive graphics. Studies the advances in graphics hardware and algorithms that are allowing applications such as video games, simulators, and virtual reality to become capable of near cinematic-quality visuals at real-time rates. Topics include non-photorealistic rendering, occlusion culling, level of detail, terrain rendering, shadow generation, image-based rendering, and physical simulation. Over several projects throughout the semester students work in small teams to develop a small 3-D game engine incorporating some state-of-the-art techniques.

**CS 447 - (3) (Y)**
**Image Synthesis**
*Prerequisite:* Grade of C- or better in CS 445 or equivalent working knowledge.
Provides a broad overview of the theory and practice of rendering. Discusses classic rendering algorithms, although most of the course focuses on either fundamentals of image synthesis or current methods for physically based rendering. The final project is a rendering competition.

**CS 448 - (3) (Y)**
**Computer Animation**
*Prerequisite:* Grade of C- or better in CS 445 or equivalent working knowledge.
Introduces both fundamental and advanced computer animation techniques. Discusses such traditional animation topics as keyframing, procedural algorithms, camera control, and scene composition. Also introduces modern research techniques covering dynamic simulation, motion capture, and feedback control algorithms. These topics help prepare students for careers as technical directors in the computer animation industry and assist in the pursuit of research careers.

**CS 453 - (3) (Y)**
**Electronic Commerce Technologies**
*Prerequisite:* CS 340 with a grade of C- or higher.
History of Internet and electronic commerce on the web; case studies of success and failure; cryptographic techniques for privacy, security, and authentication; digital money; transaction processing; wired and wireless access technologies; Java; streaming multimedia; XML; Bluetooth. Defining, protecting, growing, and raising capital for an e-business.

**CS 457 - (3) (Y)**
**Computer Networks**
*Prerequisite:* CS 216 and CS 333 with grades of C- or higher.
Intended as a first course in communication networks for upper-level undergraduate students. Topics include the design of modern communication networks; point-to-point and broadcast network solutions; advanced issues such as Gigabit networks; ATM networks; and real-time communications. Cross-listed as ECE 457.

**CS 458 - (3) (Y)**
**Internet Engineering**
*Prerequisite:* CS/ECE 457 with a grade of C- or better.
An advanced course on computer networks on the technologies and protocols of the Internet. Topics include the design principles of the Internet protocols, including TCP/IP, the Domain Name System, routing protocols, and network management protocols. A set of laboratory exercises covers aspects of traffic engineering in a wide-area network.

**CS 462 - (3) (Y)**
**Database Systems**
*Prerequisite:* CS 202 and 216 with grades of C- or higher.
Introduces the fundamental concepts for design and development of database systems. Emphasizes relational data model and conceptual schema design using ER model, practical issues in commercial database systems, database design using functional dependencies, and other data models. Develops a working relational database for a realistic application.
CS 493 - (1-3) (S)
Independent Study
**Prerequisite:** Instructor permission.
In-depth study of a computer science or computer engineering problem by an individual student in close consultation with departmental faculty. The study is often either a thorough analysis of an abstract computer science problem or the design, implementation, and analysis of a computer system (software or hardware).

CS 494 - (1-3) (S)
Special Topics in Computer Science
**Prerequisite:** Instructor permission; additional specific requirements vary with topics. Content varies annually, depending on instructor interests and the needs of the department. Similar to CS 551 and CS 751, but taught strictly at the undergraduate level.

CS 551 - (1-3) (S)
Selected Topics in Computer Science
**Prerequisite:** Instructor permission. Content varies annually, depending on students’ needs and interests. Recent topics included the foundations of computation, artificial intelligence, database design, real-time systems, Internet engineering, and electronic design automation.

CS 586 - (3) (Y)
Introductory Circuit Analysis
**Prerequisite:** APMA 111. An introduction to the fundamental scientific principles governing information science and engineering. Topics include: definition of information, entropy, information representation in analog and digital forms, information transmission, spectrum and bandwidth, information transformation including data compression, filtering, encryption, and error correction; information storage and display; and large-scale information systems. Technologies for implementing information functions.

CS 588 - (3) (Y)
Cryptology: Principles and Applications
**Prerequisite:** CS 302 with a grade of C- or higher.
Introduces the basic principles and mathematical concepts of cryptography including information theory, classical ciphers, symmetric key cryptosystems and public-key cryptosystems. Develops applications of cryptography such as anonymous email, digital cash and code signing.

CS 571 - (3) (Y)
Translation Systems
**Prerequisite:** CS 302, 340, and 333 with grades of C- or higher.
Presents the theory, design, and specification of translation systems. Translation systems are the tools used to translate a source language program to a form that can be executed. Students design, specify, and implement various translators by applying classical translation theory using rigorous specification techniques to describe the inputs and outputs of the translators.

CS 587 - (3) (Y)
Security in Information Systems
**Prerequisite:** CS 340 and either CS/ECE 457 or CS 414 with grades of C- or higher.
This course focuses on security as an aspect of a variety of software systems. We will consider software implementations of security related policies in the context of operating systems, networks, and data bases. Topics include: operating system protection mechanisms, intrusion detection systems, formal models of security, cryptography and associated security protocols, data base security, worms, viruses, network and distributed system security, and policies of privacy and confidentiality.

ECE 200 - (3) (S)
Science of Information
An introduction to the fundamental scientific principles governing information science and engineering. Topics include: definition of information, entropy, information representation in analog and digital forms, information transmission, spectrum and bandwidth, information transformation including data compression, filtering, encryption, and error correction; information storage and display; and large-scale information systems. Technologies for implementing information functions.

ECE 203 - (3) (S)
Introductory Circuit Analysis
**Prerequisite:** APMA 111. Elementary electrical circuit concepts and their application to linear circuits with passive elements; use of Kirchhoff’s voltage and current laws to derive circuit equations; solution methods for first- and second-order transient and DC steady-state responses; AC steady-state analysis; frequency domain representation of signals; trigonometric and complex Fourier series; phasor methods; complex impedance; transfer functions and resonance; Thévenin/Norton equivalent models; controlled sources. Six laboratory assignments.

ECE 204 - (4) (Y)
Electronics I
**Prerequisite:** ECE 203. Studies the modeling, analysis, design, computer simulation, and measurement of electrical circuits which contain non-linear devices such as junction diodes, bipolar junction transistors, and field effect transistors. Includes the gain and frequency response of linear amplifiers, power supplies, and other practical electronic circuits. Three lecture and three laboratory hours.

ECE 230 - (3) (S)
Digital Logic Design
Includes number systems and conversion; Boolean algebra and logic gates; minimization of switching functions; combinational network design; flip-flops; sequential network design; arithmetic networks. Introduces computer organization and assembly language. Six laboratory assignments. Cross-listed as CS 230.

ECE 303 - (3) (Y)
Solid State Devices
**Prerequisite:** ECE 203.
Analyzes the basics of band theory and atomic structure; charge-transport in solids; current voltage characteristics of semiconductor devices, including p-n junction diodes, bipolar transistors, Schottky diodes, and insulated-gate field-effect transistors; electron emission; and superconductive devices.

ECE 307 - (4) (Y)
Electronics II
**Prerequisite:** ECE 204.
Construction of electronic circuit design to specifications. Focuses on computer simulation, construction, and testing of designed circuits in the laboratory to verify predicted performance. Includes differential amplifiers, feedback amplifiers, multivibrators, and digital circuits. Three lecture and three laboratory hours.

ECE 309 - (3) (Y)
Electromagnetic Fields
**Prerequisite:** PHYS 241E, APMA 213, and ECE 203.
Analyzes the basic laws of electromagnetic theory, beginning with static electric and magnetic fields, and concluding with dynamic E&M fields; plane wave propagation in various media; Maxwell’s Laws in differential and integral form; electrical properties of matter; transmission lines, waveguides, and elementary antennas.

ECE 310 - (4) (Y)
Electromechanical Energy Conversion
**Prerequisite:** ECE 203, PHYS 241E, and CS 101, or instructor permission.
Analyzes the principles of electromechanical energy conversion; three-phase circuit analysis; magnetic circuits and nonlinearity; transformers; DC, synchronous, and induction machines; equivalent circuit models; power electronic control of machines. Laboratory, computer, and design exercises complement coverage of fundamental principles.

ECE 323 - (3) (Y)
Signals and Systems I
**Prerequisite:** ECE 203 and APMA 213.
Develops tools for analyzing signals and systems operating in continuous-time, with applications to control, communications, and signal processing. Primary concepts are representation of signals, linear time-invariant systems, Fourier analysis of signals, frequency response, and frequency-domain input/output analysis, the Laplace transform, and linear feedback principles. Practical examples are employed throughout, and regular usage of computer tools (Matlab, CC) is
ECE 324 - (3) (Y)
Signals and Systems II
Prerequisite: ECE 323.
Sequel to ECE 323; provides analogous tools for analyzing discrete-time signals and systems, with applications to discrete-time signal processing and control. Sampling and reconstruction of continuous-time signals provides the transition between CT and DT settings. State space methods are also introduced.

ECE 333 - (2) (S)
Computer Architecture
Prerequisite: CS 201 and ECE/CS 230 with grades of C- or higher.
Includes the organization and architecture of computer systems hardware; instruction set architectures; addressing modes; register transfer notation; processor design and computer arithmetic; memory systems; hardware implementations of virtual memory, and input/output control and devices. Cross-listed as CS 333.

ECE 363 - (2) (Y)
Digital Integrated Circuits
Prerequisite: ECE/CS 230 and ECE 204.

ECE 402 - (3) (Y)
Linear Control Systems
Prerequisite: ECE 323 or instructor permission.
Explores the modeling of linear dynamic systems via differential equations and transfer functions utilizing state space representations and classical input-output representations; the analysis of systems in the time and frequency domains; study of closed-loop systems; state-space methods and the classical stability tests, such as the Routh-Hurwitz criterion, Nyquist criterion, root-locus plots and Bode plots. Studies compensation design through lead and lag networks, rate feedback, and linear state-variable feedback.

ECE 403 - (1.5) (Y)
Control Laboratory
Corequisite: ECE 402.
A laboratory consisting of design, analysis, construction, and testing of electrical and electromechanical circuits and devices.

ECE 407, 408 - (1-3) (SI)
Electrical Engineering Projects
Prerequisite: Instructor permission. Under faculty supervision, students plan a project of at least one semester's duration, conduct the analysis or design and test, and report on the results. If this work is to be the basis for an undergraduate thesis, the course should be taken no later than the seventh semester.

ECE 409 - (3) (Y)
RF Circuit Design and Wireless Systems
Prerequisite: ECE 309, 307, 323.
Design and analysis of wireless communication circuits. Topics covered include transmission lines, antennas, filters, amplifiers, mixers, noise, and modulation techniques. The course is built around a semester long design project.

ECE 410 - (1.5) (Y)
Electromechanical Energy Conversion Laboratory
Prerequisite: ECE 203 and PHYS 241.
Laboratory investigations of electromechanical energy conversion. Includes three-phase circuit analysis; magnetic coupling, magnetic forces, and nonlinearity; transformers; DC, synchronous and induction machines; equivalent circuit models; and power electronic control of machines.

ECE 411 - (3) (SI)
Bioelectricity
Prerequisite: ECE 203, BIOM 201, or instructor permission.
Studies the biophysical mechanisms governing production and transmission of bioelectric signals, measurement of these signals and their analysis in basic and clinical electrophysiology. Introduces the principles of design and operation of therapeutic medical devises used in the cardiovascular and nervous systems. Includes membrane potential, action potentials, channels and synaptic transmission, electrodes, electrocardiography, pacemakers, defibrillators, and neural assist devices. Cross-listed as BIOM 441.

ECE 412 - (3) (Y)
Digital Control Systems
Prerequisite: ECE 402 or instructor permission.
Analyzes the design of dynamic systems that contain digital computers; the Z transform; block diagrams and transfer functions in the z-domain; block diagrams, frequency response and stability in the z-domain; state space methods; and design using the z-transform and state methods.

ECE 415 - (1.5) (Y)
Microelectronic Integrated Circuit Fabrication Laboratory
Corequisite: ECE 564.
Fabrication and testing of MOS capacitors. Determination of material properties, including carrier concentration, mobility, lifetime, orientation, and layer thickness. Device fabrication using oxidation, diffusion, evaporation, and device testing of MOS and power bipolar transistors.

ECE 420 - (3) (Y)
Communications
Prerequisite: APMA 310, ECE 324.
Explores the statistical methods of analyzing communications systems: random signals and noise, statistical communication theory, and digital communications. Analysis of baseband and carrier transmission techniques; and design examples in satellite communications.

ECE 422 - (1.5) (Y)
Communication Systems Laboratory
Prerequisite: ECE 324; corequisite: ECE 420.
Provides first-hand exposure to communications practice, including response of systems, signal theory, modulation and detection, sampling and quantization, digital signal processing, and receiver design.

ECE 434 - (3) (Y)
Fault-Tolerant Computing
Prerequisite: ECE/CS 333, APMA 213 and 310 or equivalent, with grades of C- or higher, or instructor permission.
Focuses on the techniques for designing and analyzing dependable computer-based systems. Topics include fault models and effects, fault avoidance techniques, hardware redundancy, error detecting and correcting codes, time redundancy, software redundancy, combinatorial reliability modeling, Markov reliability modeling, availability modeling, maintainability, safety modeling, trade-off analysis, design for testability, and the testing of redundant digital systems. Cross-listed as CS 434.

ECE 435 - (4.5) (Y)
Computer Organization and Design
Prerequisite: ECE 333 or instructor permission.
Integration of computer organization concepts, such as data flow, instruction interpretation, memory systems, interfacing, and microprogramming with practical and systematic digital design methods such as behavioral versus structural descriptions, divide-and-conquer, hierarchical conceptual levels, trade-offs, iteration, and postponement of detail. Design exercises are accomplished using a hardware description language and simulation.

ECE 436 - (4.5) (Y)
Advanced Digital Design
Prerequisite: ECE 435.
Analyzes digital hardware and design; digital system organization; digital technologies; and testing. A semester-long hardware design project is conducted.

ECE 457 - (3) (Y)
Computer Networks
Corequisite: CS 333.
A first course in communication networks for upper-level undergraduate students. Topics include the design of modern communication networks; point-to-point and broadcast network solutions; advanced issues such as Gigabit networks; ATM networks; and real-time communications. Cross-listed as CS 457.

ECE 473 - (3) (Y)
Analog Integrated Circuits
Prerequisite: ECE 303 and 307.
Topics include the design and analysis of analog integrated circuits; feedback amplifier analysis and design, including stability, compensation, and offset-correction; layout and floor-planning issues associated with mixed-signal IC design; selected applications of analog circuits such as A/D and D/A converters, references, and comparators; extensive use of CAD tools for design entry, simulation, and layout; and the creation of an analog integrated circuit design project.
ECE 482 - (1.5) (Y)
Microwave Engineering Laboratory
Corequisite: ECE 556 or instructor permission.
Analyzes the measurement and behavior of high-frequency circuits and components; equivalent circuit models for lumped elements; measurement of standing waves, power, and frequency; use of vector network analyzers and spectrum analyzers; and computer-aided design, fabrication, and characterization of microstrip circuits.

ECE 484 - (2) (O)
Wireless Communications
Prerequisite: ECE 423 and 420.
This is a survey course in the theory and technology of modern wireless communication systems, exemplified in cellular telephony, paging, microwave distribution systems, wireless networks, and even garage door openers. Wireless technology is inherently interdisciplinary, and the course seeks to serve the interests of a variety of students.

ECE 485 - (3) (E)
Optical Communications
Prerequisite: ECE 323, APMA 310, and ECE 420.
This course covers the basics of optical communications. The first half of the course is spent describing optical devices including the LED, laser, optical fiber, PIN photodiode, APD detectors, optical amplifiers, modulators, etc. Characteristics of devices and their effect on the overall system are discussed. The second half of the course is devoted to system design and analysis. The emphasis is on modulation/demodulation and channel control methods, defining performance measures, and describing network architectures. Common applications of optical communications are then discussed. This course is intended to complement training in communications and in optics.

ECE 525 - (3) (SI)
Introduction to Robotics
Prerequisite: ECE 402 or 621, or equivalent.
Analyzes kinematics, dynamics and control of robot manipulators, and sensor and actuator technologies (including machine vision) relevant to robotics. Includes a robotics system design project in which students completely design a robotic system for a particular application and present it in class. Includes literature related to emerging technologies and Internet resources relevant to robotics.

ECE 541 - (3) (Y)
Optics and Lasers
Prerequisite: ECE 303, 309, and 323.
Reviews the electromagnetic principles of optics: Maxwell’s equations; reflection and transmission of electromagnetic fields at dielectric interfaces; Gaussian beams; interference and diffraction; laser theory with illustrations chosen from atomic, gas, and semiconductor laser systems; photomultipliers and semiconductor-based detectors; and noise theory and noise sources in optical detection.

ECE 556 - (3) (Y)
Microwave Engineering I
Prerequisite: ECE 309.
Design and analysis of passive microwave circuits. Topics include transmission lines, electromagnetic field theory, waveguides, microwave network analysis and signal flow graphs, impedance matching and tuning, resonators, power dividers and directional couplers, and microwave filters.

ECE 563 - (3) (Y)
Introduction to VLSI
Prerequisite: ECE 203, 230.

ECE 564 - (3) (Y)
Microelectronic Integrated Circuit Fabrication
Prerequisite: ECE 303 or equivalent.
Explores fabrication technologies for the manufacture of integrated circuits and microsystems. Emphasizes processes used for monolithic silicon-based systems and basic technologies for compound material devices. Topics include crystal properties and growth, Miller indices, Czochralski growth, impurity diffusion, concentration profiles, silicon oxidation, oxide growth kinetics, local oxidation, ion implantation, crystal annealing, photolithography and pattern transfer, wet and dry etching processes, anisotropic etches, plasma etching, reactive ion etching, plasma ashing, chemical vapor deposition and epitaxy; evaporation, sputtering, thin film evaluation, chemical-mechanical polishing, multilevel metal, device contacts, rapid thermal annealing, trench isolation, process integration, and wafer yield.

ECE 576 - (3) (Y)
Digital Signal Processing
Prerequisite: ECE 323 and 324, or equivalent.
Fundamentals of discrete-time signal processing are presented. Topics include discrete-time linear systems, z-transforms, the DFT and FFT algorithms, digital filter design, and problem-solving using the computer.

ECE 578 - (1.5) (Y)
Digital Signal Processing Laboratory
Prerequisite: ECE 323 and 324; corequisite: ECE 576.
This course provides hands-on exposure to real-time digital signal sampling (DSP) using general-purpose DSP processors. The laboratory sequence explores sampling/reconstruction, aliasing, quantization errors, fast Fourier transform, spectral analysis, and FIR/IIR digital filter design and implementation. Programming is primarily in C++, with exposure to assembly coding.

ECE 586, 587 - (1-3) (SI)
Special Topics in Electrical and Computer Engineering
Prerequisite: Instructor permission.
A first-level graduate/advanced undergraduate course covering a topic not normally covered in the course offerings. The topic usually reflects new developments in the electrical and computer engineering field. Offering is based on student and faculty interests.

Engineering (Interdepartmental)

ENGR 141R, 142R - (3) (Y)
Synthesis Design I and II
Prerequisite: first-year Rodman scholar status.
Introduces engineering, emphasizing the creative aspects of the profession. Rudiments of design methodology utilizing a case study approach with individual and small team assignments/projects. Evolution of concepts to multi-objective design examples, decision-making and optimization; cases varying from small product design to large scale facilities with life-cycle impact. Instruction on estimations, sketching, computer graphics, economics, spreadsheet analysis, human factors, planning and scheduling, elementary statistics, safety and risk analysis, materials and manufacturing, engineering ethics. Lectures followed by recitation or workshop sessions.

ENGR 162 - (4) (Y)
Introduction to Engineering
Prerequisite: enrollment in engineering or permission of course coordinator.
Integrates problem solving and design practice. Encourages the development of skills in using computer application packages for web page design, modeling and visualization (CAD), spreadsheets, and a math solver. Applies these skills to computer assignments and team design projects that feature conceptual design, analytical design, and design and build activities. Topics include methodologies for computation, problem solving, and design; graphing data; linear regression; plotting functions; matrix manipulation; modeling and visualization; and engineering optimization.

ENGR 488 - (3) (Y)
Aspects of Engineering Practice
This course will concentrate in examining and clarifying human values and practices in organizations. It is intended to complement the technical education programs offered by SEAS. The course will provide an introduction to a number of critical skills and competencies that will be very useful in the technical and business world. These include leadership, working in teams, management of organizations, conflict resolution, balancing career and personal needs and analyzing specific situations and exploring alternative outcomes.

ENGR 489 - (0-3) (S)
Industrial Applications
Students register for this course to complement an industry work experience. Topics focus on the application of engineering principles, analysis, methods and best practices in an industrial setting. A final report is
required. Registration is only offered on a Credit/No Credit basis. Courses taken for Credit/No Credit may not be used for any major or degree requirements.

**ENGR 492 - (0) (Y)**

**Engineering License Review**

*Corequisite: formal application for state registration.*

Overview of registration laws and procedures. Review of engineering fundamentals preparatory to public examination for the “Engineer in Training” part of the professional engineers examination. Three hours of lecture up to the licensing examination.

**ENGR 495, 499 - (3) (Y)**

**Special Topics in Engineering**

*Prerequisite: instructor permission.*

Advance projects course to be taken in parallel with STS 401, 402, or can be used for an advanced undergraduate course on a topic not covered in the course offerings.

### Materials Science and Engineering

**MSE 201 - (3) (S)**

**Materials That Shape Our Civilization**

A general review of structure, properties, methods of production, uses and world supply of the materials on which present and past civilizations have been based, including materials used in heavy industry, construction, communications, energy production, and medicine as well as textiles and naturally-occurring organic materials. Cross-listed as EVSC 201.

**MSE 209 - (3) (Y)**

**Introduction to the Science and Engineering of Materials**

The collective properties of the materials in an engineering structure often dictate the feasibility of the design. Provides the scientific foundation for understanding the relations between the properties, microstructure, and behavior during use of metals, polymers, and ceramics. Develops a vocabulary for the description of the empirical facts and theoretical ideas about the various levels of structure from atoms, through defects in crystals, to larger scale morphology of practical engineering materials.

**MSE 301 - (3) (Y)**

**Corrosion and its Prevention**

*Prerequisite: MSE 209 or instructor permission.*

Includes basic electrochemical principles and terminology, definitions and magnitude of corrosion, thermodynamics and kinetics of corrosion, examples of corrosion, experimental techniques to measure and evaluate corrosion, corrosion prevention, passivation, stress corrosion cracking, and hydrogen embrittlement.

**MSE 301L - (1) (Y)**

**Corrosion Engineering Laboratory**

Provides instruction in standard corrosion experiments that demonstrate the instrumentation of corrosion testing and some of the accelerated forms of evaluating metals’ susceptibility to various forms of corrosion attack. Standard experiments involving cathodic protection, anodic protection, and inhibitors. MSE 301 may be taken without the lab, but MSE 301L may not be taken without the lecture.

**MSE 304 - (3) (Y)**

**Structure and Properties of Polymeric Materials**

*Prerequisite: MSE 209 or equivalent.*

Examines polymeric materials from their molecular structure and morphological organization to their macroscopic properties. Topics include polymerization reactions; molecular weight determination; solution behavior; organization of crystalline and amorphous polymers; rubber elasticity; crystallization kinetics; morphology; mechanical, optical, and electrical properties; applications and materials selection; and degradation and recycling.

**MSE 304L - (1) (Y)**

**Structures and Properties Laboratory**

*Prerequisite: MSE 209.*

Demonstrates the phenomena and experimental techniques used to establish the relationships between the structures and properties of metals and polymers. Experiments include viscometry, X-ray diffraction, light scattering, optical microscopy, hardness and impact tests, thermal analysis, and computer simulations.

**MSE 305 - (3) (Y)**

**Phase Diagrams and Kinetics of Materials**

*Prerequisite: MSE 209 or instructor permission.*

Demonstrates that the interplay of thermodynamic driving forces and kinetics of mass transfer defines the formation of complex microstructures in real materials. The course begins with an overview of classical thermodynamics and applies these concepts to the analysis of phase equilibrium and phase transformations in one-component systems and binary solutions. Students learn how to read, analyze and even construct phase diagrams from thermodynamic data. The second part of the course concerns basic concepts of kinetic phenomena in materials, with the focus on diffusion and phase transformations. Two computer laboratory projects are incorporated into the course material.

**MSE 306 - (3) (Y)**

**Physical Metallurgy Principles: Structures and Properties of Metals**

*Prerequisite: MSE 209; MSE 305 recommended.*

Presents physical metallurgy concepts at an advanced undergraduate level. Important structural concepts include crystallography, bonding, point defects, dislocations, grain boundaries, twins, phase transformations, and precipitates. In parallel, an introduction to structure characterization via optical metallography, X-ray diffraction and electron microscopy is provided. The properties of interest are primarily structural: modulus, thermal expansion, strength, and their anisotropies, however, the relationships between structure and other properties, such as conductivity, will be also discussed. Throughout the course, relevant information about the structure, properties and alloys of numerous metals and alloys will be woven into the discussion of the underlying concepts.

**MSE 310 - (3) (Y)**

**Materials Science Laboratory**

*Prerequisite: MSE 209 or instructor permission.*

Experimental study of the structure and properties of materials. Course amplifies topics covered in MSE 209 through experimentation and analysis. Experiment topics include atomic and microscopic structure, mechanical properties of metals, polymers and composites, electrical properties, and corrosion characteristics. Introduction to modern experimental methods and instruments used for materials characterization. Two lecture hours and three laboratory hours.

**MSE 307 - (3) (Y)**

**Materials for Electronic, Optical and Magnetic Applications**

*Prerequisite: MSE 209, CHE 151, PHYS 241 recommended.*

The course introduces the basics of materials interactions with electrons and electromagnetic radiation and describes the classes of materials that exhibit useful electronic, optical, magnetic, and superconductive properties. Particular attention will be devoted to the intrinsic (structure, chemistry) and extrinsic (processing, microstructure) material features that determine these properties. Examples of application of such materials in commercial electronic systems in common use are discussed.

**MSE 451, 452 - (5) (Y)**

**Special Project in Materials Science and Engineering**

*Prerequisite: Professional standing and prior approval by a faculty member who is project supervisor.*

A project in the materials science field that requires individual laboratory investigation. Each student works on an individual project in the research area of a supervisor. The student is required to conduct a literature search and to become familiar with the necessary experimental techniques, such as electron microscopy, X-ray diffraction, and ultra-high vacuum techniques. A comprehensive report on the results of the experimental investigation and a final examination are required. One hour of conference, eight hours of laboratory per week.

**MSE 491, 492 - (3) (SI)**

**Special Topics in Materials Science**

Advanced undergraduate course on topics not normally covered in other course offerings. The topic usually reflects new developments in the materials science and engineering field. Offerings are based on student and faculty interests.
Introduction to Biomaterials
Prerequisite: MSE 209 and BIOM 201 or equivalent, or instructor permission.

Provides a multi-disciplinary perspective on the phenomenon and processes which govern material-tissue interactions with the soft tissue, hard tissue, and cardiovascular environments. Emphasizes both sides of the biomaterials interface, examining the events at the interface, and discussing topics on material durability and tissue compatibility.

Modeling in Materials Science
Prerequisite: At least two 300-400 level MSE courses or instructor permission.

Computational (primarily classical) methods of atomistic, mesoscopic, continuum, and multiscale modeling are discussed in the context of real materials-related problems (mechanical and thermodynamic properties, phase transformations, microstructure evolution during processing). Success stories and limitations of contemporary computational methods are considered. The emphasis is on getting practical experience in designing and performing computer simulations. A number of pre-written computer codes are provided. Students use and modify the pre-written codes and write their own simulation and data analysis codes while working on their homework assignments and term projects.

Deformation and Fracture Mechanics of Structural Materials
Prerequisite: MSE 206 or instructor permission.

Considers deformation and fracture through integration of materials science microstructure and solid mechanics principles, emphasizing the mechanical behavior of metallic alloys and engineering polymers. Metal deformation is understood based on elasticity theory and dislocation concepts. Fracture is understood based on continuum fracture mechanics and microstructural damage mechanisms. Additional topics include fatigue loading, elevated temperature behavior, material embrittlement, time-dependency, experimental design, and life prediction.

Electronic, Optical, and Magnetic Properties of Materials
Explore the fundamental physical laws governing electrons in solids, and show how that knowledge can be applied to understanding electronic, optical and magnetic properties. Students will gain an understanding of how these properties vary between different types of materials, and thus why specific materials are optimal for important technological applications. It will also be shown how processing issues further define materials choices for specific applications.
ity; orbital perturbations; introduction to estimation theory; patched-conic analysis of interplanetary flight; Lambert’s two-point boundary value problem; mission planning; chemical rocket propulsion; propellant requirements; staging; atmospheric reentry dynamics; the space environment; and an introduction to spacecraft attitude dynamics.

MAE 312 - (3) (SI)
Thermal Systems Analysis
Prerequisite: MAE 210.
Analyzes the thermodynamics of reactive and nonreactive, multi-component systems; energy cycles; and thermodynamic analysis of energy conversion systems.

MAE 314 - (3) (Y)
Elements of Heat and Mass Transfer
Prerequisite: MAE 321.
Analyzes steady state and transient heat conduction in solids with elementary analytical and numerical solution techniques; fundamentals of radiant heat transfer, including considerations for black, gray, and diffuse surfaces and the electrical analogy for systems having multiple surfaces; free and forced convective heat transfer with applications of boundary layer theory, Reynolds analogy, and dimensional analysis; and an introduction to mass transfer by diffusion using the heat-mass transfer analogy. Introduction to thermal design through a project.

MAE 321 - (3) (Y)
Fluid Mechanics
Prerequisite: APMA 213 and MAE 210.
Introduction to fluid flow concepts and equations; integral and differential forms of mass, momentum, and energy conservation with emphasis on one-dimensional flow; fluid statics; Bernoulli’s equation; viscous effects; Couette flow, Poiseuille flow, and pipe flow; introduction to boundary layers; one-dimensional compressible flow; normal shock waves; flow with friction; flow with heat addition; isothermal flow; and applications.

MAE 322 - (3) (Y)
Advanced Fluid Mechanics
Prerequisite: MAE 321 or equivalent, APMA 314.
Analyzes ideal fluids; velocity potential; stream function; complex potential; Blasius theorem; boundary conditions; superposition; circulation; vorticity; thin airfoil theory; two-dimensional gas dynamics; acoustic waves; normal and oblique shock waves; shock reflections; Prandtl-Meyer expansion; quasi one-dimensional compressible flow; converging-diverging nozzles; diffusers; choked flows; flow with friction; flow with heat addition; isothermal flow; linearized flows; Prandtl-Glauert correction; and applications.

MAE 331 - (3) (Y)
Aerospace Structures
Prerequisite: MAE 231.
Analyzes the design of elements under combined stresses; bending and torsional stresses in thin-walled beams; energy and other methods applied to statically determinate and indeterminate aerospace structural elements; buckling of simple structural members; and matrix and finite element analysis.

MAE 340 - (3) (SI)
Applied Computer Graphics
Prerequisite: MAE 232 and APMA 213.
Presents general concepts of dynamical systems modeling and provides mathematical tools to develop and analyze models that describe input/output behaviors of physical systems. Topics include basic elements of mechanical and electrical systems, transfer function, frequency response, stability and poles, resonance and natural frequency, transient and time constant, steady state and DC gain, electrical and mechanical systems analogy, system decomposition, block diagram, state space model, and control design. Reviews and frequently uses Newton’s law, Kirchhoff’s law, Laplace transform, and linear algebra. Introduces computer software (Matlab) for numerical analysis and simulations of dynamical systems.

MAE 373 - (3) (Y)
Flight Vehicle Dynamics
Prerequisite: MAE 201 and 232.
Introduces definitions and concepts and includes a review of longitudinal static stability; rigid body dynamics; general equations of motion, rotating coordinate systems; small disturbance theory; atmospheric flight mechanics; stability derivatives; motion analysis of aircraft; static and dynamic stability; aircraft handling qualities; and an introduction to flight control systems and automatic stabilization.

MAE 381 - (3) (Y)
Experimental Methods Laboratory
Prerequisite: PHYS 241E, MAE 200L, and MAE 209; corequisite: MAE 371.
The study of basic concepts and methods in engineering measurements and data analysis. Basic topics include mechanical and electrical sensors and measurement instruments, measurement uncertainty, statistic and data analysis. Additional topics include digital signal processing and data acquisition systems using Labview™. Applications are to mechanical and aero/thermofluids devices. Two lecture and two laboratory hours.

MAE 382 - (3) (Y)
Aerodynamics Laboratory
Prerequisite: MAE 201, 321 and 381; corequisite: MAE 322.
Investigates low-speed nozzle and jet flows, wing aerodynamic behaviors in a small low-speed wind tunnel, and aerodynamic model testing in a larger low-speed wind tunnel. Building, testing, and trajectory-tracking for small rockets; trajectory predictions. Examines supersonic flow and aerodynamic behaviors in a small supersonic wind tunnel.

MAE 384 - (2) (Y)
Mechanical Engineering Laboratory
Prerequisite: MAE 210L, 321, 381; corequisite: MAE 314, 362.
Application of experimental methods to the design of experiments. Examination of test equipment and procedures through the operation of test facilities for heat transfer, mechanical and fluid systems including data acquisition and processing systems. Four week project to design and construct a test rig for a mechanical or thermal device or system. Two lecture and two laboratory hours.
areas and current problems in mechanical engineering. Topics vary based on student and faculty interest.

MAE 493, 494 - (3) (SI)
Special Topics in Aerospace Engineering
Prerequisite: Fourth-year standing.
Applies basic engineering science, design methods, and systems analysis to developing areas and current problems in aerospace engineering. Topics vary based on student and faculty interest.

MAE 495, 496 - (1.5) (Y)
Mechanical Engineering Special Project
Prerequisite: Professional standing and prior approval by a faculty member who is project supervisor.
Individual survey, analysis, or apparatus project in the mechanical engineering field, concluded with the submission of a formal report. Subject originates with students wishing to develop a technical idea of personal interest. One hour conference per week.

MAE 497, 498 - (1.5) (Y)
Aerospace Engineering Special Projects
Prerequisite: Fourth-year standing and consent of a department faculty member to serve as technical advisor.
Applied research on a year-long basis in areas pertinent to aerospace engineering; conducted in close consultation with a departmental faculty advisor. Includes the design and construction of experiments, computational analysis, or the investigation of physical phenomena. The research may be related to ongoing faculty research and may be the topic of the senior thesis, but its scope must be significantly beyond that required for the thesis.

Physics

PHYS 142E - (3) (Y-SS)
General Physics I
Prerequisite: APMA 109; corequisite: PHYS 142W.
Analyzes classical mechanics, including vector algebra, particle kinematics and dynamics, energy and momentum, conservation laws, rotational dynamics, oscillatory motion, gravitation, thermodynamics, and kinetic theory of gases. Three lecture hours.

PHYS 142R - (3) (Y)
General Physics I
Prerequisite: Rodman scholar status.
Covers the same material as PHYS 142E, with certain topics treated in greater depth.

PHYS 142W - (1) (Y-SS)
General Physics I Workshop
Corequisite: PHYS 142E.
A required two-hour workshop accompanying PHYS 142E, including laboratory and tutorial activities.

PHYS 241E - (3) (Y)
General Physics II
Prerequisite: PHYS 142E and APMA 111.
Analyzes electrostatics, including conductors and insulators; DC circuits; magnetic forces and fields; magnetic effects of moving charges and currents; electromagnetic induction; Maxwell’s equations; electromagnetic oscillations and waves. Introduces geometrical and physical optics. Three lecture hours; one hour recitation.

PHYS 241W - (1) (Y)
General Physics Laboratory
Corequisite: PHYS 241E.
Laboratory exercises in classical physics. Two hours laboratory.

Science, Technology and Society

STS 101 - (3) (Y)
Engineering, Technology, and Society
Introduces the nature of engineering knowledge and practice; the influential role of engineering in shaping the world; and the ways in which social institutions, practices, and values influence engineers’ work. A variety of readings explore these topics. Framed as an introduction to the profession, the course promotes students’ abilities in creative and critical thinking and their skills in communications used in engineering practice, including oral presentations, written proposals, technical descriptions, memoranda, and abstracts. Drawing on a range of sources, students also complete a substantial research project that integrates course topics.

STS 200 - (3) (IR)
Topics in Technology and Society
Prerequisite: STS 101 or instructor permission.
Relates technology or engineering to the broader culture. The specific subject will differ from time to time.

STS 201 - (3) (IR)
Thomas Jefferson’s Interests in Science and Technology
Prerequisite: STS 101 or instructor permission.
Introduces Jefferson’s use of scientific thinking in his major accomplishments and the influence of public policy, agriculture, education, invention, architecture, and religion. Readings in his writings, class discussions, guest lectures and field visits to local centers of Jefferson research. Short papers, in-class presentations, and a research paper are required.

STS 203 - (3) (Y)
Man and Machine: Visions of Tyranny and Freedom in 19th- and 20th-Century Literature
Prerequisite: STS 101.
Analysis of attitudes toward the problem of the machine and technological advances in modern civilization, as reflected in selected American and European writings and films. Discussions, oral presentations, papers, and a final exam.

STS 204 - (3) (Y)
Technology, Aggression, and Peace
Prerequisite: STS 101.
A study of the human potential for aggression and the relationship of technology to this potential. Students read and discuss a variety of theories about human behavior and the destructive impulse in humankind. Short essays, a research paper, group projects, and oral presentations enable students to build and practice communications skills.

STS 206 - (3) (IR)
American Environmental History
Prerequisite: STS 101, ENWR 110, or equivalent.
Explores the historical relationship between people and the environment in North America, from colonial times to the present. Topics include the role of culture, economics, politics, and technology in that relationship.

STS 207 - (3) (Y)
Utopias and the Technological Society
Prerequisite: STS 101.
Lectures, readings, and discussions compare earlier and modern designs of the ideal society, stressing the relationship of their basic technologies to historical reality. Such writers as Plato, Thomas More, and Aldous Huxley are considered. Students give oral presentations, write short papers, and design a personal utopia.

STS 208 - (3) (IR)
The History of Flight
Prerequisite: STS 101.
Explores the development of flight from the earliest historical records of peoples’ interest in flying through the achievements of the space age. Emphasizes the social and cultural impacts of flight, advances in technology, and the significance of the contribution of individuals. Guest lectures, film showings, visits to aviation museums, and student reports and projects supplement regular classroom lecture and discussion.

STS 209 - (3) (IR)
The History of Space Flight
Prerequisite: STS 101.
Explores the history of space flight, from peoples’ earliest interest in rockets through the most recent developments in aerospace technology. Examines the contributions of various scientists, engineers, and inventors to space travel; the major eras of aerospace history and the impacts of U.S. and international space programs on society.

STS 210 - (3) (Y)
Technology and Social Change in 19th-Century America
Prerequisite: STS 101.
A study of the impacts of nineteenth-century American industrial development on the community, the worker, and engineering. Students make oral and written presentations, write short papers, and a research paper.

STS 211 - (3) (IR)
Values of Professionals
Prerequisite: STS 101.
Examines the ways technical and non-technical professionals attribute worth to an idea, action, or object. Develops the student’s abilities to discern, in the values typical of specific occupations, elements of the job (monetary gain), the calling (service and self-fulfillment), and the profession (conformity to...
“guild” standards. Representative literature is read and discussed; each student is expected to speak and write articulately about values issues and to conduct elementary research in the topic.

**STS 212 - (3) (IR)**

**Religion and Technology**

*Prerequisite: STS 101.*

A historical examination of the role of religion in the early development of technology; technology as a secular substitute for religion; and religious critiques of contemporary technological society. Equal time is spent on lectures, student-led discussions of the readings, and student oral presentations. Short papers and a major research project on a particular denomination’s or congregation’s attitudes toward technology-related issues.

**STS 213 - (3) (IR)**

**American Technological and Industrial History in the Twentieth Century**

*Prerequisite: STS 101.*

Surveys the technological, business, and economic history of the U. S. from the 1860s to the 1980s. Focuses on key industries (railroads, autos, computers), corporate structures and functions, government intervention in the economy, and popular attitudes toward technological change.

**STS 300 - (3) (IR)**

**Advanced Topics in Technology and Culture**

*Prerequisite: STS 101 and six credits of general education electives.*

Specific topics vary. Fulfills STS 200-level writing and speaking requirements.

**STS 301 - (1) (S)**

**Topics in Science, Technology, and Culture**

Supplements existing undergraduate courses with additional research assignments. Generally taken by students wishing to fulfill the requirements for the minor in the history of science and technology.

**STS 303 - (3) (SI)**

**The Presentation of Technical Information**

*Prerequisite: STS 101 or ENWR 110 or instructor permission.*

The principles of adapting scientific and technical information for communication in various media and for a variety of audiences and purposes.

**STS 305 - (3) (SI)**

**Readings in the Literature of Science and Technology**

*Prerequisite: STS 101 or ENWR 110 or instructor permission.*

Readings in scientific and philosophical texts and discussions of the nature of scientific and technological thought. Students conduct panel discussions on new technologies and their intellectual and social impacts.

**STS 311 - (3) (SI)**

**Readings in the History of Science and Technology**

*Prerequisite: STS 101 or ENWR 110 or instructor permission.*

Readings and discussion of selected works in the classic writings of engineers and scientists from the earliest records to the Renaissance.

**STS 312 - (3) (IR)**

**History of Technology and Invention**

*Prerequisite: STS 101 or ENWR 110 or instructor permission.*

Surveys advances of technological knowledge through the ages. Includes the achievements of Egypt, Greece, and Rome; the beginnings of the concept of a labor-saving device in the middle ages; the technological background of the Industrial Revolution; the recent role of technology in shaping modern society.

**STS 313 - (3) (Y)**

**Scientific and Technological Thinking**

*Prerequisite: STS 101 or ENWR 110, or instructor permission.*

Explores the ways scientists and inventors think, using concepts, theories, and methods borrowed from several disciplines, but focusing especially on psychology. Topics include experimental simulations of scientific reasoning, a cognitive framework for understanding creativity, and modeling discovery on a computer. Students read and discuss articles and conduct a short research project. Fulfills STS 200-level writing and speaking requirements.

**STS 315 - (3) (Y)**

**Invention and Design**

*Prerequisite: STS 101 or ENWR 110, or instructor permission.*

Investigates the way technology is created and improved. Offers a collaborative learning environment in which multi-disciplinary teams invent and design several modules that emulate problems, such as the invention of the telephone or the design of an expert system. Includes readings from psychology, history, computing, ethics, and engineering. Students keep design notebooks, present team paper results, and write an integrative paper. Fulfills STS 200-level writing and speaking requirements. Cross-listed as PSYC 419.

**STS 395 - (1-3) (SI)**

**Independent Study: Technology in Culture**

*Prerequisite: STS 101, a 200-level STS course, and instructor permission.*

Special tutorial with a topic declared in advance. Limited to undergraduate SEAS students with third- or fourth-year standing. Not to substitute for STS 401, 402. The topic, work plan, and conditions are arranged by contract between instructor and student and approved by the division chair, with a copy to be filed in the division office.

**STS 401 - (3) (S, SS)**

**Western Technology and Culture**

*Prerequisite: A 200 level STS course or instructor permission.*

Considers the social and cultural context of technology and science in Western civilization. More specifically, the course considers what constitutes scientific and technological progress, focusing especially on ethical and cultural dimensions. The undergraduate thesis project, which is initiated in this course, emphasizes oral and written communications at a professional level, and the role of social constraints and ethical obligations in engineering practice.

**STS 402 - (3) (S, SS)**

**The Engineer, Ethics, and Society**

*Prerequisite: STS 401.*

Readings on, and discussions of, various kinds of valuing (social, institutional, scientific, intellectual, and personal) characteristic of professional work in engineering and applied science in modern technological society. Students complete the thesis project technical report. Continued consideration of indirect and unintended impacts of new technology and of health and safety issues.

**STS 403 - (1) (SS)**

**Research Proposal Writing**

A course in technical and scientific communication for students entering the accelerated Bachelor’s/Master’s Program. Offered in the summer session between the sixth and seventh semesters. Part of the required undergraduate humanities sequence for students in the accelerated program.

**STS 501 - (3) (Y)**

**Perceptions of Technology in the Western World**

*Prerequisite: Students in the accelerated Bachelor’s/Master’s Program.*

Fall semester. May be taken in either the fourth or fifth year of the student’s program. Seminars exploring the role of technology in the Western world, based on assigned readings in the history, philosophy, or culture of technology.

**STS 502 - (2) (Y)**

**Thesis and Research Presentation**

*Prerequisite: Students in the tenth semester of the accelerated Bachelor’s/Master’s Program.*

Spring semester. Seminars, lectures, and discussions related to research writing, leading to completion of the master’s thesis (or project in departments not requiring a thesis). Topics include organization and style in thesis writing with attention to logical, rhetorical, and ethical issues in science and engineering research writing.

**STS 600 - (3) (Y)**

**Effective Technical Communication**

*Prerequisite: Graduate student status; instructor permission.*

Study and practice in effective presentation of technical information in both written and oral form. Organizing for small- and large-scale presentations: summaries, proposals, scientific and technical reports, theses and dissertations, and articles for publication. Review of conventions of technical style and essentials of grammar and syntax. Assignments to be drawn from the student’s thesis or other research where possible. Course does not offer instruction in remedial English or English as a second language.
Systems and Information Engineering

**SYS 201 - (3) (Y)**

**Systems Engineering Concepts**  
*Prerequisite: APMA 111 and 212.*  
Three major dimensions of systems engineering are covered and their efficacy demonstrated through case studies. (1) The history, philosophy, art, and science upon which systems engineering is grounded, including guiding principles and steps in the systems engineering approach to problem solving. (2) The building blocks of mathematical models, including: state variables, decision variables, random variables, exogenous variables, inputs and outputs, objective functions, and constraints. (3) Project management methods and tools in systems modeling, including: influence diagrams, event trees, requirements analysis, questionnaires, multi-objective decision trees, and life cycle analysis.

**SYS 202 - (3) (Y)**

**Data and Information Engineering**  
*Prerequisite: CS 101 and major in systems engineering; corequisite: CS 201.*  
Provides students with the background necessary to model, store, manipulate, and exchange information throughout an information system to support decision-making. Incorporates both conceptual bases and corresponding technology standards, including Unified Modeling Language (UML), SQL, and XML. Covers the development of conceptual (semantic) models for describing data and their relationships; relational models; effective use of SQL for data definition and manipulation; web-based technologies for disseminating information; and the major components of modern information systems. Emphasizes application of these technologies through the analysis, design, and implementation of web-enabled database systems.

**SYS 204 - (3) (Y)**

**Data Management and Information Management**  
*Prerequisite: CS 110 or ENGR 162, or instructor permission.*  
Introduces the integration and acquisition of information for decision-making using information technology. Discusses the impact of rapid software and hardware development on information integration, including the essential methodologies of client server and database systems. Topics include client server technology, the design and analysis of relational database systems, exposure to Microsoft Access, and the fourth-generation language SQL. This course is not intended for systems engineering majors. Students may not receive credit for both SYS 202 and SYS 204.

**SYS 257 - (3) (Y)**

**Management of E-Commerce Systems**  
*Prerequisite: CS 110 or ENGR 162, or instructor permission.*  
An introduction to the management, technology and performance assessment of electronic business systems. The course emphasizes the intimate relationship between business planning and technology planning for e-businesses. Details of specific e-commerce technologies will be covered as well as approaches to e-business planning. Topics include: technologies, architectures, and infrastructures; information security and privacy; supply-chain management and customer relationship management; requirements definition and analysis; development lifecycles; customer behaviors; performance models; service metrics; waiting and response times; traffic characteristics; load forecasts and scenarios; resources and costs estimation; risk analysis; optimization; capacity planning; and e-business financial planning and deployment.

**SYS 312 - (3) (Y)**

**Deterministic Decision Models**  
*Prerequisite: SYS 201; corequisite: APMA 308.*  
Introduction to optimization models involving network structure: theory, algorithms, and applications. Survey of optimization models ranging from network models with special structured, e.g. shortest path models, to unstructured linear and nonlinear optimization models. Applications include (1) telecommunications network planning and design, (2) design and utilization of transportation and distribution networks, and (3) project management and scheduling.

**SYS 321 - (3) (Y)**

**Human Machine Interface**  
*Prerequisite: SYS 201 and major in systems engineering.*  
Introduces human physiology and psychology, and covers principles of human-centered systems design. Students will learn methods for task and work analysis and will practice designing and evaluating several systems. Includes group projects.

**SYS 323 - (3) (Y)**

**System Evaluation**  
*Prerequisite: APMA 312, SYS 201, 321, and major in systems engineering.*  
Focuses on the evaluation of candidate systems designs and design performance measures. Includes identification of system goals; requirements and performance measures, including cost and non-technical requirements; design of experiments for performance evaluation; techniques of decision analysis for trade-studies (ranking of alternatives); presentation of system evaluations; and generation of a business case for presenting analysis results. Illustrates the concepts and processes of systems evaluations using case studies.

**SYS 355 - (1) (Y)**

**Systems Engineering Design Colloquium I**  
*Prerequisite: Third-year standing in systems engineering.*  
Students learn about the practice of systems engineering directly from practicing systems engineers. A variety of topics are covered by invited speakers from industry, government, and the academy (many of whom are alumni of our undergraduate program). Discussions include engineering design projects, alternative career paths, graduate studies, professional development and advancement strategies, and more immediate options and opportunities for summer internships and capstone projects.

**SYS 360 - (3) (Y)**

**Stochastic Decision Models**  
*Prerequisite: APMA 310 and 312, or instructor permission.*  
Introduction to mathematical modeling of forecasts and decisions under uncertainty using principles of statistical decision theory; judgmental and Bayesian techniques for probabilistic forecasting; forecast verification methods; static and sequential decision models for quality control, inventory control, queue management, hazard warnings; and economic, investment, and weather-sensitive decisions.

**SYS 362 - (4) (Y)**

**Discrete Event Simulation**  
*Prerequisite: CS 201, APMA 310, 312, and major in systems engineering.*  
A first course in the theory and practice of discrete-event simulation. Monte Carlo methods, generating random numbers and variates, spreadsheet add-ins and applications, sampling distributions and confidence intervals, input analysis and distribution fitting. Discrete-event dynamic systems, modeling, simulation logic and data structures, output analysis, model verification and validation, comparing alternative systems, simulation optimization, case studies. Applications span communication, computer, distribution, health-care, manufacturing, service, and transportation systems. Modern simulation software tools, including animation.

**SYS 421 - (4) (Y)**

**Linear Statistical Models**  
*Prerequisite: SYS 360, APMA 312, and major in systems engineering.*  
This course shows how to use linear statistical models for analysis in engineering and science. The course emphasizes the use of regression models for description, prediction, and control in a variety of applications. Building on multiple regression, the course also covers principal component analysis, analysis of variance and covariance, logistic regression, time series methods, and clustering. Course lectures concentrate on the theory and practice of model construction while laboratories provide a series of open-ended problem solving situations that illustrate the applicability of the models.

**SYS 453 - (3) (S)**

**Systems Design I**  
*Prerequisite: SYS 321, 360, and major in systems engineering.*  
A design project extending throughout the fall semester. Involves the study of an actual open-ended situation, including problem formulation, data collection, analysis and interpretation, model building for the purpose of evaluating design options, model analysis, and generation of solutions. Includes an appropriate computer laboratory experience.
SYS 454 - (3) (S)
Systems Design II
Prerequisite: SYS 453 and major in systems engineering.
A design project extending throughout the spring semester. Involves the study of an actual open-ended situation, including problem formulation, data collection, analysis and interpretation, model building for the purpose of evaluating design options, model analysis, and generation of solutions. Includes an appropriate computer laboratory experience.

SYS 455 - (1) (Y)
Systems Engineering Design Colloquium II
Prerequisite: Fourth-year standing in systems engineering.
A colloquium that allows fourth-year students to learn about systems engineering directly from practicing systems engineers. Invited speakers discuss engineering design projects, new developments in systems engineering, design, innovation, and project management. Students present ideas and experiences from their Capstone design projects.

SYS 481 - (3) (IR)
Selected Topics in Systems Engineering
Prerequisite: As specified for each offering. Detailed study of a selected topic determined by the current interest of faculty and students. Offered as required.

SYS 482 - (3) (Y)
Human-Computer Interaction
To learn basic aspects of human factors in the design of information support systems. We will cover: (1) basic human performance issues (physiology, memory, learning, problem-solving, human error), (2) the user interface design process (task analysis, product concept, functional requirements, prototype, design, and testing.) Students will gain basic skills in the analysis and design of human-machine systems through in-class exercises and two course projects. The course is also designed to help you practice different communication skills (interviewing, written analysis, and oral presentation).

SYS 495 - (IR)
Supervised Projects in Systems Engineering
Prerequisite: As specified for each offering. Independent study or project research under the guidance of a faculty member. Offered as required.

Technology Management and Policy

TMP 351 - (3) (Y)
The Technology and Product-Development Life Cycle
Prerequisite: Third-year standing or instructor permission.
Views technology, technology management, and product and process development from within a corporation. Emphasizes how firms manage or make decisions about technology and product development investments (research and development, project selection, product choices, process choices and improvement, new market introduction, product discontinuance or replacement). Course is built around a life cycle construct.

TMP 352 - (3) (Y)
Science and Technology Public Policy
Examines the “macro” aspects of science and technology management, namely the development of public policies aimed at promoting and regulating science and technology. Topics include the justifications for the federal government’s efforts to promote or regulate science and technology; the historical evolution of the federal government’s involvement in science policy; the players, organizations, and agencies who make science policy in the federal government; the reasons the government funds the research it does; how science and technology is regulated by the government; and, the roles state and local governments play in the development of local science and technology policies. Explores how science and technology policies are developed in response to challenges posed by the world economy, and how other countries manage their science and technology policies.

TMP 399 - (3) (SI)
Case Studies in Technology Management and Policy
A special topics course examining the interaction of technology, management, and policy issues in a specific context. The course could be organized around a technology, a company, an industrial or governmental sector, a piece of legislation, a court decision, a social issue, a time-period, a political entity, or some combination of these.

Faculty

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