College of Engineering and Applied Sciences

www.eas.asu.edu

Peter E. Crouch, Ph.D., Dean

PURPOSE

The purpose of the College of Engineering and Applied Sciences is to provide students with a range of educational opportunities by which they may achieve competence in the major branches of engineering, in computer science, and construction. Considerable effort is spent on the development and delivery of well-rounded programs that enhance student preparation for professional careers, lifelong learning, and responsible participation as a member of society.

For more information, access the college's Web site at www.eas.asu.edu.

ORGANIZATION

The College of Engineering and Applied Sciences is composed of the following academic and service units (with seven departments making up the School of Engineering):

Del E. Webb School of Construction

School of Engineering
Department of Bioengineering
Department of Chemical and Materials Engineering
Department of Civil and Environmental Engineering
Department of Computer Science and Engineering
Department of Electrical Engineering
Department of Industrial Engineering
Department of Mechanical and Aerospace Engineering

Research Centers. The college is committed to the development of research programs of national prominence and to the concept that research is an important part of its educational role. The college encourages the participation of qualified undergraduate students and graduate students in various research activities. Most of the faculty are involved in government or industry-sponsored research programs in a wide variety of topics. A partial list of these topics includes aerodynamics, biotechnology, computer design, computer-integrated manufacturing, environmental fluid dynamics, innovative engineering education, microelectronics manufacturing, power systems, semiconductor materials and devices, signal processing, solar energy, solid-state electronic devices, structural dynamics, telecommunications, thermosciences, and transportation systems. This research is carried out in the departments and schools listed above and in the following interdisciplinary research centers:

Center for Low Power Electronics
Center for Research on Education in Science, Mathematics, Engineering, and Technology
Center for Solid State Electronics Research
Center for System Science and Engineering Research
Institute for Manufacturing Enterprise Systems
Telecommunications Research Center

Center for Professional Development. The Center for Professional Development, often in cooperation with the college's academic units and research centers, provides a variety of technical conferences, seminars, short courses, and televised and satellite-transmitted programs to enable engineers, scientists, and managers to continue the lifelong learning that is so necessary in a constantly changing world. Programs may be conducted on campus, at various off-campus locations, or at company sites upon request. For more information, visit the Center for Professional Development in ECG 148, call 480/965-1740, or access the center's Web site at www.eas.asu.edu/cpd.

ADMISSION

The admission criteria and standards for the B.S. in Computer Science and the B.S.E. in Computer Systems Engineering programs are currently under review and are changing effective spring 2002. For current information, visit the Computer Science and Engineering advising office in GWC 302, call 480/965-3199, or access the Web site at cse.asu.edu.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

Professional Status Requirements

				Minimum Scores		Transfer GPA*	
Student	School	High School Rank	ABOR GPA	ACT	SAT	Resident	Nonresident
Resident	Construction	Upper 25%	3.00	23	1140	—	—
	Engineering	Upper 25%	3.00	23	1140	—	—
Nonresident	Construction	Upper 25%	3.00	24	1140	—	—
	Engineering	Upper 25%	3.00	24	1140	—	—
Transfer	Construction	—	—	—	—	2.25	2.50
	Engineering	—	—	—	—	2.50	2.50

* The cumulative GPA is calculated using all credits from ASU as well as all transfer credits from other colleges and universities.

Individuals wishing to be admitted to freshman standing in the College of Engineering and Applied Sciences should have completed certain secondary-school units. These units are identified in the requirements for each of the two schools in the college. If these conditions are not met, additional university course work, possibly unacceptable for degree credit, may be required.

Entrance requirements of this college may differ from those of other ASU academic units. Students may be admitted under one of two different classifications, professional or preprofessional.

Professional Status. For admission to professional status, Arizona residents and nonresidents must meet one of the requirements as listed in the appropriate section of the "Professional Status Requirements" table, on this page. In addition, students who are required to take the Test of English as a Foreign Language (TOEFL) must earn a score of at least 550 (230 on the computerized version).

Students admitted to the university after successful completion of the General Education Development examination are admitted as preprofessional students within their major. Professional status is attained by meeting the minimum ACT or SAT score required for admission as listed in the "Professional Status Requirements" table, on this page.

For Computer Science and Computer Systems Engineering professional status requirements, see "Admission Requirements," page 245.

Preprofessional Status. In the College of Engineering and Applied Sciences, there are two versions of *preprofessional status*. One applies to a college-level preprofessional status; the conditions associated with the CEAS preprofessional status are described in the following material. The second version is of concern only to students interested in pursuing majors within the Department of Computer Science and Engineering (CSE); for descriptive material on the CSE preprofessional status, see "Department of Computer Science and Engineering," page 245, or access the CSE Web site at cse.asu.edu.

A student not admissible to professional status within the college but otherwise regularly admissible to ASU as stated in "Undergraduate Admission," page 58, may be admitted as a *preprofessional* student to any one of the academic programs of the college. A student admitted into this classification follows the freshman-sophomore sequence of courses as required by the chosen major. Courses are selected with the assistance of an academic advisor. After completing a minimum of 30 semester hours of required or approved elective courses *with a cumulative GPA equivalent to that required of transfer students and corresponding to the chosen major, students may apply for admission to professional status*. Preprofessional students are not permitted to register for 300- and 400-level courses in the college until their status is changed to the professional classification.

Readmission. Students applying for readmission to professional status for any program in this college must have a cumulative GPA for all college course work equal to that of the transfer admission requirements shown in the "Professional Status Requirements" table, on this page.

Transfer into and Within the College. Students transferring between academic programs within the college or from other colleges within the university must meet both the cumulative GPA requirement and the catalog requirements of the desired program in effect at the time of transfer. Students who are transferring from an Arizona community college and have been in continuous residence may continue under the catalog in effect at the time of their entrance into the community college.

Transfer Students. A student who contemplates transferring into this college from another institution, whether a community college or four-year institution, should carefully study the catalog material pertaining to the particular program and consult an advisor in this college before enrolling in the other institution. These steps assure a smooth transition at the time of transfer. Transfer students may request admission to either preprofessional or professional status in any of the programs offered by this college.

The minimum requirements for admission of resident, nonresident, and transfer students to the professional program are shown in the "Professional Status Requirements" table, on this page. The academic units may impose additional admission and graduation requirements beyond the minimum specified by the college.

Credit is granted for transferred courses deemed equivalent to corresponding courses in the selected program of study, subject to grade and ASU resident credit requirements. No grades lower than "C" are accepted as transfer credit to meet the graduation requirements of this college.

College of Engineering and Applied Sciences Baccalaureate Degrees and Majors

Major	Degree	Concentration	Administered By
Del E. Webb School of Construction			
Construction[1]	B.S.	General building construction, heavy construction, residential construction, specialty construction	Del E. Webb School of Construction
School of Engineering			
Aerospace Engineering[1]	B.S.E.	—	Department of Mechanical and Aerospace Engineering
Bioengineering[1]	B.S.E.	—	Department of Bioengineering
Chemical Engineering[1]	B.S.E.	—	Department of Chemical and Materials Engineering
Civil Engineering[1]	B.S.E.	Construction engineering, environmental engineering	Department of Civil and Environmental Engineering
Computer Science[1]	B.S.	Software Engineering	Department of Computer Science and Engineering
Computer Systems Engineering[1]	B.S.E.	—	Department of Computer Science and Engineering
Electrical Engineering[1]	B.S.E.	—	Department of Electrical Engineering
Engineering Interdisciplinary Studies[2]	B.S.	—	School of Engineering
Engineering Special Studies[1]	B.S.E.	Premedical engineering	School of Engineering
Industrial Engineering[1]	B.S.E.	—	Department of Industrial Engineering
Materials Science and Engineering[1]	B.S.E.	—	Department of Chemical and Materials Engineering
Mechanical Engineering[1]	B.S.E.	—	Department of Mechanical and Aerospace Engineering

1 This major requires a minimum of 128 semester hours to complete.

2 Applications for this program are not being accepted at this time.

Credits transferred from a community college or two-year institution are applied only as lower-division credits. For a listing of the acceptable courses transferable to the various college degree programs, prospective Arizona community college transfer students should consult their advisors and refer to the ASU transfer guides available on the Web at www.asu.edu/provost/articulation.

It should be noted that some courses taken in other ASU colleges or other universities may be acceptable for general university credit but may not be acceptable toward the degree requirements of this college. Determination of those particular courses acceptable to a specific degree program is made within the appropriate academic unit with the approval of the dean.

ADVISING

For assistance and counseling in planning a program of study, each student in this college is assigned a faculty advisor who is familiar with the chosen field of specialization and who must be consulted before registering each semester. The student should inform the advisor of any outside work or activity so that course loads may be adjusted accordingly.

Most students attending college find it necessary to obtain part-time employment; consequently, it is suggested that a careful balance of work and class requirements be considered to avoid academic problems.

Students enrolled in an undergraduate degree program in this college may register for a maximum of 19 semester hours each semester. Any student wanting to register for more than the maximum must submit a petition and have an approval on file before registering for the overload.

Students who are enrolled in an undergraduate nondegree status in this college must obtain advising and approval to register before registering each semester from the director of Student Academic Services in ECG 205. For more information, see “Admission of Undergraduate Nondegree Applicants,” page 64

UNDERGRADUATE DEGREES

The faculty in the College of Engineering and Applied Sciences offer programs leading to the B.S. and B.S.E. degrees with majors in the subjects shown in the “College of Engineering and Applied Sciences Baccalaureate Degrees and Majors,” on this page. Each major is administered by the academic unit indicated.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

College of Engineering and Applied Sciences Graduate Degrees and Majors

Major	Degree	Concentration	Administered By
Del E. Webb School of Construction			
Construction	M.S.	Construction science, facilities, management	Del E. Webb School of Construction
School of Engineering			
Aerospace Engineering	M.S., M.S.E., Ph.D.	—	Department of Mechanical and Aerospace Engineering
Bioengineering	M.S., Ph.D.	—	Department of Bioengineering
Chemical Engineering	M.S., M.S.E., Ph.D.	—	Department of Chemical and Materials Engineering
Civil Engineering	M.S., M.S.E., Ph.D.	—	Department of Civil and Environmental Engineering
Computer Science	M.C.S., M.S., Ph.D.	—	Department of Computer Science and Engineering
Electrical Engineering	M.S., M.S.E., Ph.D.	—	Department of Electrical Engineering
Engineering	M.E.[1]	—	School of Engineering
Engineering Science	M.S., M.S.E., Ph.D.	—	School of Engineering
Industrial Engineering	M.S., M.S.E., Ph.D.	—	Department of Industrial Engineering
Materials Engineering	M.S., M.S.E.	—	Department of Chemical and Materials Engineering
Materials Science	M.S.[2]	—	Committee on the Science and Engineering of Materials
Mechanical Engineering	M.S., M.S.E., Ph.D.	—	Department of Mechanical and Aerospace Engineering
Science and Engineering of Materials	Ph.D.[2]	High-resolution nanostructure analysis, solid-state device materials design	Committee on the Science and Engineering of Materials

[1] This collaborative program is offered by the three state universities.
[2] This program is administered by the Graduate College.

Integrated B.S.E.-M.S. Program. To provide greater program flexibility, qualified students of the School of Engineering may undertake a program with an integrated fourth- and fifth-year sequence of study in one of several fields of specialization in engineering. This program provides an opportunity to meet the increasing demands of the profession for graduates who can begin their engineering careers at an advanced level.

Students admitted to this program are assigned a faculty committee that supervises a program of study in which there is a progression in the course work and in which earlier work is given application in the later engineering courses for both the bachelor's and master's degrees. Entry into the integrated program requires an application submitted to the dean through the faculty advisor and the department chair. Applications are reviewed by a school committee that recommends the appropriate action to the dean. The application may be submitted in the fifth semester.

GRADUATE DEGREES

The faculty in the College of Engineering and Applied Sciences offer master's and doctoral degrees as shown in the "College of Engineering and Applied Sciences Graduate Degrees and Majors" table, on this page. School of Engineering faculty participate in offering the Master of Engineering (M.E.) as a collaborative degree program offered by Arizona's three state universities. For more information, see the *Graduate Catalog.*

ASU EXTENDED CAMPUS

The College of Extended Education was created in 1990 to extend the resources of ASU throughout Maricopa County, the state, and the region. The College of Extended Education is a university-wide college that oversees the ASU Extended Campus and forms partnerships with other ASU colleges, including the College of Engineering and Applied Sciences, to meet the instructional and informational needs of a diverse community.

The ASU Extended Campus goes beyond the boundaries of the university's three physical campuses to provide access to quality academic credit and degree programs for working adults through flexible schedules; a vast network of off-campus sites; classes scheduled days, evenings, and weekends; and innovative delivery technologies including television, the Internet, and Independent Learning. The Extended Campus also offers a variety of professional continuing education and community outreach programs.

For more information, see "ASU Extended Campus," page 703, or access the Web site at www.asu.edu/xed.

UNDERGRADUATE DEGREE REQUIREMENTS

For detailed information on the degree requirements of a major in the College of Engineering and Applied Sciences, refer to that department's or school's individual description on the following pages.

UNIVERSITY GRADUATION REQUIREMENTS

In addition to department and school requirements, students must meet all university graduation requirements (see "University Graduation Requirements," page 79). A well-planned program of study enables students to meet all requirements in a timely fashion. Students are encouraged to consult with an academic advisor in planning a program to ensure that they comply with all necessary requirements.

General Studies Requirement

All students enrolled in a baccalaureate degree program must satisfy a university requirement of a minimum of 35 hours of approved course work in General Studies. General Studies courses are listed in the "General Studies Courses" table, page 86, in the course descriptions in this catalog, in the *Schedule of Classes,* and in the *Summer Sessions Bulletin,* or on the Web. Consult with an advisor for an approved list of courses.

First-Year Composition Requirement

As a minimum, completion of ENG 101 and 102, or ENG 107 and 108, or ENG 105 with grades of "C" or higher is required for graduation from ASU in any baccalaureate program. See "First-Year Composition Requirement," page 79. Any student whose written or spoken English in any course is unsatisfactory may be required by the appropriate director or department chair to take additional course work.

COLLEGE DEGREE REQUIREMENTS

Pass/Fail Grades

Students enrolled in the college do not receive degree credit for pass/fail courses taken at this institution. In addition, no course in this college is offered for pass/fail credit. Students requesting credit for pass/fail courses taken at another institution must file a Petition for Adjustment to Curriculum Requirements to the department of their major. Each request is judged on its particular merits.

Entry into Upper-Division Courses

Before enrolling in courses at the 300 level and above, students must be in good academic standing in professional program status in this college and have the approval of their advisors. A student who is not in good academic standing must secure approval from his or her advisor and the college's Student Academic Services. Students whose grades in 300-level courses are unsatisfactory may be required to retake one or more courses for which credit has previously been granted.

The departments and schools have certain additional requirements that must be met in addition to the above college requirements, and students should consult them for details.

Non-CEAS Students. Students who are not admissible to programs in this college and who enroll in another college at ASU may not register for any 300- or 400-level courses in this college unless they are required in their degree programs and the students have the proper course prerequisites.

Currency of Course Work

Courses taken more than five years before admission to degree programs in this college are not normally accepted for transfer credit at the option of the department in which the applicant wishes to enroll. Courses completed within the five years preceding admission are judged as to their applicability to the student's curriculum.

ACADEMIC STANDARDS

Probation. A student is expected to make satisfactory progress toward completion of degree requirements to continue enrollment in the college. Any one of the following conditions is considered unsatisfactory progress and results in the student being placed on probationary status:

1. a semester or summer session with a GPA less than or equal to 1.50;
2. two successive semesters with GPAs less than 2.00; or
3. an ASU cumulative GPA less than 2.00.

Students on probation are subject to disqualification if

1. they do not attain a semester GPA of 2.25;
2. their cumulative GPA is below 2.00 at the end of the probationary semester; or
3. they are placed on probation for two consecutive semesters.

Courses completed during the summer sessions may not be used to reevaluate a student's fall semester probationary status.

Students on academic probation are not allowed to register for more than 13 semester hours of course work. Probationary students may not register for the next semester without a special permit from an advisor in Student Academic Services. Special permits are not given until grades are recorded by the registrar for the current semester.

Disqualification. During a semester on academic probation, a student who fails to meet the retention standards specified above is disqualified. Students may request a review of their disqualification status by contacting the director of Student Academic Services in ECG 205. Any disqualified student who is accepted by another college at ASU may not register for courses in this college unless the courses are required for the new major. Disqualified students who do register for courses in this college may be withdrawn from these courses any time during that semester. Furthermore, students at the university who have been disqualified academically by this college are not eligible to enroll in summer session courses in this college until the disqualification period has expired and they have been reinstated.

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Student and instructor work together in engineering lab.

Tim Trumble photo

Reinstatement. The college does not accept an application for reinstatement until the disqualified student has remained out of this college for at least a 12-month period. Merely having remained in a disqualified status for this period of time does not, in itself, constitute a basis for reinstatement. Proof of ability to do satisfactory college work in the chosen discipline is required, for example, completing at least 15 semester hours of pertinent courses in the discipline at a community college with a GPA of 2.50 or higher, and a cumulative GPA of 2.50 or higher for all courses completed.

Student Academic Services. The College of Engineering and Applied Sciences maintains a unit to assist individual students in various matters. This office coordinates the work of the College Academic Standards Committee; administers the probation, disqualification, and readmission processes, student disciplinary actions, and grade grievances; and reviews and processes requests for medical and compassionate withdrawal. This office also administers the college's scholarship program. Additional information is available at www.eas.asu.edu/sas.

STUDENT RESPONSIBILITIES

Course Prerequisites. Students should consult the *Schedule of Classes* and the catalog for course prerequisites. Students who register for courses without the designated prerequisites may be withdrawn without the student's consent at any time before the final examination. Such withdrawal may be initiated by the instructor, the chair of the department offering the course, the director of Student Academic Services, or the dean of the college. In such cases, students will not receive monetary reimbursement. However, such withdrawal is considered to be unrestricted as described under "Grading System," page 72, and does not count against the number of restricted withdrawals allowed.

SPECIAL OPPORTUNITIES

Cooperative Education. The co-op program is a work-study plan of education that alternates periods of academic study with periods of employment in business, industry, or government. Students who choose this program ideally complete 12 months of employment and graduate with both the academic background and practical experience gained from working with professionals in a chosen field.

A student in the college is eligible to apply to the co-op program upon completion of 45 or more hours of classes required for the selected major. Transfer students are required to complete at least one semester at ASU before beginning work. All student applicants must have a GPA of at least 2.50 and the approval of an advisor and the dean of the college.

To maintain continuous student status in the university, each co-op student must be enrolled in ASE 399 Cooperative Work Experience for one semester hour during each work session. Such credit cannot be applied toward degree requirements. For more information, visit Student Academic Services in ECG 205, or call 480/965-1750, and visit the Career Services office in SSV 329, or call 480/965-2350.

Foundation Coalition. ASU is a member of the Foundation Coalition, a National Science Foundation-funded group of seven institutions of higher learning across the U.S. that is working to improve engineering education. Foundation Coalition programs are intended to

1. demonstrate and promote the interrelationships of subject matter within the curriculum;
2. improve the interpersonal skills of students and the understanding of concepts through the use of more teaming and cooperative learning environments;
3. increase the use of technology in the curriculum; and
4. assess and evaluate intended improvements.

Such changes address the desires of employers, increase the numbers of baccalaureate degrees earned by members of currently underrepresented groups, and promote curriculum improvement. Foundation Coalition programs are available to all freshmen and sophomores in the School of Engineering and to juniors and seniors in Electrical Engineering and Industrial Engineering.

Foundation Coalition programs offer students a more hands-on, team-based, computer-intensive approach to the curriculum. The freshman programs provide an important opportunity for new students to get to know a small group of students, making a large university seem less overwhelming. The programs also involve more interactions with faculty and access to special tutors. All students get a team-based, computer-intensive education in ECE 100 (or ECE 194) Introduction to Engineering Design, and the Foundation Coalition program extends this experience to many more subjects and courses.

Freshmen Foundation Coalition programs offer both an integrated set of courses that include engineering, calculus, physics, and English in both the first and second semesters, and smaller course packages that include engineering, math, science, and English. In these packages, the same set of students take all of the courses in the package in high-tech, team-promoting classrooms while the faculty work together to deliver a unified set of courses. Sophomore programs involve courses in mathematics, mechanics, and electrical circuits.

Students interested in these programs should see their department advisor, visit the Foundation Coalition Office in ECG 303, call 480/965-5350, or access the Web site at www.eas.asu.edu/~asufc.

Minority Engineering Program. The staff of the Minority Engineering Program (MEP) is available to assist the academic and professional development of prospective, newly admitted, and continuing students through a variety of support services. In addition, advice on financial aid, scholarships, and employment is provided. For more information, visit the MEP office in ECG 307, call 480/965-8275, or access the MEP Web site at www.eas.asu.edu/~omep.

Women in Applied Sciences and Engineering Program. The Women in Applied Sciences and Engineering (WISE) Program hosts seminars and workshops, and provides outreach programs to high school and community college students to acquaint students with a variety of technical careers. The WISE Center, in room ECG 214, is open for study groups, tutoring, and informal discussions. For more information, call 480/965-6882, or access the Web site at www.eas.asu.edu/~wise.

Honor Societies. Students in the College of Engineering and Applied Sciences are encouraged to seek information concerning entry into those honor societies for which they may qualify. Membership in such organizations enhances the student's professional stature. The following honor societies are active within the college:

Alpha Pi Mu—Industrial Engineering Honor Society
Chi Epsilon—Civil Engineering Honor Society
Eta Kappa Nu—Electrical Engineering Honor Society
Pi Tau Sigma—Mechanical Engineering Honor Society
Sigma Gamma Tau—Aerospace Engineering Honor Society
Sigma Lambda Chi—Construction Honor Society
Tau Beta Pi—National Engineering Honor Society
Upsilon Pi Epsilon—National Computer Science Honor Society

Information on any of these organizations may be obtained from the respective department or school offices.

Honors Students. The College of Engineering and Applied Sciences participates in the programs of the Barrett Honors College, which provides enhanced educational experiences to academically superior undergraduate students. Participating students can major in any academic program. A description of the requirements and the opportunities offered by the Barrett Honors College can be found in "Curriculum," page 118.

Internships. A variety of internship programs exist within the college. Information on these programs can be obtained from the Engineering Internship Program coordinator in the office of the associate dean for Academic Affairs.

Scholarships. Information and applications for academic scholarships for continuing students may be obtained by contacting the college's Student Academic Services or the various department or school offices. Other scholarships may be available through the university Student Financial Assistance Office. For application and more information, access the Web site at www.eas.asu.edu/sas.

ROTC. Students pursuing a commission through either the Air Force or Army ROTC programs are required to take courses in the Department of Aerospace Studies or Department of Military Science. To preclude excessive overloads, these students should plan on at least one additional semester to complete degree requirements. Because of accreditation requirements, aerospace studies (AES) or military science (MIS) courses are not acceptable for degree credit in engineering as social and behavioral science or humanities and fine arts under General Studies. ROTC students must also meet all other degree requirements of this college.

GENERAL INFORMATION

Definition of Terms. The terms used in this college to describe offerings are defined below for purposes of clarity.

Program of Study. This broad term describes the complete array of courses included in the study leading to a degree.

Major. This term describes a specialized group of courses contained within the program of study. Example: program of study—engineering; major—Civil Engineering.

Area of Study (Technical Electives) or Concentration. Each of these terms describes a selection of courses within a major or among one or more majors. The number of technical electives varies from curriculum to curriculum. In several majors, the technical electives must be chosen from preselected groups. For this reason the choice of specific technical electives for an area of study should be made with the advice and counsel of an advisor. Example: major—Mechanical Engineering; area of study—thermosciences.

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Del E. Webb School of Construction

construction.asu.edu

480/965-3615

SCOB 241

William W. Badger, Director

Professors: Badger, Mulligan

Associate Professors: Ariaratnam, Bashford, Chasey, Duffy, Ernzen, Kashiwagi, Sawhney, Walsh, Weber, Wiezel

Assistant Professors: Fiori, Knutson

Visiting Eminent Scholar: Schexnayder

PURPOSE

Construction careers are so broadly diversified that no single curriculum prepares the student for universal entry into all fields. As an example, heavy construction contractors usually place more emphasis on technical and engineering science skills than do residential contractors/developers, who usually prefer a greater depth of knowledge in management and construction. To ensure a balanced understanding of the technical, professional, and philosophical standards that distinguish modern-day constructors, advisory groups representing leading associations of contractors and builders provide counsel in curriculum development. Construction has a common core of engineering science, management, and behavioral courses on which students may build defined concentrations to suit individual backgrounds, aptitudes, and objectives. These concentrations are not absolute but generally match major divisions of the construction industry.

DEGREES

Construction—B.S.

The faculty in the Del E. Webb School of Construction offer the B.S. degree in Construction. Four concentrations are available: general building construction, heavy construction, residential construction, and specialty construction.

Each concentration is arranged to accent requisite technical skills and to develop management, leadership, and competitive qualities in the student. Prescribed are a combination of General Studies courses, technical courses basic to engineering and construction, and courses on a broad range of applied management subjects fundamental to the business of construction contracting.

Construction—M.S.

The faculty in the school also offer the M.S. degree in Construction. Details for this degree are found in the *Graduate Catalog.*

Professional Accreditation and Affiliations. The Del E. Webb School of Construction is a member of the Associated Schools of Construction, an organization dedicated to the development and advancement of construction education. The construction program is accredited by the American Council for Construction Education.

SPECIAL PROGRAMS

The Del E. Webb School of Construction maintains a cooperative agreement with community colleges within Arizona and also with selected out-of-state colleges and universities to structure courses that are directly transferable into the construction program at ASU.

Student Organizations. The school has a chapter of Sigma Lambda Chi, a national honor society that recognizes high academic achievement in accepted construction programs. The school is also host to the Associated General Contractors of America student chapter, the National Association of Home Builders student chapter, and the Construction Women's Alliance.

Scholarships. Apart from those given by the university, a number of scholarships from the construction industry are awarded to students registered in the construction program. The scholarships are awarded on the basis of academic achievement and participation in activities of the construction program.

ADMISSION

For information regarding requirements for admission, transfer, retention, qualification, and reinstatement, see "Undergraduate Admission," page 58; "Admission," page 207; and "College Degree Requirements," page 211. A preprofessional category is available for applicants deficient in regular admission requirements. Vocational and craft-oriented courses taught at the community colleges are not accepted for credit toward a bachelor's degree in Construction.

BASIC REQUIREMENTS

Students complete the following basic requirements before registering for advanced courses: (1) All first-semester, first-year courses and the university First-Year Composition requirement (see "University Graduation Requirements," page 79) must be completed by the time the student has accumulated 48 semester hours of program requirements, and (2) all second-semester, first-year courses must be completed by the time the student has completed 64 semester hours of program requirements. Transfer students are given a one-semester waiver. Participation in a summer field internship activity is required for all students between the second and third years of the program.

Any student not making satisfactory progress is permitted to register for only those courses required to correct any deficiencies.

DEGREE REQUIREMENTS

A minimum of 128 semester hours with at least 50 hours at the upper-division level is required for graduation in general building construction, heavy construction, residential construction, and specialty construction. Students in all concentrations are required to complete a construction core of science-based engineering, construction, and management courses.

GRADUATION REQUIREMENTS

A student must earn a grade of "C" or higher in the mathematics and physics courses listed in the program of study.

In addition to fulfilling school and major requirements, majors must satisfy the General Studies requirements as noted in "General Studies," page 83, and all university graduation requirements as noted in "University Graduation Requirements," page 79. Note that all three General Studies awareness areas are required. Consult your advisor for an approved list of courses.

SCHOOL COURSE REQUIREMENTS

The school requires that the General Studies requirement be satisfied in the following manner:

Humanities and Fine Arts/Social and Behavioral Sciences

CON	101	Construction and Culture: A Built Environment *HU, G, H*	3
ECN	111	Macroeconomic Principles *SB*	3
ECN	112	Microeconomic Principles *SB*	3
HU/SB and awareness area courses as needed			3
HU/SB and awareness area courses as needed (upper division)			3
Total			15

Literacy and Critical Inquiry

COM	225	Public Speaking *L*	3
CON	496	Construction Contract Administration *L*	3
Total			6

Natural Sciences

PHY	111	General Physics *SQ*[1]	3
PHY	112	General Physics *SQ*[2]	3
PHY	113	General Physics Laboratory *SQ*[1]	1
PHY	114	General Physics Laboratory *SQ*[2]	1
Total			8

Mathematical Studies

MAT	270	Calculus with Analytic Geometry I *MA*	4
STP	226	Elements of Statistics *CS*	3
Total			7
General Studies/school requirements total[3]			36

1 Both PHY 111 and 113 must be taken to secure SQ credit.

2 Both PHY 112 and 114 must be taken to secure SQ credit.

3 Because of the school's requirement for MAT 270, the total semester hours exceed the General Studies requirement of 35.

Construction Major Requirements Common to *All* Concentrations (Except as Noted)

ACC	230	Uses of Accounting Information I or ACC 394 ST: Financial Analysis and Accounting for Small Businesses (3)*	3
CEE	340	Hydraulics and Hydrology	3
CON	221	Applied Engineering Mechanics: Statics	3
CON	243	Heavy Construction Equipment, Methods, and Materials	3
CON	244	Working Drawings Analysis	1
CON	251	Microcomputer Applications for Construction	3
CON	252	Building Construction Methods, Materials, and Equipment	3
CON	273	Electrical Construction Fundamentals	3
CON	296	Field Internship	0
CON	310	Testing of Materials for Construction	3
CON	323	Strength of Materials	3
CON	341	Surveying	3
CON	345	Mechanical Systems	3
CON	371	Construction Management and Safety	3
CON	383	Construction Estimating	3
CON	389	Construction Cost Accounting and Control *CS*	3
CON	424	Structural Design	3
CON	450	Soil Mechanics in Construction	3
CON	453	Construction Labor Management	3
CON	455	Construction Project Management	3
CON	463	Foundations	3
CON	495	Construction Planning and Scheduling *CS*	3
ECE	100	Introduction to Engineering Design *CS*	3
LES	305	Legal, Ethical, and Regulatory Issues in Business or LES 306 Business Law (3) (ASU West) or LES 380 Consumer Perspective of Business Law (3)	3
Physical science elective with lab			4
Total common to all concentrations			71

* ACC 394 ST: Financial Analysis and Accounting for Small Businesses is recommended.

Advisor-approved alternates/transfer credits for these courses may vary from the total required semester hours indicated. Such variances do not reduce the minimum of 128 semester hours required for the degree.

The course work for the first two years is the same for all concentrations.

First Semester

CON	101	Construction and Culture: A Built Environment *HU, G, H*	3
ECN	111	Macroeconomic Principles *SB*	3
ENG	101	First-Year Composition	3
MAT	270	Calculus with Analytic Geometry I *MA*	4
PHY	111	General Physics *SQ*[1]	3
PHY	113	General Physics Laboratory *SQ*[1]	1
Total			17

Second Semester

CON	244	Working Drawings Analysis	1
ECE	100	Introduction to Engineering Design *CS*	3
ECN	112	Microeconomic Principles *SB*	3
ENG	102	First-Year Composition	3
PHY	112	General Physics *SQ*[2]	3
PHY	114	General Physics Laboratory *SQ*[2]	1
HU elective with awareness area as needed			3
Total			17

Third Semester

CON	221	Applied Engineering Mechanics: Statics	3
CON	243	Heavy Construction Equipment, Methods, and Materials	3
CON	251	Microcomputer Applications for Construction	3
CON	273	Electrical Construction Fundamentals	3
STP	226	Elements of Statistics *CS*	3
Total			15

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

Fourth Semester

ACC 230 Uses of Accounting Information I 3
or ACC 394 ST: Financial Analysis and Accounting for Small Businesses[3] (3)
COM 225 Public Speaking *L* 3
CON 252 Building Construction Methods, Materials, and Equipment 3
CON 323 Strength of Materials 3
Physical science elective with lab 4

Total 16

[1] Both PHY 111 and 113 must be taken to secure SQ credit.
[2] Both PHY 112 and 114 must be taken to secure SQ credit.
[3] ACC 394 ST: Financial Analysis and Accounting for Small Businesses is recommended.

Concentration in General Building Construction

The general building construction concentration provides a foundation for students who wish to pursue careers as estimators, project managers, project engineers, and eventually, owners of firms engaged in the construction of industrial, commercial, and institutional structures. Educational focus is on building systems required for the mass development and production of large-scale projects. General building construction is addressed as an integrated process from conception through delivery of completed facilities to users.

Requirements

CON 472 Development Feasibility Reports *L* 3
CON 483 Advanced Building Estimating 3
PUP 432 Planning and Development Control Law 3
or PUP 433 Zoning Ordinances, Subdivision Regulations, and Building Codes (3)
REA 380 Real Estate Fundamentals 3
Upper-division technical elective 3

Total 15

Concentration in Heavy Construction

The heavy construction concentration prepares students for careers related to the public works discipline. Typical projects in which they are involved are highways, railroads, airports, power plants, rapid transit systems, process plants, harbor and waterfront facilities, pipelines, dams, tunnels, bridges, canals, sewerage and water works, and mass earthwork.

Requirements

CON 344 Route Surveying 3
CON 486 Heavy Construction Estimating 3
Upper-division business electives 6
Upper-division technical elective 3

Total 15

Concentration in Residential Construction

The residential construction concentration prepares students for careers in the residential sector of the industry. This concentration covers the specific methods and processes during the planning, production, marketing, and business-related activities common to residential construction.

Requirements

CON 377 Residential Construction Production Procedures 3
CON 477 Residential Construction Business Practices 3
CON 484 Internship 3
MKT 300 Principles of Marketing 3
PUP 432 Planning and Development Control Law 3
or PUP 433 Zoning Ordinances, Subdivision Regulations, and Building Codes (3)

Total 15

Concentration in Specialty Construction

The specialty construction concentration prepares students for careers with specialty constructors, such as mechanical and electrical construction firms. It emphasizes the construction process at the trade contractor level.

Requirements

CON 468 Mechanical and Electrical Estimating 3
CON 471 Mechanical and Electrical Project Management 3
CON 494 ST: Cleanroom Construction 3
Upper-division business electives 6

Total 15

CONSTRUCTION (CON)

CON 101 Construction and Culture: A Built Environment. (3)
fall and spring
Analyzes the cultural context of construction, emphasizing its centrality in the evolution and expansion of built environments as expressions of ethical and historical value systems. Lecture, speakers.
General Studies: HU, G, H

CON 221 Applied Engineering Mechanics: Statics. (3)
fall and spring
Vectors, forces and moments, force systems, equilibrium, analysis of basic structures and structural components, friction, centroids, and moments of inertia. Prerequisites: MAT 270; PHY 111, 113.

CON 243 Heavy Construction Equipment, Methods, and Materials. (3)
fall and spring
Emphasizes "Horizontal" construction. Fleet operations, maintenance programs, methods, and procedures to construct tunnels, roads, dams, and the excavation of buildings. Lab, field trips.

CON 244 Working Drawings Analysis. (1)
fall and spring
In-depth analysis of construction drawings (blueprint reading), interpreting symbols, dimensioning, projections, and general plan organization. Extensive workbook activity. Lecture, lab.

CON 251 Microcomputer Applications for Construction. (3)
fall and spring
Applies the microcomputer as a problem-solving tool for the constructor. Uses spreadsheets, information management, and multimedia software. Prerequisite: ECE 100.

CON 252 Building Construction Methods, Materials, and Equipment. (3)
fall and spring
Emphasizes "Vertical" construction. Methods, materials, codes, and equipment used in building construction corresponding to the 16 division "Master Format." Lecture, lab.

CON 273 Electrical Construction Fundamentals. (3)
fall and spring
Circuits and machinery. Power transmission and distribution, with emphasis on secondary distribution systems. Measurements and instrumentation. Lecture, field trips. Prerequisites: PHY 112, 114.

CON 294 Special Topics. (1–4)
selected semesters
Topics may include the following:
- Working Drawings and Specifications Analysis

CON 296 Field Internship. (0)
summer
Participation as interns on construction projects to observe and experience the daily activities. Internship.

CON 310 Testing of Materials for Construction. (3)
fall and spring
Structural and behavioral characteristics, engineering properties, measurements, and application of construction materials. Not open to engineering students. Lecture, lab. Prerequisite: CON 323.

CON 323 Strength of Materials. (3)
fall and spring
Analyzes strength and rigidity of structural members in resisting applied forces. Stress, strain, shear, moment, deflections, combined stresses, connections, and moment distribution. Both U.S. and SI units of measurement. Prerequisite: CON 221.

CON 341 Surveying. (3)
fall and spring
Theory and field work in construction and land surveys. Lecture, lab. Prerequisite: MAT 170.

CON 344 Route Surveying. (3)
spring
Simple, compound, and transition curves, including reconnaissance, preliminary, and location surveys. Calculation of earthwork. Dimensional control for construction projects. Lecture, lab. Prerequisites: CON 243, 341.

CON 345 Mechanical Systems. (3)
fall and spring
Design parameters and equipment related to heating and cooling systems for mechanical construction. Computer-aided calculations. Lecture, field trips. Prerequisites: CON 252; PHY 111, 113.

CON 371 Construction Management and Safety. (3)
fall and spring
Organization and management theory applied to the construction process. Leadership functions. Safety procedures and equipment. OSHA requirements for construction. Prerequisite: CON 252.

CON 377 Residential Construction Production Procedures. (3)
spring
Process used in residential construction. How a house is built: design, permits, scheduling, codes, contracting, site management, mechanical/electrical. Prerequisite: CON 252.

CON 383 Construction Estimating. (3)
fall and spring
Drawings and specifications. Methods and techniques used in construction estimating procedures. Introduces computer software used in industry. Lecture, project workshops. Prerequisites: a combination of CON 243 and 251 and 252 or only instructor approval.

CON 389 Construction Cost Accounting and Control. (3)
fall and spring
Nature of construction cost. Depreciation and tax theory and variable equipment costs. Cash flow theory, investment models, profitability, and analysis. Computer applications. Funding sources and arrangements. Builder's insurance. Prerequisites: ACC 230 (or 394 ST: Financial Analysis and Accounting for Small Businesses); CON 251.
General Studies: CS

CON 424 Structural Design. (3)
fall
Economic use of concrete, steel, and wood in building and engineered structures. Design of beams, columns, concrete formwork, and connections. Lecture, field trips. Prerequisite: CON 310.

CON 450 Soil Mechanics in Construction. (3)
fall and spring
Soil mechanics as applied to the construction field, including foundations, highways, retaining walls, and slope stability. Relationship between soil characteristics and geologic formations. Not open to engineering students. Lecture, lab. Prerequisite: CON 323.

CON 453 Construction Labor Management. (3)
fall and spring
Labor and management history, union, and open shop organization of building and construction workers; applicable laws and government regulations; goals, economic power, jurisdictional disputes, and grievance procedures. Lecture, lab. Prerequisites: CON 371; ECN 112.

CON 455 Construction Project Management. (3)
fall and spring
Study of methods for coordinating people, equipment, materials, money, and schedule to complete a project on time and within approved cost. Lecture, class projects. Prerequisite: CON 371. Pre- or corequisite: CON 495.

CON 463 Foundations. (3)
spring
Subsurface construction theory and practice for description, excavations, exploration, foundations, pavements, and slopes. Evaluation of specifications and plans of work. Lecture, recitation, field trips. Prerequisites: CON 424, 450.

CON 468 Mechanical and Electrical Estimating. (3)
fall
Analysis and organization of performing a cost estimate for both mechanical and electrical construction projects. Computer usage. Prerequisites: a combination of CON 273 and 345 and 383 or only instructor approval.

CON 471 Mechanical and Electrical Project Management. (3)
spring
Specialty contracts and agreements, scheduling, material handling, labor unit analysis, and job costing for mechanical and electrical construction. Prerequisite: CON 371.

CON 472 Development Feasibility Reports. (3)
fall and spring
Integrates economic location theory, development cost data, market research data, and financial analysis into a feasibility report. Computer orientation. Prerequisite: REA 380.
General Studies: L

CON 477 Residential Construction Business Practices. (3)
fall
Topics addressed include development, marketing, financing, legal issues, and sales. Prerequisite: CON 377 or instructor approval.

CON 483 Advanced Building Estimating. (3)
fall and spring
Concepts of pricing and markup, development of historic costs, life cycle costing, change order and conceptual estimating, and emphasizing microcomputer methods. Prerequisite: CON 383.

CON 484 Internship. (1–12)
selected semesters

CON 486 Heavy Construction Estimating. (3)
fall
Methods analysis and cost estimation for construction of highways, bridges, tunnels, dams, and other engineering works. Lecture, field trips. Prerequisites: CON 344, 383.

CON 494 Special Topics. (1–4)
fall and spring
Topics may include the following:
- Cleanroom Construction. (3)
  fall

CON 495 Construction Planning and Scheduling. (3)
fall and spring
Various network methods of project scheduling, such as AOA, AON Pert, bar-charting, line-of-balance, and VPM techniques. Microcomputers used for scheduling, resource allocation, and time/cost analysis. Lecture, lab. Prerequisites: CON 383; STP 226. Pre- or corequisite: CON 389.
General Studies: CS

CON 496 Construction Contract Administration. (3)
fall and spring
Surveys administrative procedures of general and subcontractors. Studies documentation, claims, arbitration, litigation, bonding, insurance, and indemnification. Discusses ethical practices. Lecture, field trips. Prerequisites: COM 225 or ECE 300; senior standing.
General Studies: L

CON 533 Strategies of Estimating and Bidding. (3)
fall
Explores advanced concepts of the estimating process, such as modeling and statistical analysis, to improve bid accuracies. Prerequisite: CON 483 or 486 or instructor approval.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

CON 540 Construction Productivity. (3)
fall
Productivity concepts. Data collection. Analysis of productivity data and factors affecting productivity. Means for improving production and study of productivity improvement programs. Pre- or corequisite: CON 495.

CON 543 Construction Equipment Engineering. (3)
spring
Analyzes heavy construction equipment productivity using case studies. Applies engineering fundamentals to the planning, selection, and utilization of equipment. Lecture, case studies.

CON 545 Construction Project Management. (3)
spring
Theory and practice of construction project management. Roles of designer, owner, general contractor, and construction manager. Lecture, field trips. Pre- or corequisite: CON 495.

CON 547 Strategic Planning. (3)
fall
Business planning process of the construction enterprise. Differences between publicly held and closely held businesses and their exposure.

CON 561 International Construction. (3)
spring
Investigation of the cultural, social, economic, political, and management issues related to construction in foreign countries and remote regions.

CON 565 Performance-Based Systems. (3)
fall
Identifying the multicriteria methodology in the procurement of facilities contractual work. Prerequisite: instructor approval.

CON 567 Advanced Procurement Systems. (3)
spring
Development of multicriteria decision procurement model for selecting the performing contractor. Prerequisite: instructor approval.

CON 570 Cleanroom Construction I. (3)
fall
Design issues for cleanroom facilities; the construction's viewpoint including planning, structures, mechanical, and tool installation. Lecture, site visits. Prerequisite: instructor approval.

CON 571 Cleanroom Construction II. (3)
spring
Construction issues for cleanroom facilities including scheduling, cost estimating, project management, mechanical, safety certification, and tool hook-up. Lecture, site visits. Prerequisite: CON 570 or instructor approval.

CON 575 Information Technology in Construction. (3)
spring
Use of information technology in the construction enterprise for improved communications, process modeling, and decision making. Prerequisite: instructor approval.

CON 589 Construction Company Financial Control. (3)
fall
Financial accounting and cost control at the company level in construction companies. Accounting systems. Construction project profit calculations. Financial analysis. Lecture, case studies.

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see "Omnibus Courses," page 56.

School of Engineering

480/965-1726

ECG 104

Ronald J. Roedel, Director

PURPOSE

A large percentage of all engineering degree holders are found in leadership positions in a wide variety of industrial settings. Although an education in engineering is generally considered to be one of the best technical educations, it also provides an opportunity for the development of many additional attributes, including ethical and professional characteristics. In this era of rapid technological change, an engineering education serves society well as a truly liberal education. Society's needs in the decades ahead call for engineering contributions on a scale not previously experienced. The well-being of civilization as we know it may depend upon how effectively this resource is developed.

Students studying engineering at ASU are expected to acquire a thorough understanding of the fundamentals of mathematics and the sciences and their applications to the solution of problems in the various engineering fields. The program is designed to develop a balance between science and engineering and an understanding of the economic and social consequences of engineering activity. The goals include the promotion of the general welfare of the engineering profession.

The courses offered are designed to meet the needs of the following students:

1. those who wish to pursue a career in engineering;
2. those who wish to do graduate work in engineering;
3. those who wish to have one or two years of training in mathematics, applied science, and engineering in preparation for some other technical career;
4. those who desire preengineering for the purpose of deciding which program to undertake or those who desire to transfer to another college or university; and
5. those who wish to take certain electives in engineering while pursuing another program in the university.

ADMISSION

For information regarding requirements for admission, transfer, retention, disqualification, and reinstatement, see "Undergraduate Admission," page 58; "Admission," page 207; "College Degree Requirements," page 211; and "Academic Standards," page 211.

Individuals who are beginning their initial college work in the School of Engineering should have completed certain secondary school units in addition to the minimum university admission requirements. Four units are required in mathematics; a course with trigonometry should be included. The laboratory sciences chosen must include at least one unit in physics and one unit in chemistry. Calculus, biology, and computer programming are also recommended. Students who do not meet the college's subject matter requirements may be required to complete additional university course work that may not apply toward an engineering degree. One or more of the courses—CHM 113 General Chemistry, CSE 181 Applied Problem Solving with Visual BASIC, MAT 170 Precalculus, and PHY 105 Basic Physics—may be required to satisfy omissions or deficiencies upon admission.

DEGREES

The Bachelor of Science in Engineering (B.S.E.) degree consists of three parts:

1. university requirements (e.g., General Studies, First-Year Composition);
2. an engineering core; and
3. a major.

The B.S. degree in Computer Science consists of two parts: (1) university requirements (e.g., General Studies, First-Year Composition); and (2) a major.

The courses identified for each of these parts are intended to meet requirements imposed by the university and by the professional accrediting agency, Accreditation Board for Engineering and Technology, Inc. (ABET), for programs in engineering and computing science, respectively.

In addition to First-Year Composition, the university requires, through the General Studies requirement, courses in literacy and critical inquiry, humanities and fine arts, social and behavioral sciences, mathematical studies, and natural sciences (see "General Studies," page 83). There are also requirements for historical awareness, global awareness, and cultural diversity in the United States. ABET imposes additional requirements, particularly in mathematics and the basic sciences and in the courses for the major.

The engineering core is an organized body of knowledge that serves as a foundation to engineering and to specialized studies in a particular engineering major.

The courses included in the engineering core are taught in such a manner that they serve as basic background material (1) for all engineering students who will be taking subsequent work in the same and related subject areas; and (2) for those students who may not desire to pursue additional studies in a particular subject area. Thus, subjects within the engineering core are taught with an integrity and quality appropriately relevant to the particular discipline but always with an attitude and concern for both engineering in general and for the particular major(s).

The majors available are of two types: (1) those associated with a particular department within the School of Engineering (for example, Electrical Engineering and Civil Engineering) and (2) those offered as concentrations in Engineering Special Studies (for example, premedical engineering). With the exception of the Computer Science major, all curricula are extensions beyond the engineering core and cover a wide variety of subject areas within each field. Some of the credits in the major are reserved for the student's use as an area of study. These credits are traditionally referred to as *technical electives.*

Majors and areas of study are offered by the seven departments:

Department of Bioengineering
Department of Chemical and Materials Engineering
Department of Civil and Environmental Engineering
Department of Computer Science and Engineering
Department of Electrical Engineering
Department of Industrial Engineering
Department of Mechanical and Aerospace Engineering

The major in Engineering Special Studies is administered by the Office of the Dean. Engineering Special Studies makes use of the general structure of the engineering curricula noted above and provides students with an opportunity for study in engineering concentrations not available in the traditional engineering curricula at ASU.

The first two years of study are concerned primarily with general education requirements, English proficiency, and the engineering core. The final two years of study are concerned with the engineering core and the major, with a considerable part of the time being spent on the major.

The semester-by-semester selection of courses may vary from one field to another, particularly at the upper-division level, and is determined by the student in consultation with a faculty advisor. An example of a typical full-time freshman-year schedule is shown below; depending on a particular student's circumstances, many other examples are possible.

Typical Freshman Year

CHM	114	General Chemistry for Engineers *SQ*	4
ECE	100	Introduction to Engineering Design *CS*	3
ECN	111	Macroeconomic Principles *SB*	3
		or ECN 112 Microeconomic Principles *SB* (3)	
ENG	101	First-Year Composition	3
ENG	102	First-Year Composition	3
MAT	270	Calculus with Analytic Geometry I *MA*	4
MAT	271	Calculus with Analytic Geometry II *MA*	4
PHY	121	University Physics I: Mechanics *SQ**	3
PHY	122	University Physics Laboratory I *SQ**	1
HU/SB and awareness area course			3
Total			31

* Both PHY 121 and 122 must be taken to secure SQ credit.

Well-prepared students who have no outside commitments can usually complete the program of study leading to an undergraduate degree in engineering in four years (eight semesters at 16 semester hours per semester). Many students, however, find it advantageous or necessary to devote more than four years to the undergraduate program by pursuing, in any semester, fewer studies than are regularly prescribed. Where omissions or deficiencies exist—e.g., in chemistry, computer programming, English, mathematics, and physics—the student must complete more than the minimum of 128 semester hours. Therefore, in cases of

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

inadequate secondary preparation, poor health, or financial necessity requiring considerable time for outside work, the undergraduate program is extended beyond four years.

DEGREE REQUIREMENTS

The degree programs in engineering at ASU are intended to develop habits of quantitative thought having equal utility for both the practice of engineering and other professional fields. In response to the opportunities provided by changing technology, educational research, and industrial input, possible improvements of various aspects of these programs are routinely considered. It is the intent of the faculty that all students be appropriately prepared in the four areas described below.

1. *Oral and written English.* Communication skills are an essential component of an engineering education. All engineering students must complete the university First-Year Composition requirement (see "University Graduation Requirements," page 79), and the literacy and critical inquiry component (see "Five Core Areas," page 83) of the General Studies requirement, which involves two courses beyond First-Year Composition.
2. *Selected nonengineering topics.* This area ensures that the engineering student acquires a satisfactory level of basic knowledge in the humanities and fine arts, social and behavioral sciences, mathematical studies, and the natural sciences. Courses in these subjects give engineers an increased awareness of their social responsibilities, provide an understanding of related factors in the decision-making process, and also provide a foundation for the study of engineering. Required courses go toward fulfilling the General Studies requirement. Additional courses in mathematics and the basic sciences are selected to meet ABET requirements.

   Because of accreditation requirements, aerospace studies (AES) and military science (MIS) courses are not acceptable for engineering degree credit in fulfilling the humanities and fine arts and social and behavioral science portions of the General Studies requirement.
3. *Selected engineering topics.* This area involves courses in engineering science and engineering design. The courses further develop the foundation for the study of engineering and provide the base for specialized studies in a particular engineering discipline. The specific courses are included in the engineering core and in the major. While some departmental choices are allowed, all students are required to take ECE 100 Introduction to Engineering Design and ECE 300 Intermediate Engineering Design as part of the engineering core. These courses, together with other experiences in the engineering core and in the major, serve to integrate the study of design, the "process of devising a system, component, or process to meet desired needs" (ABET), throughout the engineering curricula.
4. *Specific engineering discipline.* This area provides a depth of understanding of a more definitive body of knowledge that is appropriate for a specific engineering discipline. Courses build upon the background provided by the earlier completed portions of the curriculum and include a major design experience as well as technical electives that may be selected by the student with the assistance of an advisor. The catalog material for the individual engineering majors describes specific departmental requirements.

COURSE REQUIREMENTS

A summary of the degree requirements is as follows:

First-Year Composition	6
General Studies/school requirements	56
Engineering core	14–18
Major (including area of study or concentration)*	48–52
Minimum total	128

* The requirements for each of the majors offered are described on the following pages.

Specific course requirements for the B.S. and B.S.E. degrees follow.

First-Year Composition

Choose among the course combinations below	6
ENG 101 First-Year Composition (3)	
ENG 102 First-Year Composition (3)	
—*or*—	
ENG 105 Advanced First-Year Composition (3)	
Elective chosen with an advisor (3)	
—*or*—	
ENG 107 English for Foreign Students (3)	
ENG 108 English for Foreign Students (3)	
Total	6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences[1]

ECN 111 Macroeconomic Principles *SB*	3
or ECN 112 Microeconomic Principles *SB* (3)	
HU and awareness area courses	6 or 9
SB and awareness area course(s)	6 or 3
Total	15

Literacy and Critical Inquiry

ECE 300 Intermediate Engineering Design *L*	3
ECE 400 Engineering Communications *L*	3
or approved department L course (3)	
Total	6

Mathematical, Computation, and Quantitative Studies

ECE 100 Introduction to Engineering Design *CS*	3
MAT 270 Calculus with Analytic Geometry I *MA*	4
MAT 271 Calculus with Analytic Geometry II *MA*	4
MAT 272 Calculus with Analytic Geometry III *MA*	4
MAT 274 Elementary Differential Equations *MA*	3
Department mathematics elective	2
Total	20

Natural Sciences/Basic Sciences

CHM 114 General Chemistry for Engineers *SQ*	4
or CHM 116 General Chemistry *SQ* (4)	
PHY 121 University Physics I: Mechanics *SQ*[2]	3
PHY 122 University Physics Laboratory I *SQ*[2]	1

PHY 131 University Physics II: Electricity and Magnetism *SQ*[3] 3
PHY 132 University Physics Laboratory II *SQ*[3] 1
Department basic science elective 3

Total 15
General Studies/school requirements total 56

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[1] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU or SB requirements. Courses in the awareness areas of global, historical, and cultural diversity in the United States must also be represented in the program of study. One course must be upper-division.

[2] Both PHY 121 and 122 must be taken to secure SQ credit.

[3] Both PHY 131 and 132 must be taken to secure SQ credit.

Engineering Core Requirement

In addition in ECE 100 and 300, which also fulfill a portion of the university General Studies requirement, a minimum of five of the following eight courses are required. Courses selected are subject to departmental approval. See department requirements.

ECE 201 Electrical Networks I 4
ECE 210 Engineering Mechanics I: Statics 3
ECE 212 Engineering Mechanics II: Dynamics 3
ECE 214 Engineering Mechanics 4
ECE 313 Introduction to Deformable Solids 3
ECE 334 Electronic Devices and Instrumentation 4
ECE 340 Thermodynamics 3
or CHE 342 Applied Chemical Thermodynamics (4)
or MSE 430 Thermodynamics of Materials (3)
ECE 350 Structure and Properties of Materials 3
or ECE 351 Civil Engineering Materials (3)
or ECE 352 Properties of Electronic Materials (4)
Choose one microcomputer/microprocessor course below ..... 3 or 4
BME 470 Microcomputer Applications in Bioengineering (4)
CHE 461 Process Control *CS* (4)
CSE 225 Assembly Language Programming and Microprocessors (Motorola) (4)
or EEE 225 Assembly Language Programming and Microprocessors (Motorola) (4)
CSE 226 Assembly Language Programming and Microprocessors (Intel) (4)
or EEE 226 Assembly Language Programming and Microprocessors (Intel) (4)
IEE 463 Computer-Aided Manufacturing and Control *CS* (3)

GRADUATION REQUIREMENTS

To qualify for graduation from the School of Engineering, a student must have a minimum cumulative GPA of 2.00 in addition to having a GPA of at least 2.00 for the courses in the major field.

PROFESSIONAL ACCREDITATION

The undergraduate programs in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Systems Engineering, Electrical Engineering, Industrial Engineering, Materials Science and Engineering, and Mechanical Engineering are accredited by the Engineering Accreditation Commission of ABET, Baltimore, Maryland, 410/347-7700. The B.S. program in Computer Science is accredited by the Computer Science Accreditation Commission of ABET.

ANALYSIS AND SYSTEMS (ASE)

ASE 100 College Adjustment and Survival. (2)
fall and spring
Explores career goals and majors. Emphasizes organization and development of study skills, including time management, stress management, and use of the library.

ASE 194 Special Topics. (1–4)
fall
Topics may include the following:
- MEP Academic Success. (2)

ASE 399 Cooperative Work Experience. (1)
fall, spring, summer
Work periods with industrial firms or government agencies alternated with full-time course work. Not open to students from other colleges. May be repeated for credit. Prerequisites: 45 hours completed in major with 2.50 GPA; dean approval.

ASE 485 Engineering Statistics. (3)
fall, spring, summer
Designing statistical studies for solutions to engineering problems. Methods include regression, design and analysis of experiments, and other statistical topics. Prerequisite: ECE 380.
General Studies: CS

ASE 490 Project in Design and Development. (2–3)
fall, spring, summer
Individual project in creative design and synthesis. May be repeated for credit. Prerequisite: senior standing.

ASE 496 Professional Seminar. (0)
fall and spring
Topics of interest to students in the engineering special and interdisciplinary studies.

ASE 500 Research Methods: Engineering Statistics. (3)
fall, spring, summer
Designing statistical studies for solutions to engineering problems. Methods include regression, design and analysis of experiments, and other statistical topics. Prerequisite: ECE 380.

ASE 582 Linear Algebra in Engineering. (3)
fall
Development and solution of systems of linear algebraic equations. Applications from mechanical, structural, and electrical fields of engineering. Prerequisite: MAT 242 (or its equivalent).

ASE 586 Partial Differential Equations in Engineering. (3)
spring
Development and solution of partial differential equations in engineering. Applications in solid mechanics, vibrations, and heat transfer. Prerequisites: MAT 242, 274.

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

ENGINEERING CORE (ECE)

ECE 100 Introduction to Engineering Design. (3)
fall and spring
Introduces engineering design; teaming; the profession of engineering; computer models in engineering; communication skills; quality and customer satisfaction. Prerequisites: high school computing and physics and algebra courses (or their equivalents).
General Studies: CS

ECE 194 Special Topics. (1–4)
fall and spring
Topics may include the following:
- Introduction to Engineering Design I
- Introduction to Engineering Design II

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

ECE 200 Elements of Engineering Design. (3)
fall and spring
Advanced version of ECE 100 for students who transfer to ASU after completion of the stated prerequisites. Credit is allowed for only ECE 100 or 200. Lecture, lab. Prerequisite for engineering majors: ENG 101 (or 105); MAT 270; PHY 121, 122. Prerequisite for Construction majors: ENG 101 (or 105); MAT 270; PHY 111, 113. Pre- or corequisite for engineering majors: CHM 113 or 114 or 116.

ECE 201 Electrical Networks I. (4)
fall, spring, summer
Introduces electrical networks. Component models, transient, and steady-state analysis. Lecture, lab. Prerequisite: ECE 100 or 194 (ST: Introduction to Engineering Design I and ST: Introduction to Engineering Design II) or 200. Pre- or corequisites: MAT 274; PHY 131, 132.

ECE 210 Engineering Mechanics I: Statics. (3)
fall, spring, summer
Force systems, resultants, equilibrium, distributed forces, area moments, fluid statics, internal stresses, friction, energy criterion for equilibrium, and stability. Lecture, recitation. Prerequisites: ECE 100 or 194 (ST: Introduction to Engineering Design I and ST: Introduction to Engineering Design II) or 200; MAT 271 (or 291); PHY 121, 122.

ECE 212 Engineering Mechanics II: Dynamics. (3)
fall, spring, summer
Kinematics and kinetics of particles, translating and rotating coordinate systems, rigid body kinematics, dynamics of systems of particles and rigid bodies, and energy and momentum principles. Lecture, recitation. Prerequisites: ECE 210; MAT 274.

ECE 214 Engineering Mechanics. (4)
fall, spring, summer
Force systems, resultants, moments and equilibrium. Kinematics and kinetics of particles, systems of particles and rigid bodies. Energy and momentum principles. Lecture, recitation. Prerequisites: ECE 100 or 194 (ST: Introduction to Engineering Design I and ST: Introduction to Engineering Design II) or 200; MAT 274; PHY 121, 122.

ECE 294 Special Topics. (1–4)
selected semesters
Topics may include the following:
- Elements of Engineering Design

ECE 300 Intermediate Engineering Design. (3)
fall, spring, summer
Engineering design process concentrating on increasing the ability to prepare well-written technical communication and to define problems and generate and evaluate ideas. Teaming skills enhanced. Prerequisites: ECE 100 or 194 (ST: Introduction to Engineering Design I and ST: Introduction to Engineering Design II) or 200; ENG 102 (or 105 or 108); at least two other engineering core courses.
General Studies: L

ECE 313 Introduction to Deformable Solids. (3)
fall, spring, summer
Equilibrium, strain-displacement relations, and stress-strain-temperature relations. Applications to force transmission and deformations in axial, torsional, and bending of bars. Combined loadings. Lecture, recitation. Prerequisites: ECE 210 (or 214); MAT 274.

ECE 334 Electronic Devices and Instrumentation. (4)
fall, spring, summer
Applies electric network theory to semiconductor circuits. Diodes/transistors/amplifiers/opamps/digital logic gates, and electronic instruments. Lecture, lab. Prerequisite: ECE 201.

ECE 340 Thermodynamics. (3)
fall, spring, summer
Work, heat, and energy transformations and relationships between properties; laws, concepts, and modes of analysis common to all applications of thermodynamics in engineering. Lecture, recitation. Prerequisites: CHM 114 (or 116); ECE 210 (or 214); PHY 131, 132. Pre- or corequisite: MAT 274.

ECE 350 Structure and Properties of Materials. (3)
fall, spring, summer
Basic concepts of material structure and its relation to properties. Application to engineering problems. Prerequisites: CHM 114 (or 116); PHY 121, 122.

ECE 351 Civil Engineering Materials. (3)
fall and spring
Structure and behavior of civil engineering materials. Laboratory investigations and test criteria. Lecture, lab. Prerequisite: ECE 313.

ECE 352 Properties of Electronic Materials. (4)
fall, spring, summer
Schrodinger's wave equation, potential barrier problems, bonds of crystals, the band theory of solids, semiconductors, superconductor dielectric, and magnetic properties. Prerequisites: CHM 114 (or 116); MAT 274; PHY 241.

ECE 380 Probability and Statistics for Engineering Problem Solving. (3)
fall and spring
Applications-oriented course with computer-based experience using statistical software for formulating and solving engineering problems. 2 hours lecture, 2 hours lab. Prerequisite: MAT 271.
General Studies: CS

ECE 384 Numerical Methods for Engineers. (4)
fall and spring
Numerical methods and computational tools for selected problems in engineering. Prerequisites: ECE 100 or 194 (ST: Introduction to Engineering Design I and ST: Introduction to Engineering Design II) or 200; MAT 274; at least two other engineering core courses. Pre- or corequisite: MAT 272.

ECE 394 Special Topics. (1–4)
fall and spring
Topics may include the following:
- Conservation Principles. (4)
- Engineering Systems. (4)
- Introduction to Manufacturing Engineering. (3)
- Properties that Matter. (3)

ECE 400 Engineering Communications. (3)
fall, spring, summer
Planning and preparing engineering publications and oral presentations, based on directed library research related to current engineering topics. Prerequisites: ENG 102 (or 105 or 108); completion of General Studies L requirement (or ECE 300); senior standing in an engineering major.
General Studies: L

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

SOCIETY, VALUES, AND TECHNOLOGY (STE)

STE 208 Patterns in Nature. (4)
fall and spring
Project-oriented science course with computer training to develop critical thinking and technical skills for student-oriented K–12 science lessons. Lecture, lab. Cross-listed as PHS 208. Credit is allowed for only PHS 208 or STE 208. Prerequisite: a college-level course in science or instructor approval.
General Studies: SQ

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

Department of Bioengineering

www.eas.asu.edu/~bme
480/965-3028
ECG 334

Eric J. Guilbeau, Chair

Professors: Guilbeau, Towe

Associate Professors: Garcia, He, Iasemidis, Massia, Pizziconi Sweeney, Yamaguchi

Assistant Professors: Muthuswamy, Panitch, Vernon

Senior Research Professional: Brandon

The faculty in the Department of Bioengineering offer the B.S.E. degree in Bioengineering. The major builds on a broad base of knowledge within the basic and mathematical sciences and the engineering core. The major offers graduates excellent career opportunities.

Faculty within the department also participate in the Engineering Special Studies program in premedical engineering, which is described separately in "Programs in Engineering Special Studies," page 273.

BIOENGINEERING—B.S.E.

Bioengineering (synonyms: biomedical engineering, medical engineering) is the discipline of engineering that applies principles and methods from engineering, the physical sciences, the life sciences, and the medical sciences to understand, define, and solve problems in medicine, physiology, and biology. The mission of the bioengineering program at ASU is to educate students to use engineering and scientific principles and methods to develop instrumentation, materials, diagnostic and therapeutic devices, artificial organs, or other equipment and technologies needed in medicine and biology and to discover new fundamental principles regarding the functioning and structure of living systems. The overall goal of the program is to produce high-quality graduates with a broad-based education in engineering and the life and natural sciences who are well prepared for further graduate study in bioengineering, a career in the medical device or biotechnology industries, a career in biomedical research, or entry into a medical or other health profession school.

The program's mission is achieved by having its faculty and graduate teachers fulfill the following objectives: to provide students with a strong foundation in mathematics, the physical and life sciences, and basic engineering; and to give students a balance of theoretical understanding and ability in order to apply modern techniques, skills, and tools for problem solving at the interface of engineering with the biological and medical sciences. Students demonstrate an ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and nonliving materials and systems. Students are able to design systems, devices, components, processes, and experiments with an understanding of manufacturing processes to meet real-world needs for solutions to problems in the biomedical device industries, medicine, and the life sciences. Students are able to communicate effectively as bioengineers in oral, written, computer-based, and graphical forms. Faculty seek to instill students with a sense of commitment to professionalism and ethical responsibility as bioengineers. Students are given opportunities to interact with and gain real-world experience with local and national medical device and technology industries, health-care organizations, educational institutions, and constituent populations. Faculty seek to develop within students an understanding of and positive approach toward continued lifelong learning of new technologies and relevant issues in the discipline of bioengineering.

Graduate degree programs in Bioengineering are offered at ASU at the master's and doctoral levels. For more information, consult the *Graduate Catalog.*

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Bioengineering. A minimum of 50 upper-division semester hours is required. Students must attain a GPA of at least 2.00 for the courses in the major field.

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, students must satisfy all university graduation requirements. See "University Graduation Requirements," page 79.

COURSE REQUIREMENTS

The course work, in semester hours, for the undergraduate degree can be classified into the following categories:

First-Year Composition

Choose among the course combinations below 6
ENG 101 First-Year Composition (3)
ENG 102 First-Year Composition (3)
———*or*———
ENG 105 Advanced First-Year Composition (3)
Elective chosen with an advisor (3)
———*or*———
ENG 107 English for Foreign Students (3)
ENG 108 English for Foreign Students (3)

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences
ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
HU/SB and awareness area courses 12

Total 15

Literacy and Critical Inquiry
BME 413 Biomedical Instrumentation *L*....................................3
BME 423 Biomedical Instrumentation Laboratory *L*....................1

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

ECE	300	Intermediate Engineering Design *L*	3
Total			7

Natural Sciences/Basic Sciences

CHM	113	General Chemistry *SQ*	4
CHM	116	General Chemistry *SQ*	4
PHY	121	University Physics I: Mechanics *SQ*[1]	3
PHY	122	University Physics Laboratory I *SQ*[1]	1
PHY	131	University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY	132	University Physics Laboratory II *SQ*[2]	1
Total			16

Mathematical Studies

ECE	100	Introduction to Engineering Design *CS*	3
ECE	384	Numerical Methods for Engineers	4
MAT	270	Calculus with Analytic Geometry I *MA*	4
MAT	271	Calculus with Analytic Geometry II *MA*	4
MAT	272	Calculus with Analytic Geometry III *MA*	4
MAT	274	Elementary Differential Equations *MA*	3
Total			22
General Studies/school requirements total			60

Engineering Core

ECE	201	Electrical Networks I	4
ECE	210	Engineering Mechanics I: Statics	3
ECE	334	Electronic Devices and Instrumentation	4
ECE	340	Thermodynamics	3
ECE	350	Structure and Properties of Materials	3
Total			17

Major

BIO	188	General Biology II *SQ*	4
BME	201	Introduction to Bioengineering *L*	3
BME	318	Biomaterials	3
BME	331	Biomedical Engineering Transport: Fluids	3
BME	334	Bioengineering Heat and Mass Transfer	3
BME	416	Biomechanics	3
BME	417	Biomedical Engineering Capstone Design I	3
BME	435	Physiology for Engineers	4
BME	470	Microcomputer Applications in Bioengineering	4
BME	490	Biomedical Engineering Capstone Design II	3
ECE	380	Probability and Statistics for Engineering Problem Solving *CS*	3
Technical electives			9
Minimum total			45

[1] Both PHY 121 and 122 must be taken to secure SQ credit.

[2] Both PHY 131 and 132 must be taken to secure SQ credit.

The major BME courses require a grade of “C” or higher to advance in the program and to receive a baccalaureate degree.

Bioengineering Areas of Study

Technical electives should in general be selected from one of the following emphasis areas. Students can elect to emphasize biochemical engineering, bioelectrical engineering, biomaterials engineering, biomechanical engineering, biomedical imaging engineering, biosystems engineering, molecular and cellular bioengineering, or premedical engineering in their studies. A student may also, with prior approval of the department, select a general area of study or combination of courses that support a career in bioengineering not covered by the following areas.

Biochemical Engineering. This area is designed to strengthen the student’s knowledge of chemistry and transport phenomena and is particularly well suited for students interested in biotechnology. Students should choose technical electives from the following:

BCH	361	Principles of Biochemistry or BCH 461 General Biochemistry (3)	3
BCH	462	General Biochemistry	3
CHE	475	Biochemical Engineering	3
CHE	476	Bioreaction Engineering	3
CHE	477	Bioseparation Processes	3
CHM	331	General Organic Chemistry	3
CHM	332	General Organic Chemistry	3
CHM	335	General Organic Chemistry Laboratory	1
CHM	336	General Organic Chemistry Laboratory	1
MIC	420	Immunology: Molecular and Cellular Foundations	3

Bioelectrical Engineering. This area is designed to strengthen the student’s knowledge of electrical systems, electronics, and signal processing. Students considering a career in bioelectric phenomena, biocontrol systems, medical instrumentation, neural engineering, or electrophysiology should consider this area of study. Students should choose technical electives from the following:

BME	350	Signals and Systems for Bioengineers or EEE 303 Signals and Systems (3)	3
BME	419	Biocontrol Systems	3
EEE	302	Electrical Networks II	3
EEE	425	Digital Systems and Circuits or EEE 433 Analog Integrated Circuits (3)	3

Biomaterials Engineering. This area integrates the student’s knowledge of materials science and engineering with biomaterials science and engineering concepts for the design of materials intended to be used for the development of medical and diagnostic devices. It emphasizes structure-property relationships of engineering materials (metals, polymers, ceramics, and composites) and biological materials, biomaterial-host response phenomena, technical and regulatory aspects of biomaterials testing and evaluation. Students interested in careers in the biomaterials, medical device, or biotechnology industries should consider this area of study. Students must take the following two courses:

MSE	353	Introduction to Materials Processing and Synthesis	3
MSE	355	Introduction to Materials Science and Engineering	3

Students should choose additional technical electives from the following:

BME	494	ST: Biopolymeric Drug Delivery	3
MSE	431	Corrosion and Corrosion Control	3
MSE	441	Analysis of Material Failures	3
MSE	470	Polymers and Composites	3
MSE	471	Introduction to Ceramics	3

Biomechanical Engineering. This area is designed to strengthen the student’s knowledge of mechanics and control theory. Students interested in careers related to biomechanical analyses, the design of orthotic/prosthetic devices and orthopaedic implants, forensic biomechanics, and rehabilitation engineering should consider this area of study. While students may choose any combination of the following technical electives, it is recommended that courses be selected from one of three subareas: movement biomechanics, rehabilitation engineering, or orthopaedic biomechanics. The movement biomechanics area is designed to strengthen the student's knowledge of dynamics and control theory. Students interested in analyzing pathological movement disorders, sports techniques, and neuromuscular control should select courses from this area. Rehabilitation engineering emphasizes the design of highly functional products for people with disabilities. Biomechanical, electrical, and mechanical design procedures are used to develop new assistive devices, orthoses, and prostheses. The student primarily interested in the material properties of bones, cartilage, soft tissues, and the design of implants for tissue repair and replacement should select courses from the orthopaedic biomechanics area.

Recommended subarea selections of courses are as follows:

Movement Biomechanics

BME 350 Signals and Systems for Bioengineers 3
or EEE 303 Signals and Systems (3)
BME 419 Biocontrol Systems 3
ECE 212 Engineering Mechanics II: Dynamics 3
EPE 334 Functional Anatomy and Kinesiology 3
or EPE 414 Electromyographic Kinesiology (3)

Rehabilitation Engineering

ECE 212 Engineering Mechanics II: Dynamics 3
EPE 334 Functional Anatomy and Kinesiology 3
IEE 437 Human Factors Engineering 3
or DSC 344 Human Factors in Design (3)
IND 354 Principles of Product Design 3
MAE 341 Mechanism Analysis and Design 3

Orthopaedic Biomechanics

ECE 212 Engineering Mechanics II: Dynamics 3
ECE 313 Introduction to Deformable Solids 3
EPE 412 Biomechanics of the Skeletal System 3
MAE 404 Finite Elements in Engineering 3

Biomedical Imaging Engineering. This area is designed to strengthen the student's knowledge of radiation interactions, health physics, medical diagnostic imaging (MRI, PET, X-ray, CT), radiation protection, and nuclear instrumentation. Students considering careers in medical engineering or health physics should consider this area of study. Students should choose technical electives from the following or other departmental approved electives:

BME 350 Signals and Systems for Bioengineers 3
or EEE 303 Signals and Systems (3)
BME 494 ST: Scanning Probe Microscopy 3
EEE 460 Nuclear Concepts for the 21st Century 3
PHY 361 Introductory Modern Physics 3

Biosystems Engineering. This area is designed to strengthen the background of students interested in physiological systems modeling and analysis and design and evaluation of artificial organs and medical devices. Analyzing physiological systems and designing artificial organs require knowledge in integrating electrical, mechanical, transport, and thermofluid systems. Students considering careers in medical device industries, clinical engineering, or artificial organs should consider this area of study.

Students should choose technical electives from the following:

BME 350 Signals and Systems for Bioengineers 3
or BME 419 Biocontrol Systems (3)
BME 411 Biomedical Engineering I 3
BME 412 Biomedical Engineering II 3
BME 415 Biomedical Transport Processes 3
CHE 476 Bioreaction Engineering 3

Molecular and Cellular Bioengineering. This area is designed to strengthen and integrate the student's knowledge of molecular and cellular biology, biochemistry, and biomaterials science and engineering for the design of biomolecular- and cellular-based hybrid medical and diagnostic devices. It is particularly suited for students interested in pursuing graduate studies in molecular and cellular bioengineering and health-related biotechnologies.

Students are encouraged to choose the following courses:

BIO 353 Cell Biology 3
BME 494 ST: Biotechnology Laboratory Techniques 3
CHM 331 General Organic Chemistry 3

Students should choose additional or alternative technical electives from the following;

BCH 361 Principles of Biochemistry 3
or BCH 461 General Biochemistry (3)
BIO 340 General Genetics 4
or MBB 350 Applied Genetics (4)
or PLB 350 Applied Genetics (4)
BIO 343 Genetic Engineering and Society 4
or MBB 343 Genetic Engineering and Society (4)
BME 494 ST: Cell Biotechnology 3
BME 494 ST: Introduction to Molecular, Cellular, and Tissue Engineering 3
CHE 475 Biochemical Engineering 3
or CHE 476 Bioreaction Engineering (3)
or CHE 477 Bioseparation processes (3)
CHM 335 General Organic Chemistry Laboratory 1

Premedical Engineering. This area is designed to meet the needs of students desiring entry into a medical, dental, or veterinary school. The course sequence provides an excellent background for advanced study leading to a career in research in the medical or life sciences. Technical electives must include the following:

CHM 331 General Organic Chemistry 3
CHM 332 General Organic Chemistry 3
CHM 335 General Organic Chemistry Laboratory 1
CHM 336 General Organic Chemistry Laboratory 1

Additional technical electives should be chosen from any of the course offerings listed for the other bioengineering areas of study listed. Note that, to fulfill medical school admission requirements, BIO 187 General Biology is required in addition to the degree requirements and cannot generally be used as a technical elective.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

Bioengineering Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM 113	General Chemistry *SQ*	4
ECE 100	Introduction to Engineering Design *CS*	3
ENG 101	First-Year Composition	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
Total		14

Second Semester

CHM 116	General Chemistry *SQ*	4
ENG 102	First-Year Composition	3
MAT 271	Calculus with Analytic Geometry II *MA*	4
PHY 121	University Physics I: Mechanics *SQ*[1]	3
PHY 122	University Physics Laboratory I *SQ*[1]	1
Total		15

Second Year

First Semester

BIO 188	General Biology II *SQ*	4
BME 201	Introduction to Bioengineering *L*	3
ECE 210	Engineering Mechanics I: Statics	3
MAT 272	Calculus with Analytic Geometry III *MA*	4
PHY 131	University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY 132	University Physics Laboratory II *SQ*[2]	1
Total		18

Second Semester

ECE 201	Electrical Networks I	4
ECE 350	Structure and Properties of Materials	3
ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
MAT 274	Elementary Differential Equations *MA*	3
HU/SB and awareness area course[3]		3
Total		16

Third Year

First Semester

BME 331	Biomedical Engineering Transport: Fluids	3
BME 435	Physiology for Engineers	4
ECE 300	Intermediate Engineering Design *L*	3
ECE 340	Thermodynamics	3
ECE 384	Numerical Methods for Engineers	4
Total		17

Second Semester

BME 318	Biomaterials	3
BME 334	Bioengineering Heat and Mass Transfer	3
ECE 334	Electronic Devices and Instrumentation	4
ECE 380	Probability and Statistics for Engineering Problem Solving *CS*	3
HU/SB and awareness area course[3]		3
Total		16

Fourth Year

First Semester

BME 413	Biomedical Instrumentation *L*	3
BME 416	Biomechanics	3
BME 417	Biomedical Engineering Capstone Design I	3
BME 423	Biomedical Instrumentation Laboratory *L*	1
HU/SB and awareness area course[3]		3
Technical elective(s)		3
Total		16

Second Semester

BME 470	Microcomputer Applications in Bioengineering	4
BME 490	Biomedical Engineering Capstone Design II	3
HU/SB and awareness area course[3]		3
Technical electives		6
Total		16
Total degree requirements		128

[1] Both PHY 121 and 122 must be taken to secure SQ credit.
[2] Both PHY 131 and 132 must be taken to secure SQ credit.
[3] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU and SB requirements.

BIOENGINEERING (BME)

BME 201 Introduction to Bioengineering. (3)
fall and spring
Impact of bioengineering on society. Develops an awareness of the contributions of bioengineering to solve medical and biological problems. Prerequisite: ENG 101 or 102 or 105 or 108.
General Studies: L

BME 202 Global Awareness Within Biomedical Engineering Design. (3)
selected semesters
Introduction to ethical, legal, social, economic, and technical issues arising from the design and implementation of bioengineering technology. Lecture, critical discourse. Prerequisites: ECE 100; ECN 111 (or 112); ENG 102 (or 105).
General Studies: L/HU

BME 318 Biomaterials. (3)
spring
Material properties of natural and artificial biomaterials. Tissue and blood biocompatibility. Uses of materials to replace body parts. Prerequisite: ECE 350.

BME 331 Biomedical Engineering Transport: Fluids. (3)
fall
Transport phenomena with emphasis on biomedical engineering fluid systems. Prerequisites: MAT 274; PHY 131.

BME 334 Bioengineering Heat and Mass Transfer. (3)
spring
Applies the principles of heat and mass transfer phenomena to solution of problems in medicine and medical device design. Prerequisite: ECE 340. Prerequisite with a grade of “C” or higher: BME 331.

BME 350 Signals and Systems for Bioengineers. (3)
spring
Applies principles of calculus and ordinary differential equations to modeling and analysis of responses, signals, and signal transfers in biosystems. Prerequisites: ECE 201; MAT 272, 274.

BME 411 Biomedical Engineering I. (3)
once a year
Reviews diagnostic and prosthetic methods using engineering methodology. Introduces transport, metabolic, and autoregulatory processes in the human body. Prerequisite with a grade of “C” or higher: BME 334.

BME 412 Biomedical Engineering II. (3)
once a year
Reviews electrophysiology and nerve pacing applications. Introduces biomechanics and joint/limb replacement technology, cardiovascular and pulmonary fluid mechanics, and the application of mathematical modeling. Prerequisite: instructor approval.

BME 413 Biomedical Instrumentation. (3)
fall
Principles of medical instrumentation. Studies of medical diagnostic instruments and techniques for the measurement of physiologic variables in living systems. Prerequisites: ECE 300, 334. Prerequisite with a grade of “C” or higher: BME 435. Corequisite: BME 423.
General Studies: L (if credit also earned in BME 423)

BME 415 Biomedical Transport Processes. (3)
once a year
Principles of momentum, heat, and mass transport with applications to medical and biological systems and medical device design. Prerequisites: MAT 274; PHY 131.

BME 416 Biomechanics. (3)
fall
Mechanical properties of bone, muscle, and soft tissue. Static and dynamic analysis of human movement tasks such as locomotion. Prerequisite with a grade of "C" or higher: BME 318.

BME 417 Biomedical Engineering Capstone Design I. (3)
fall
Technical, regulatory, economic, legal, social, and ethical aspects of medical device systems engineering design. Lecture, field trips. Prerequisite: ECE 300. Prerequisites with a grade of "C" or higher: BME 318, 334.

BME 419 Biocontrol Systems. (3)
fall
Applies linear and nonlinear control systems techniques to analysis of neuromusculoskeletal, cardiovascular, thermal, and mass transfer systems of the body. Prerequisites: ECE 201; MAT 274.

BME 423 Biomedical Instrumentation Laboratory. (1)
fall
Laboratory experience with problems, concepts, and techniques of biomedical instrumentation in static and dynamic environments. Lab. Prerequisites: ECE 300, 334. Prerequisite with a grade of "C" or higher: BME 435. Corequisite: BME 413.
General Studies: L (if credit also earned in BME 413)

BME 435 Physiology for Engineers. (4)
fall
Physiology of the nervous, muscular, cardiovascular, endocrine, renal, and respiratory systems. Emphasizes use of quantitative methods in understanding physiological systems. Lecture, lab. Prerequisites: a combination of BIO 188 and CHM 116 and PHY 131 or only instructor approval.

BME 470 Microcomputer Applications in Bioengineering. (4)
spring
Uses microcomputers for real-time data collection, analysis, and control of experiments involving actual and simulated physiological systems. Lecture, lab. Prerequisites: ECE 100, 334. Prerequisite with a grade of "C" or higher: BME 435.

BME 490 Biomedical Engineering Capstone Design II. (1–5)
spring
Individual projects in medical systems or medical device design and development. Lecture, lab. Prerequisite with a grade of "C" or higher: BME 417.

BME 494 Special Topics. (1–4)
selected semesters
Topics may include the following:
- Biopolymeric Drug Delivery. (3)
- Biotechnology Laboratory Techniques. (3)
- Cell Biotechnology. (3)
- Introduction to Molecular, Cellular, and Tissue Engineering. (3)
- Scanning Probe Microscopy. (3)

BME 496 Professional Seminar. (1–3)
fall and spring
Professional and ethical aspects with a discussion of responsibilities. Lecture, field trips. Prerequisite: instructor approval.

BME 511 Biomedical Engineering I. (3)
once a year
Diagnostic and prosthetic methods using engineering methodology. Transport, metabolic, and autoregulatory processes in the body.

BME 512 Biomedical Engineering II. (3)
once a year
Electrophysiology and nerve pacing applications. Introduces biomechanics and joint/limb replacement, technology, cardiovascular and pulmonary fluid mechanics, and mathematical modeling.

BME 513 Biomedical Instrumentation. (3)
fall
Principles of medical instrumentation. Studies of medical diagnostic instruments and techniques for the measurement of physiologic variables in living systems.

BME 514 Advanced Biomedical Instrumentation. (3)
selected semesters
Principles of applied biophysical measurements using bioelectric and radiological approach. Prerequisites: ECE 334; MAT 274 (or its equivalent).

BME 515 Biomedical Transport Processes. (3)
selected semesters
Principles of momentum, heat, and mass transport with applications to medical and biological systems and medical device design. Prerequisite: instructor approval.

BME 516 Topics in Biomechanics. (3)
fall
Mechanical properties of bone, muscle, and soft tissue. Static and dynamic analysis of human movement tasks, including in-depth project. Prerequisite: instructor approval.

BME 518 Introduction to Biomaterials. (3)
spring
Topics include structure property relationships for synthetic and natural biomaterials, biocompatibility, and uses of materials to replace body parts. Prerequisite: ECE 350 (or its equivalent) or instructor approval.

BME 519 Topics in Biocontrol Systems. (3)
fall
Linear and nonlinear control systems analysis of neuromusculoskeletal, cardiovascular, thermal, and mass transfer systems of the body, including in-depth project. Prerequisites: both ECE 201 and MAT 274 or only instructor approval.

BME 520 Bioelectric Phenomena. (3)
selected semesters
Study of the origin, propagation, and interactions of bioelectricity in living things; volume conductor problem, mathematical analysis of bioelectric interactions, and uses in medical diagnostics.

BME 521 Neuromuscular Control Systems. (3)
spring
Overview of sensorimotor brain structures. Application of nonlinear, adaptive, optimal, and supervisory control theory to eye-head-hand coordination and locomotion.

BME 522 Biosensor Design and Application. (3)
once a year
Theory and principles of biosensor design and application in medicine and biology. Principles of measurements with biosensors. Prerequisite: instructor approval.

BME 523 Physiological Instrumentation Lab. (1)
fall
Laboratory experience with problems, concepts, and techniques of biomedical instrumentation in static and dynamic environments. Lab. Prerequisites: BME 435; ECE 334. Pre- or corequisite: BME 513.

BME 524 Fundamentals of Applied Neural Control. (3)
once a year
Fundamental concepts of electrical stimulation and recording in the nervous system with the goal of functional control restoration. Pre- or corequisite: BME 435 or instructor approval.

BME 525 Surgical Techniques. (2)
spring
Principles of surgical techniques, standard operative procedures, federal regulations, guidelines, and state-of-the-art methods. Lecture, lab.

BME 532 Prosthetic and Rehabilitation Engineering. (3)
once a year
Analysis and critical assessment of design and control strategies for state-of-the-art medical devices used in rehabilitation engineering. Pre- or corequisite: BME 416 or 516 or EPE 610.

BME 533 Transport Processes I. (3)
fall
Unified treatment of momentum, heat, and mass transfer from molecular theory, and continuum points of view. Continuum equations of microscopic and macroscopic systems and multicomponent and

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L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

multiphase systems. Cross-listed as CHE 533. Credit is allowed for only BME 533 or CHE 533.

BME 534 Transport Processes II. (3)
spring
Continuation of BME 533 or CHE 533, emphasizing mass transfer. Cross-listed as CHE 534. Credit is allowed for only BME 534 or CHE 534. Prerequisite: BME 533 or CHE 533.

BME 543 Thermodynamics of Chemical Systems. (3)
fall
Classical and statistical thermodynamics of nonideal physicochemical systems and processes; prediction of optimum operating conditions. Cross-listed as CHE 543. Credit is allowed for only BME 543 or CHE 543.

BME 544 Chemical Reactor Engineering. (3)
spring
Reaction rates, thermodynamics, and transport principles applied to the design and operation of chemical reactors. Cross-listed as CHE 544. Credit is allowed for only BME 544 or CHE 544. Prerequisite: BME 543 or CHE 543.

BME 551 Movement Biomechanics. (3)
spring
Mechanics applied to the analysis and modeling of physiological movements. Computational modeling of muscles, tendons, joints, and the skeletal system with application to sports and rehabilitation. Prerequisite: BME 416 or 516 or instructor approval.

BME 566 Medical Imaging Instrumentation. (3)
selected semesters
Design and analysis of imaging systems and nuclear devices for medical diagnosis, therapy, and research. Laboratory experiments using diagnostic radiology, fluoroscopy, ultrasound, and CAT scanning. Lecture, lab. Prerequisite: instructor approval.

BME 568 Medical Imaging. (3)
selected semesters
CT, SPECT, PET, and MRI. 3-dimensional *in vivo* measurements. Instrument design, physiological modeling, clinical protocols, reconstruction algorithms, and quantitation issues. Prerequisite: instructor approval.

BME 593 Applied Project. (1–12)
selected semesters

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

Department of Chemical and Materials Engineering

www.eas.asu.edu/~cme

480/965-3313

ECG 202

Subhash Mahajan, Chair

Regents’ Professor: Mayer

Professors: Adams, Dey, Krause, Mahajan, Newman, Picraux, Raupp, Sieradzki

Associate Professors: Alford, Beaudoin, Beckman, Burrows, Rivera, Sierks, Van Schilfgaarde

Assistant Professors: Allen, Chawla, Dillner, Razatos

The faculty in the Department of Chemical and Materials Engineering offer the B.S.E. degree in Chemical Engineering and in Materials Science and Engineering. Each of these majors builds on a broad base of knowledge within the basic and mathematical sciences and the engineering core. Each offers excellent career opportunities.

Chemical engineers design and operate processes that may include chemical change. They combine the science of chemistry with the discipline of engineering in order to solve complex problems in a wide variety of industries. Challenging job opportunities exist not only in the chemical and petroleum industries, but also in the plastics, electronics, computer, metals, space, food, drug, and health care industries. In these industries, chemical engineers practice in a wide variety of occupations including environmental control, surface treatments, energy and materials transformation, biomedical applications, fermentation, protein recovery, extractive metallurgy, and separations. In the environmental area, chemical engineers develop methods to reduce the pollution created in manufacturing processes, devise techniques to recover usable materials from wastes, design waste storage and treatment facilities, and design pollution control strategies.

Materials science and engineering uses fundamental knowledge in chemistry and physics to correlate relationships between the structure and processing of materials and their properties. Students educated in this discipline decide how to optimize existing materials or how to develop new advanced materials and processing techniques. Students who major in materials science and engineering will find employment opportunities in a variety of industries and research facilities, which include aerospace, electronics, energy conversion, manufacturing, medical devices, semiconductors, and transportation.

CHEMICAL ENGINEERING—B.S.E.

Chemical engineers are generally concerned with transfer within and between liquid, gas, and solid phases and the chemical changes that may also occur. The engineers design and operate processes that accommodate such changes, including the chemical activation of materials. Typically this involves complex multicomponent systems wherein the interactions between species have to be considered and analyzed. The new challenge in chemical engineering is to apply the principles of fluid dynamics, mass transfer, solution thermodynamics, reaction kinetics, and separation techniques to technological endeavors such as pollution control within manufacturing and the environment, integrated circuit design, solid-state surface treatments, and materials processing.

Consequently, in addition to the chemical and petroleum industries, chemical engineers find challenging opportunities in the plastics, solid-state, electronics, computer, metals, space, food, drug, and health care industries, where they practice in a wide variety of occupations, such as environmental control, surface treatments, energy and materials transformations, biomedical applications, fermentation, protein recovery, extractive metallurgy, and separations. While a large percentage of the industrial positions are filled by graduates with bachelor’s degrees, there are lucrative and creative opportunities in research and development for those who acquire postgraduate education.

Subspecializations have developed within the profession. However, the same broad body of knowledge is generally expected of all chemical engineers for maximum flexibility in industrial positions. The preparation for chemical engineering is accomplished by a blend of classroom instruction and laboratory experience.

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Chemical Engineering. A minimum of 50 upper-division semester hours is required. Students must attain a GPA of at least 2.00 for the courses in the major field.

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 79.

COURSE REQUIREMENTS

The course work for the undergraduate degree can be classified into the following categories (in semester hours):

First-Year Composition

Choose among the course combinations below 6

ENG 101 First-Year Composition (3)
ENG 102 First-Year Composition (3)

———*or*———

ENG 105 Advanced First-Year Composition (3)
Elective chosen with an advisor (3)

———*or*———

ENG 107 English for Foreign Students (3)
ENG 108 English for Foreign Students (3)

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
HU/SB and awareness area courses[1] 12

Total 15

Literacy and Critical Inquiry

CHE 352 Transport Laboratories *L* 3
ECE 300 Intermediate Engineering Design *L* 3

Total 6

Natural Sciences/Basic Sciences

CHM 113 General Chemistry *SQ* 4
CHM 116 General Chemistry *SQ* 4
CHM 331 General Organic Chemistry 3
CHM 335 General Organic Chemistry Laboratory 1
PHY 121 University Physics I: Mechanics *SQ*[2] 3
PHY 122 University Physics Laboratory I *SQ*[2] 1

Total 16

Mathematical Studies

ECE 100 Introduction to Engineering Design *CS* 3
ECE 384 Numerical Methods for Engineers 4
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 22
General Studies/school requirements total 59

Engineering Core

CHE 342 Applied Chemical Thermodynamics 4
CHE 461 Process Control *CS* 4
ECE 394 ST: Conservation Principles 4
ECE 394 ST: Engineering Systems 4
ECE 394 ST: Properties that Matter 3

Total 19

Major

CHE 311 Introduction to Chemical Processing 3
CHE 331 Transport Phenomena I: Fluids 3
CHE 332 Transport Phenomena II: Energy Transfer 3
CHE 333 Transport Phenomena III: Mass Transfer 3
CHE 432 Principles of Chemical Engineering Design 3
CHE 442 Chemical Reactor Design 3
CHE 451 Chemical Engineering Laboratory 2
CHE 462 Process Design 3
CHM 332 General Organic Chemistry 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
Technical electives 15

Total 44

[1] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU or SB requirements.

[2] Both PHY 121 and 122 must be taken to secure SQ credit.

Students should consult with their department academic advisors to ensure that all requirements are met.

The technical elective courses must be selected from upper-division courses with an advisor's approval and must include two three-semester-hour chemistry courses; a three-semester-hour natural science or materials course; and a three-semester-hour chemical engineering course.

To fulfill accreditation requirements and to prepare adequately for the advanced chemistry courses, Chemical Engineering majors are required to take the CHM 113 and 116 introductory chemistry sequence (CHM 117 and 118 are acceptable substitutes). Other freshman chemistry courses are *not acceptable,* and transfer students who have taken another chemistry course may be required to enroll in CHM 113 and 116.

Chemical Engineering Areas of Study

Students who wish to specialize may develop an area of interest through the use of technical electives and selective substitutions for required courses. Substitutions must be approved by the advisor and the Department Standards Committee and must be consistent with ABET accreditation criteria. No substitution of CHE 462 is allowed. The following are possible elective areas with suggested courses. A student may choose electives within the general department guidelines and does not have to select one of the areas listed.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

Biochemical. Students wishing to prepare for a career in biotechnology, fermentation, food processing, pharmaceuticals, and other areas within biochemical engineering should select from the following:

Chemistry Electives

BCH 361 Principles of Biochemistry....3
or BCH 461 General Biochemistry (3)
BCH 462 General Biochemistry....3

Technical Electives

CHE 475 Biochemical Engineering....3
CHE 476 Bioreaction Engineering....3
CHE 477 Bioseparation Processes....3
CHE 494 ST: Biotechnology Techniques....3

Biomedical. Students who are interested in biomedical engineering but wish to maintain a strong, broad chemical engineering base should select from the following:

Chemistry Electives

BCH 361 Principles of Biochemistry....3
or BCH 461 General Biochemistry (3)
BCH 462 General Biochemistry....3

Technical Electives

BME 318 Biomaterials....3
BME 435 Physiology for Engineers....4

Environmental. Students interested in environmental engineering are encouraged to pursue a B.S.E. degree in Chemical Engineering with this area of study. Students interested in the management of hazardous wastes and air and water pollution should select from the following:

Chemistry Electives

BCH 361 Principles of Biochemistry....3
or BCH 461 General Biochemistry (3)
CHM 302 Environmental Chemistry....3
CHM 481 Geochemistry....3
CHM 494 ST: Chemistry of Global Climate Change....3

Technical Electives

CEE 561 Physical-Chemical Treatment of Water and Waste....3
CEE 563 Environmental Chemistry Laboratory....3
CHE 474 Chemical Engineering Design for the Environment....3
CHE 478 Industrial Water Quality Engineering....3
CHE 479 Air Quality Control....3

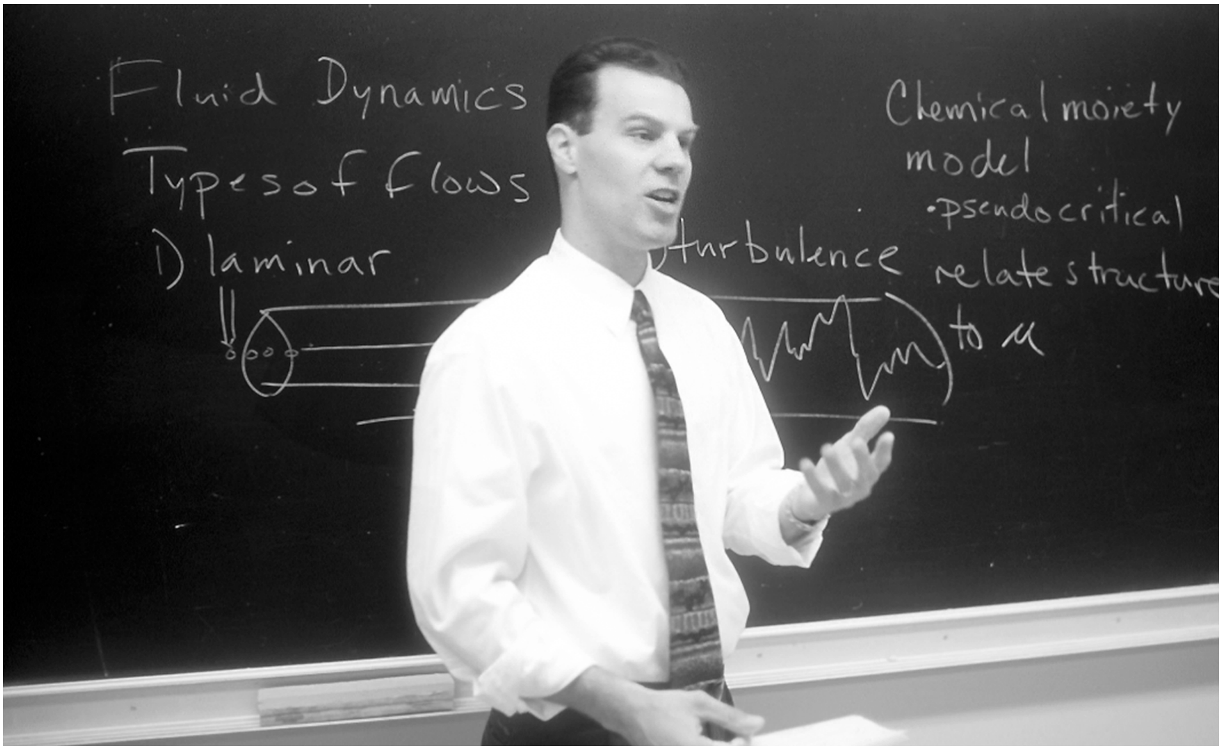
Materials. Students interested in the development and production of new materials such as alloys, ceramics, composites, polymers, semiconductors, and superconductors should select from the following:

Chemistry Electives

CHM 345 Physical Chemistry I....3
CHM 346 Physical Chemistry II....3
CHM 453 Inorganic Chemistry....3
CHM 471 Solid-State Chemistry....3

Technical Electives

BME 318 Biomaterials....3
CHE 458 Semiconductor Material Processing....3
ECE 352 Properties of Electronic Materials....4
MSE 353 Introduction to Materials Processing and Synthesis....3
MSE 354 Experiments in Materials Synthesis and Processing I....2
MSE 431 Corrosion and Corrosion Control....3
MSE 470 Polymers and Composites....3



Dr. Steve Beaudoin addresses his chemical and materials engineering class. Beaudoin has been identified by his students, a parent organization, and his colleagues as a talented faculty member and gifted researcher.

John Phillips photo

Premedical. Students planning to attend medical school should select courses from those listed under the biomedical area. In addition, BIO 187, 188, and CHM 336 must be taken to satisfy medical-school requirements but are not counted toward the Chemical Engineering bachelor's degree.

Process Engineering. The engineering core and required chemical engineering courses serve as a suitable background for students intending to enter the traditional petrochemical and chemical process industries. Students can build on this background by selecting courses with the approval of their advisor. Examples of these courses are as follows:

CHE 474	Chemical Engineering Design for the Environment	3
CHE 478	Industrial Water Quality Engineering	3
CHE 479	Air Quality Control	3
CHE 494	ST: Advanced Process Control	3
CHE 528	Process Optimization Techniques	3
CHE 556	Separation Processes	3
CHE 563	Chemical Engineering Design	3
MAE 436	Combustion	1–4

Semiconductor Processing. Students interested in the development and manufacturing of semiconductor and other electronic devices should select from the following:

Chemistry Electives

CHM 345	Physical Chemistry I	3
CHM 346	Physical Chemistry II	3
CHM 453	Inorganic Chemistry	3
CHM 471	Solid-State Chemistry	3

Technical Electives

CHE 458	Semiconductor Material Processing	3
CHE 494	Special Topics	1–4
ECE 352	Properties of Electronic Materials	4
EEE 435	Microelectronics	3
EEE 436	Fundamentals of Solid-State Devices	3
EEE 439	Semiconductor Facilities and Cleanroom Practices	3
MSE 353	Introduction to Materials Processing and Synthesis	3
MSE 354	Experiments in Materials Synthesis and Processing I	2

Chemical Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM 113	General Chemistry *SQ*	4
ECE 100	Introduction to Engineering Design *CS*	3
ENG 101	First-Year Composition	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
Total		14

Second Semester

CHM 116	General Chemistry *SQ*	4
ENG 102	First-Year Composition	3
MAT 271	Calculus with Analytic Geometry II	4
PHY 121	University Physics I: Mechanics *SQ**	3
PHY 122	University Physics Laboratory I *SQ**	1
Total		15

Second Year

First Semester

CHE 311	Introduction to Chemical Processing	3
CHM 331	General Organic Chemistry	3
CHM 335	General Organic Chemistry Laboratory	1
ECE 394	ST: Conservation Principles	4
ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
MAT 274	Elementary Differential Equations *MA*	3
Total		17

Second Semester

CHE 331	Transport Phenomena I: Fluids	3
CHM 332	General Organic Chemistry	3
ECE 394	ST: Properties that Matter	3
MAT 272	Calculus with Analytic Geometry III *MA*	4
HU/SB and awareness area course		3
Total		16

Third Year

First Semester

CHE 332	Transport Phenomena II: Energy Transfer	3
CHE 342	Applied Chemical Thermodynamics	4
ECE 300	Intermediate Engineering Design *L*	3
ECE 380	Probability and Statistics for Engineering Problem Solving	3
ECE 384	Numerical Methods for Engineers	4
Total		17

Second Semester

CHE 333	Transport Phenomena III: Mass Transfer	3
CHE 352	Transport Laboratories *L*	3
CHE 432	Principles of Chemical Engineering Design	3
ECE 394	ST: Engineering Systems	4
HU/SB and awareness area course		3
Total		16

Fourth Year

First Semester

CHE 442	Chemical Reactor Design	3
CHE 451	Chemical Engineering Laboratory	2
CHE 461	Process Control *CS*	4
HU/SB and awareness area course		3
Technical electives		6
Total		18

Second Semester

CHE 462	Process Design	3
HU/SB and awareness area course		3
Technical electives		9
Total		15
Total degree requirements		128

* Both PHY 121 and 122 must be taken to secure SQ credit.

MATERIALS SCIENCE AND ENGINEERING—B.S.E.

Materials engineers create innovations that result in new and improved materials that help drive the cutting edge of new technologies in many industries. These include the auto, aerospace, electronics, semiconductor, materials production, and health professions. The space shuttle, lightweight cars, and today's fastest computers have all been

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

developed using the latest materials technologies. In advancing today's technologies, materials engineers fulfill a wide range of job responsibilities that significantly impact other engineering disciplines and include

1. selecting the best material for a given application or developing innovative materials and processing techniques for new applications;
2. characterizing and analyzing failed products in order to redesign more reliable and robust engineering components; and
3. impacting technological advances in larger-scale projects through working in a team environment with other engineers from the chemical, electrical, mechanical, aerospace and other engineering disciplines.

The Materials Science and Engineering degree program at ASU has outstanding faculty who have national reputations in the areas of both structural and electronic materials. The faculty bring significant professional expertise to classroom teaching, which is complemented by enlightening experimental work in the program's contemporary, well-equipped laboratory facilities. This atmosphere promotes quality undergraduate research projects and senior design projects that frequently result in patents and technical publications. Examples of recent patent applications include an improved method for producing artificial Teflon arteries and an improved technique for testing steel in air bag containers. Such preparation and experiences give the programs's graduates an edge in seeking employment at the best companies or admission to the nation's leading graduate schools. The program's educational experience is also enhanced by numerous scholarships available to students ranging from entering freshman to final-year seniors.

The Materials Science and Engineering degree program is accredited by the national organization of Accreditation Board for Engineering and Technology, Inc. As such, it has an identifiable program mission, objectives, and outcomes, which reflect, encompass, and embody the unique educational development that a student experiences as he or she progresses through the program to graduation. The mission and objectives are described below.

The mission of the Materials Science and Engineering degree program is to educate students in the application of basic principles of science toward the design, utilization, and improvement of materials in engineering components and systems for the betterment of society. To accomplish this mission, the program's graduates fulfill the following objective: (1) Graduates will have the strong educational foundation in materials science and engineering that promotes success in the broad range of career opportunities available in graduate school, industry, and government; and (2) graduates will have the personal skills and values that promote their success in the rapidly changing, culturally diverse workplace that reflects the needs of contemporary society.

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Materials Science and Engineering. A minimum of 50 upper-division semester hours is required. Students must attain a GPA of at least 2.00 for the courses in the major field.

Graduation Requirements. In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 79.

Course Requirements. The undergraduate curriculum requires that students take a series of interdisciplinary courses of fundamental importance to an understanding of all engineering materials. Following these are additional courses that may be taken as technical electives to develop an area of study. The courses for the undergraduate degree can be classified into the following categories (in semester hours):

First-Year Composition

Choose among the course combinations below 6
- ENG 101 First-Year Composition (3)
- ENG 102 First-Year Composition (3)

—or—

- ENG 105 Advanced First-Year Composition (3)
- Elective chosen with an advisor (3)

—or—

- ENG 107 English for Foreign Students (3)
- ENG 108 English for Foreign Students (3)

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
HU, SB, and awareness area courses 12

Total 15

Literacy and Critical Inquiry

ECE 300 Intermediate Engineering Design *L* 3
MSE 482 Materials Engineering Design 3

Total 6

Natural Sciences/Basic Sciences

CHM 113 General Chemistry *SQ* 4
CHM 116 General Chemistry *SQ* 4
PHY 121 University Physics I: Mechanics *SQ*[1] 3
PHY 122 University Physics Laboratory *SQ*[1] 1
PHY 131 University Physics II: Electricity and Magnetism *SQ*[2] 3
PHY 132 University Physics Laboratory II *SQ*[2] 1

Total 16

Mathematical Studies

ECE 100 Introduction to Engineering Design *CS* 3
MAT 242 Elementary Linear Algebra 2
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 20
General Studies/school requirements total....57

Engineering Core

ECE 201 Electrical Networks I 4
ECE 210 Engineering Mechanics I: Statics....3
ECE 313 Introduction to Deformable Solids....3

ECE	350	Structure and Properties of Materials	3
MSE	430	Thermodynamics of Materials	3
Total			16

Major

ECE	380	Probability and Statistics for Engineering Problem Solving *CS*	3
MSE	194	ST: Challenges in Materials Engineering	1
MSE	353	Introduction to Materials Processing and Synthesis	3
MSE	354	Experiments in Materials Synthesis and Processing	2
MSE	355	Introduction to Materials Science and Engineering	3
MSE	420	Physical Metallurgy	3
MSE	421	Physical Metallurgy Laboratory	1
MSE	440	Mechanical Properties of Solids	3
MSE	450	X-ray and Electron Diffraction	3
MSE	470	Polymers and Composites	3
MSE	471	Introduction to Ceramics	3
MSE	490	Capstone Design Project	3
Select two of the following four courses[3]			6
CHM	325	Analytical Chemistry (3)	
CHM	331	General Organic Chemistry (3)	
CHM	341	Elementary Physical Chemistry (3)	
PHY	361	Introductory Modern Physics (3)	
Technical electives			12
Total			49

[1] Both PHY 121 and 122 must be taken to secure SQ credit.

[2] Both PHY 131 and 132 must be taken to secure SQ credit.

[3] To take CHM 341 Elementary Physical Chemistry, CHM 331 Organic Chemistry must be taken as the prerequisite.

Materials Science and Engineering Areas of Study

Technical electives may be selected from one or more of the following areas. A student may, with prior approval of the department, select a general area or a set of courses that would support a career objective not covered by the following categories.

Biomaterials. Students interested in the materials used in the body and other living systems to improve or replace body components should choose from the following technical electives:

BME	318	Biomaterials	3
BME	411	Biomedical Engineering I	3
BME	412	Biomedical Engineering II	3
BME	413	Biomedical Instrumentation *L*	3
BME	416	Biomechanics	3

Ceramic Materials. Students who want to develop an understanding of the chemistry and processing that control the structure and properties of ceramics and their application should select from these technical electives:

CHM	331	General Organic Chemistry	3
CHM	332	General Organic Chemistry	3
CHM	471	Solid-State Chemistry	3
EEE	435	Microelectronics	3
EEE	436	Fundamentals of Solid-State Devices	3
EEE	439	Semiconductor Facilities and Cleanroom Practices	3

Energy Systems. Students interested in the materials used in energy conversion systems such as solar energy or nuclear energy should choose from the following technical electives:

MAE	441	Principles of Design	3
MAE	442	Mechanical Systems Design	3
MSE	431	Corrosion and Corrosion Control	3
MSE	441	Analysis of Material Failures	3

Integrated Circuit Materials. Students interested in the materials used in the semiconductor industry and in how they are processed to achieve the desired properties should choose from the following technical electives:

CHE	458	Semiconductor Material Processing	3
EEE	435	Microelectronics	3
EEE	436	Fundamentals of Solid-State Devices	3
EEE	439	Semiconductor Facilities and Cleanroom Practices	3

Manufacturing and Materials Processing. Students interested in the manufacturing and processing of materials for a broad base of applications should choose from the following technical electives:

CHE	458	Semiconductor Material Processing	3
IEE	360	Manufacturing Processes	3
IEE	361	Manufacturing Processes Laboratory	1
MAE	422	Mechanics of Materials	4
MAE	441	Principles of Design	3
MAE	442	Mechanical Systems Design	3
MSE	431	Corrosion and Corrosion Control	3
MSE	441	Analysis of Material Failures	3

Mechanical Metallurgy. Students interested in understanding the design, processing, and manufacturing of metals for structural applications, such as autos, airplanes, and buildings, should choose from the following technical electives:

MAE	415	Vibration Analysis	4
MAE	422	Mechanics of Materials	4
MAE	441	Principles of Design	3
MAE	442	Mechanical Systems Design	3
MSE	431	Corrosion and Corrosion Control	3
MSE	441	Analysis of Materials Failures	3

Metallic Materials Systems. Students interested in building an understanding of the basis for the design and processing of metals and alloys should choose from the following technical electives:

MAE	351	Manufacturing Processes	3
MSE	431	Corrosion and Corrosion Control	3
MSE	441	Analysis of Material Failures	3

Polymers and Composites. Students who desire to build an understanding of the chemical and processing basis for the properties of polymers and their applications, including composite systems, should select from the following technical electives:

CHM	331	General Organic Chemistry	3
CHM	332	General Organic Chemistry	3
CHM	471	Solid-State Chemistry	3
MSE	441	Analysis of Material Failures	3

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

Materials Science and Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM 113 General Chemistry *SQ*	4
ECE 100 Introduction to Engineering Design *CS*	3
ENG 101 First-Year Composition	3
MAT 270 Calculus with Analytic Geometry I *MA*	4
MSE 194 ST: Challenges in Materials Engineering	1
Total	15

Second Semester

CHM 116 General Chemistry *SQ*	4
ENG 102 First-Year Composition	3
MAT 271 Calculus with Analytic Geometry II *MA*	4
PHY 121 University Physics I: Mechanics *SQ*[1]	3
PHY 122 University Physics Laboratory I *SQ*[1]	1
Total	15

Second Year

First Semester

ECE 210 Engineering Mechanics I: Statics	3
ECE 350 Structure and Properties of Materials	3
MAT 242 Elementary Linear Algebra	2
MAT 272 Calculus with Analytic Geometry III *MA*	4
PHY 131 University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY 132 University Physics Laboratory II *SQ*[2]	1
Total	16

Second Semester

ECE 201 Electrical Networks I	4
ECE 313 Introduction to Deformable Solids	3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS*	3
MAT 274 Elementary Differential Equations *MA*	3
Technical elective	3
Total	16

Third Year

First Semester

ECE 300 Intermediate Engineering Design *L*	3
ECN 111 Macroeconomic Principles *SB*	3
MSE 353 Introduction to Materials Processing and Synthesis	3
MSE 355 Introduction to Materials Science and Engineering	3
Advanced science course[3]	3
Total	15

Second Semester

MSE 354 Experiments in Materials Synthesis and Processing	2
MSE 420 Physical Metallurgy	3
MSE 421 Physical Metallurgy Laboratory	1
MSE 430 Thermodynamics of Materials	3
MSE 450 X-ray and Electron Diffraction	3
HU/SB and awareness area courses[4]	6
Total	18

Fourth Year

First Semester

MSE 440 Mechanical Properties of Solids	3
MSE 470 Polymers and Composites	3
MSE 471 Introduction to Ceramics	3
MSE 482 Materials Engineering Design	3
Technical electives	3
HU/SB and awareness area course[4]	3
Total	18

Second Semester

MSE 490 Capstone Design Project	3
Advanced science course[3]	3
HU/SB and awareness area course[4]	3
Technical elective	6
Total	15
Total degree requirements	128

[1] Both PHY 121 and 122 must be taken to secure SQ credit.
[2] Both PHY 131 and 132 must be taken to secure SQ credit.
[3] To take CHM 341 Elementary Physical Chemistry, CHM 331 Organic Chemistry must be taken as the prerequisite.
[4] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU and SB requirements.

GRADUATE STUDY

The faculty in the Department of Chemical and Materials Engineering also offer graduate programs leading to the M.S., M.S.E., and Ph.D. degrees. These programs provide a blend of classroom instruction and research. Many various topical and relevant research projects are available for thesis topics. Students interested in these programs should contact the department for up-to-date descriptive literature.

CHEMICAL ENGINEERING (CHE)

CHE 311 Introduction to Chemical Processing. (3)
fall
Applies chemical engineering analysis and problem solving to chemical processes material and energy balance methods and skills. Prerequisites: CHM 116; MAT 271.

CHE 331 Transport Phenomena I: Fluids. (3)
spring
Transport phenomena, with emphasis on fluid systems. Prerequisites: CHE 311; ECE 394 ST: Conservation Principles; MAT 274.

CHE 332 Transport Phenomena II: Energy Transfer. (3)
fall
Continuation of transport principles, with emphasis on energy transport in stationary and fluid systems. Prerequisite: CHE 331.

CHE 333 Transport Phenomena III: Mass Transfer. (3)
spring
Applies transport phenomena to mass transfer. Design of mass transfer equipment, including staged processes. Prerequisite: CHE 332.

CHE 342 Applied Chemical Thermodynamics. (4)
fall
Applies conservation and accounting principles with nonideal property estimation techniques to model phase and chemical equilibrium processes. Lecture, recitation. Prerequisites: CHE 311; ECE 394 ST: Conservation Principles, ECE 394 ST: Properties that Matter. Pre- or corequisite: MAT 272.

CHE 352 Transport Laboratories. (3)
spring
Demonstrates transport phenomena principles with experiments in fluid flow, heat, and mass transfer. Prerequisites: CHE 332; ECE 300. Pre- or corequisite: CHE 333.
General Studies: L

CHE 432 Principles of Chemical Engineering Design. (3)
fall
Multicomponent distillation, engineering economics, equipment sizing and costs, plant operation economics, and simulation and optimization techniques. Prerequisites: CHE 332, 342.

CHE 442 Chemical Reactor Design. (3)
spring
Applies kinetics to chemical reactor design. Prerequisite: CHE 342. Pre- or corequisite: CHE 333.

CHE 451 Chemical Engineering Laboratory. (2)
fall
Operation, control, and design of experimental and industrial process equipment; independent research projects. 6 hours lab. Prerequisites: CHE 333, 352; ECE 384.

CHE 458 Semiconductor Material Processing. (3)
selected semesters
Introduces the processing and characterization of electronic materials for semiconductor applications. Prerequisites: CHE 333, 342.

CHE 461 Process Control. (4)
fall
Process dynamics, instrumentation, and feedback applied to automatic process control. Lecture, lab. Prerequisite: ECE 394 ST: Engineering Systems.
General Studies: CS

CHE 462 Process Design. (3)
spring
Applies economic principles to optimize equipment selection and design; development and design of process systems. Prerequisites: CHE 432, 442.

CHE 474 Chemical Engineering Design for the Environment. (3)
fall
Conflict of processing materials and preserving the natural resources. Teaches students to understand and value the environment and attempt to control our impact. Prerequisites: CHE 333, 342.

CHE 475 Biochemical Engineering. (3)
selected semesters
Applies chemical engineering methods, mass transfer, thermodynamics, and transport phenomena to industrial biotechnology. Prerequisite: instructor approval.

CHE 476 Bioreaction Engineering. (3)
selected semesters
Principles of analysis and design of reactors for processing with cells and other biologically active materials; applications of reaction engineering in biotechnology. Prerequisite: instructor approval.

CHE 477 Bioseparation Processes. (3)
selected semesters
Principles of separation of biologically active chemicals; the application, scale-up, and design of separation processes in biotechnology. Prerequisite: instructor approval.

CHE 478 Industrial Water Quality Engineering. (3)
fall
Chemical treatment processing, quality criteria and control, system design, and water pollutants. Prerequisites: CHE 331; senior standing.

CHE 479 Air Quality Control. (3)
fall
Air pollutant control, effects, and origins. Chemical and physical processes, including combustion, control equipment design, dispersion, and sampling. Prerequisites: CHE 331; senior standing.

CHE 490 Chemical Engineering Projects. (1–5)
fall, spring, summer
Individual projects in chemical engineering operations and design. Prerequisite: instructor approval.

CHE 494 Special Topics. (1–4)
fall and spring
Topics may include the following:
- Advanced Process Control. (3)
- Biotechnology Techniques. (3)

CHE 496 Professional Seminar. (1–3)
fall and spring
Professional and ethical aspects with a discussion of responsibilities. Lecture, field trips. Prerequisite: instructor approval.

CHE 501 Introduction to Transport Phenomena. (3)
fall and spring
Transport phenomena, with emphasis on fluid systems. Prerequisite: transition student with instructor approval.

CHE 502 Introduction to Energy Transport. (3)
fall and spring
Continuation of transport principles, with emphasis on energy transport in stationary and fluid systems. Prerequisite: transition student with instructor approval.

CHE 503 Introduction to Mass Transport. (3)
fall and spring
Applies transport phenomena to mass transfer. Design of mass transfer equipment, including staged processes. Prerequisite: transition student with instructor approval.

CHE 504 Introduction to Chemical Thermodynamics. (3)
fall and spring
Energy relations and equilibrium conversions based on chemical potentials and phase equilibria. Prerequisite: transition student with instructor approval.

CHE 505 Introduction to Chemical Reactor Design. (3)
fall and spring
Applies kinetics to chemical reactor design. Prerequisite: transition student with instructor approval.

CHE 527 Advanced Applied Mathematical Analysis in Chemical Engineering. (3)
fall
Formulation and solution of complex mathematical relationships resulting from the description of physical problems in mass, energy, and momentum transfer and chemical kinetics.

CHE 528 Process Optimization Techniques. (3)
spring
Method for optimizing engineering processes. Experimental design and analysis; linear and nonlinear regression methods; classical, search, and dynamic programming algorithms.

CHE 533 Transport Processes I. (3)
fall
Unified treatment of momentum, heat, and mass transfer from molecular theory, and continuum points of view. Continuum equations of microscopic and macroscopic systems and multicomponent and multiphase systems. Cross-listed as BME 533. Credit is allowed for only BME 533 or CHE 533.

CHE 534 Transport Processes II. (3)
spring
Continuation of BME 533 or CHE 533, emphasizing mass transfer. Cross-listed as BME 534. Credit is allowed for only BME 534 or CHE 534. Prerequisite: BME 533 or CHE 533.

CHE 536 Convective Mass Transfer. (3)
selected semesters
Turbulent flow for multicomponent systems, including chemical reactions with applications in separations and air pollution. Prerequisite: CHE 533 or MAE 571.

CHE 543 Thermodynamics of Chemical Systems. (3)
fall
Classical and statistical thermodynamics of nonideal physicochemical systems and processes; prediction of optimum operating conditions. Cross-listed as BME 543. Credit is allowed for only BME 543 or CHE 543.

CHE 544 Chemical Reactor Engineering. (3)
spring
Reaction rates, thermodynamics, and transport principles applied to the design and operation of chemical reactors. Cross-listed as BME 544. Credit is allowed for only BME 544 or CHE 544. Prerequisite: BME 543 or CHE 543.

CHE 548 Topics in Catalysis. (3)
selected semesters
Engineering catalysis, emphasizing adsorption, kinetics, characterization, diffusional considerations, and reactor design. Other topics include mechanisms, surface analyses, and electronic structure.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

CHE 552 Industrial Water Quality Engineering. (3)
selected semesters
Water pollutants, quality criteria and control, chemical treatment processing, and system design. Case studies. Prerequisite: CHE 331 (or its equivalent).

CHE 553 Air Quality Control. (3)
selected semesters
Air pollutant origins, effects, and control. Physical and chemical processes, including dispersion, combustion, sampling, control equipment design, and special topics. Prerequisite: CHE 331 (or its equivalent).

CHE 554 New Energy Technology. (3)
selected semesters
Gasification, liquefaction pyrolysis, and combustion processes for coal, wastes, and other raw materials. In-situ processes for coal, oil, shale, and geothermal energy. Environmental quality issues.

CHE 556 Separation Processes. (3)
selected semesters
Topics in binary/multicomponent separation, rate governed and equilibration processes, mass transfer criteria, energy requirements, separating agents and devices, and staged operations.

CHE 558 Electronic Materials. (3)
selected semesters
Processing and characterization of electronic materials for semiconductor-type uses. Thermodynamics and transport phenomena, phase equilibria and structure, mass transfer, and diffusion and thermal properties.

CHE 561 Advanced Process Control. (3)
spring
Dynamic process representation, linear optimal control, optimal state reconstruction, and parameter and state estimation techniques for continuous and discrete time systems.

Fireworks mark the end of the Lantern Walk, a traditional Homecoming activity. Tim Trumble photo

CHE 563 Chemical Engineering Design. (3)
selected semesters
Computational methods; the design of chemical plants and processes.

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

MATERIALS SCIENCE AND ENGINEERING (MSE)

MSE 194 Special Topics. (1–4)
selected semesters
Topics may include the following:
- Challenges in Materials Engineering. (1)

MSE 353 Introduction to Materials Processing and Synthesis. (3)
fall
Principles of materials structure and properties with emphasis on applications in bulk and thin film materials processing and synthesis. Prerequisites: CHM 116 and PHY 131 (or their equivalents).

MSE 354 Experiments in Materials Synthesis and Processing. (2)
spring
Small groups of students complete three experiments selected from a list. Each is supervised by a selected faculty member. Lab. Prerequisite: MSE 353 (or its equivalent).

MSE 355 Introduction to Materials Science and Engineering. (3)
fall
Elements of the structure of metals and alloys, measurement of mechanical properties, and optical metallography. Lecture, lab, field trips. Prerequisite: CHM 114 or 116.

MSE 420 Physical Metallurgy. (3)
spring
Crystal structure and defects. Phase diagrams, metallography, solidification and casting, deformation, and annealing. Prerequisite: ECE 350.

MSE 421 Physical Metallurgy Laboratory. (1)
spring
Focuses on analysis of microstructure of metals and alloys and includes correlation with mechanical properties to some extent. Lab. Pre- or corequisite: MSE 420.

MSE 430 Thermodynamics of Materials. (3)
spring
Principles of statistical mechanics, statistical thermodynamics of single crystals, solutions, phase equilibrium, free energy of reactions, free electron theory, and thermodynamics of defects. Prerequisite: ECE 350.

MSE 431 Corrosion and Corrosion Control. (3)
spring in odd years
Introduces corrosion mechanisms and methods of preventing corrosion. Topics include: electrochemistry, polarization, corrosion rates, oxidation, coatings, and cathodic protection. Prerequisite: ECE 350.

MSE 440 Mechanical Properties of Solids. (3)
fall
Effects of environmental and microstructural variables of mechanical properties, including plastic deformation, fatigue, creep, brittle fracture, and internal friction. Prerequisite: ECE 350.

MSE 441 Analysis of Material Failures. (3)
spring in even years
Identifies types of failures. Analytical techniques. Fractography, SEM, nondestructive inspection, and metallography. Mechanical and electronic components. Prerequisite: ECE 350.

MSE 450 X-Ray and Electron Diffraction. (3)
spring
Fundamentals of x-ray diffraction, transmission electron microscopy, and scanning electron microscopy. Techniques for studying surfaces, internal microstructures, and fluorescence. Lecture, demonstrations. Prerequisite: ECE 350.

MSE 470 Polymers and Composites. (3)
fall
Relationship between chemistry, structure, and properties of engineering polymers. Design, properties, and behavior of fiber composite systems. Cross-listed as MAE 455. Credit is allowed for only MAE 455 or MSE 470. Prerequisites: ECE 313, 350.

MSE 471 Introduction to Ceramics. (3)
fall
Principles of structure and property relations in ceramic materials. Processing techniques. Applications in mechanical, electronic, and superconducting systems. Prerequisite: ECE 350.

MSE 482 Materials Engineering Design. (3)
fall
Principles of the design process. Feasibility and optimization. Manufacturing processes, materials selection, failure analysis, and economics. Prerequisites: ECE 313, 350.

MSE 490 Capstone Design Project. (1–3)
fall and spring
For small groups in fundamental or applied aspects of engineering materials; emphasizes experimental problems and design. Prerequisites: MSE 430, 440, 450.

MSE 510 X-Ray and Electron Diffraction. (3)
spring
Fundamentals of x-ray diffraction, transmission electron microscopy, and scanning electron microscopy. Techniques for studying surfaces, internal microstructures, and fluorescence. Lecture, demonstrations. Prerequisite: transition student with instructor approval.

MSE 511 Corrosion and Corrosion Control. (3)
spring in odd years
Introduces corrosion mechanisms and methods of preventing corrosion. Topics include: electrochemistry, polarization, corrosion rates, oxidation, coatings, and cathodic protection. Prerequisite: transition student with instructor approval.

MSE 512 Analysis of Material Failures. (3)
spring in even years
Identifies types of failures. Analytical techniques. Fractography, SEM, nondestructive inspection, and metallography. Mechanical and electronic components. Prerequisite: transition student with instructor approval.

MSE 513 Polymers and Composites. (3)
fall
Relationship between chemistry, structure, and properties of engineering polymers. Design, properties, and behavior of fiber composite systems.

MSE 514 Physical Metallurgy. (3)
spring
Crystal structure and defects. Phase diagrams, metallography, solidification and casting, and deformation and annealing. Prerequisite: transition student with instructor approval.

MSE 515 Thermodynamics of Materials. (3)
spring
Principles of statistical mechanics, statistical thermodynamics of single crystals, solutions, phase equilibrium, free energy of reactions, free electron theory, and thermodynamics of defects. Prerequisite: transition student with instructor approval.

MSE 516 Mechanical Properties of Solids. (3)
fall
Effects of environmental and microstructional variables of mechanical properties, including plastic deformation, fatigue, creep, brittle fracture, and internal friction. Prerequisite: transition student with instructor approval.

MSE 517 Introduction to Ceramics. (3)
fall
Principles of structure, property relations in ceramic materials. Processing techniques. Applications in mechanical, electronic, and superconducting systems. Prerequisite: transition student with instructor approval.

MSE 519 Physical Metallurgy Laboratory. (1)
spring
Analyzes microstructure of metals and alloys and includes some correlation with mechanical properties. Lab. Pre- or corequisite: MSE 514.

MSE 520 Theory of Crystalline Solids. (3)
selected semesters
Anisotropic properties of crystals; tensor treatment of elastic, magnetic, electric and thermal properties, and crystallography of Martensitic transformations.

MSE 521 Defects in Crystalline Solids. (3)
spring
Introduces the geometry, interaction, and equilibrium between dislocations and point defects. Discusses relations between defects and properties. Prerequisite: ECE 350 or instructor approval.

MSE 530 Materials Thermodynamics and Kinetics. (3)
spring
Thermodynamics of alloy systems, diffusion in solids, kinetics of precipitation, and phase transformations in solids. Prerequisites: ECE 340, 350.

MSE 540 Fracture, Fatigue, and Creep. (3)
spring in odd years
Relationship between microstructure and fracture; fatigue and creep properties of materials. Environmental effects and recent developments. Current theories and experimental results. Prerequisite: MSE 440 (or its equivalent).

MSE 550 Advanced Materials Characterization. (3)
fall
Analytical instrumentation for characterization of materials; SEM, SIMS, Auger, analytical TEM, and other advanced research techniques.

MSE 556 Electron Microscopy Laboratory. (3)
fall
Lab support for MSE 558. Cross-listed as SEM 556. Credit is allowed for only MSE 556 or SEM 556. Pre- or corequisite: MSE 558 or SEM 558.

MSE 557 Electron Microscopy Laboratory. (3)
spring
Lab support for MSE 559. Cross-listed as SEM 557. Credit is allowed for only MSE 557 or SEM 557. Pre- or corequisite: MSE 559 or SEM 559.

MSE 558 Electron Microscopy I. (3)
fall
Microanalysis of the structure and composition of materials using images, diffraction, x rays, and energy loss spectroscopy. Requires knowledge of elementary crystallography, reciprocal lattice, stereographic projections, and complex variables. Cross-listed as SEM 558. Credit is allowed for only MSE 558 or SEM 558. Prerequisite: instructor approval.

MSE 559 Electron Microscopy II. (3)
spring
Microanalysis of the structure and composition of materials using images, diffraction, x rays, and energy loss spectroscopy. Requires knowledge of elementary crystallography, reciprocal lattice, stereographic projections, and complex variables. Cross-listed as SEM 559. Credit is allowed for only MSE 559 or SEM 559. Prerequisite: instructor approval.

MSE 560 Strengthening Mechanisms. (3)
selected semesters
Deformation of crystalline materials. Properties of dislocations. Theories of strain hardening, solid solution, precipitation, and transformation strengthening. Prerequisite: ECE 350 (or its equivalent).

MSE 561 Phase Transformation in Solids. (3)
spring in even years
Heterogeneous and homogeneous precipitation reactions, shear displacive reactions, and order-disorder transformation.

MSE 562 Ion Implantation. (3)
selected semesters
Includes defect production and annealing. Generalized treatment, including ion implantation, neutron irradiation damage, and the interaction of other incident beams. Prerequisite: MSE 450.

MSE 570 Polymer Structure and Properties. (3)
spring in even years
Relationships between structure and properties of synthetic polymers, including glass transition, molecular relaxations, crystalline state viscoelasticity, morphological characterization, and processing.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

MSE 571 Ceramics. (3)
selected semesters
Includes ceramic processing, casting, molding, firing, sintering, crystal defects, and mechanical, electronic, and physical properties. Prerequisites: MSE 521, 561.

MSE 573 Magnetic Materials. (3)
selected semesters
Emphasizes ferromagnetic and ferrimagnetic phenomena. Domains, magnetic anisotrophy, and magnetostriction. Study of commercial magnetic materials. Prerequisite: MSE 520 (or its equivalent).

MSE 598 Special Topics. (1–4)
once a year
Topics may include the following:
- Growth and Processing of Semiconductor Devices. (3)

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see "Omnibus Courses," page 56.

Department of Civil and Environmental Engineering

www.eas.asu.edu/~civil
480/965-3589
ECG 252

Sandra L. Houston, Chair

Professors: Fox, S. Houston, W. Houston, Mamlouk, Mays, Rajan, Singhal, Witczak

Associate Professors: Abbaszadegan, Fafitis, Hinks, Johnson, Mobasher, Westerhoff

Assistant Professors: Allen, Dillner, Kaloush, Muccino, Owusu-Antwi, Peccia, Zhu

The civil engineering profession includes analysis, planning, design, construction, and maintenance of many types of facilities for government, commerce, industry, and the public domain. These facilities include high-rise office towers, factories, schools, airports, tunnels and subway systems, dams, canals, and water purification and environmental protection facilities such as solid waste and wastewater treatment systems. Civil engineers are concerned with the impact of their projects on the public and the environment, and they attempt to coordinate the needs of society with technical and economic feasibility.

Career Opportunities in the Field. University graduates with the B.S.E. degree in Civil Engineering readily find employment. Civil engineers work in many different types of companies, from large corporations to small, private consulting firms, or in governmental agencies. A civil engineering background is an excellent foundation for jobs in management and public service. Civil engineering is one of the best engineering professions from the viewpoint of international travel opportunities or for eventually establishing one's own consulting business.

Uniqueness of the Program at ASU. The Department of Civil and Environmental Engineering offers a challenging program of study designed to provide the student with the resources and background to pursue a career in a wide range of specialty areas. Some of these areas are structural, geotechnical, environmental and water resources, transportation and materials engineering. The Civil Engineering program is fully accredited by ABET. With the program, students will be prepared for the Fundamentals of Engineering examination and professional registration.

The Department of Civil and Environmental Engineering at ASU strongly believes in the development of programmatic objectives and outcomes, and a continuous quality improvement program. The four top-level learning objectives for the program deal with the ability of our graduates to

1. be technically competent,
2. be effective members of society,
3. communicate effectively, and
4. analyze and design civil engineering systems with due considerations to cost, environmental and construction factors.

Civil Engineering Areas of Study

Areas of study in the civil engineering curriculum are described below.

Environmental Engineering. This area of study includes the quality of air, water, and land resources; transport, use, and disposal of hazardous wastes; water and wastewater treatment; and water reuse.

Geotechnical/Geoenvironmental Engineering. This area of study includes the analysis and design of foundation systems, seepage control, earthdams and water resource structures, earthwork operations, fluid flow-through porous media, response of foundations and embankments to earthquakes, and solutions to environmental problems.

Structures/Materials Engineering. This area of study considers the planning, analysis and design of steel and concrete bridges, buildings, dams; special offshore and space structures; Portland cement concrete; composite materials; and structural retrofit of existing bridges.

Transportation/Materials Engineering. This area of study includes (1) transportation design and operation and (2) pavements and materials. Transportation design and operation cover geometric design of highways, traffic operations, and highway capacity and safety. Pavements and materials focus on pavement analysis and design, pavement maintenance and rehabilitation, pavement evaluation and management, characterization of highway materials, and durability of highway structures.

Water Resources Engineering. This area of study is concerned with surface and groundwater flow, planning and management of water supply, and water distribution system modeling.

The undergraduate program provides an excellent background for entry to graduate study in engineering.

UNDERGRADUATE OPPORTUNITIES IN CIVIL AND ENVIRONMENTAL ENGINEERING

Students majoring in Civil Engineering have three choices:

1. the major without a concentration;
2. the major with a concentration in construction engineering; and
3. the major with a concentration in environmental engineering.

Civil Engineering. The B.S.E. degree in Civil Engineering offers students a wide background on various areas of study within civil engineering. The degree provides basic principles of environmental, geotechnical/geoenvironmental, structural/materials, transportation/materials, and water resources engineering. Students have the option to select among a certain number of design and technical elective courses in their junior and senior years.

Civil Engineering with Construction Engineering Concentration. The B.S.E. degree in Civil Engineering with a construction engineering concentration offers students basic principles of civil engineering with the option to concentrate on construction engineering. The degree provides education based on the traditional engineering principles, construction materials and practice, quality control, and civil engineering project management.

Civil Engineering with Environmental Engineering Concentration. The B.S.E. degree in Civil Engineering with an environmental engineering concentration offers students basic principles of civil engineering with the option to concentrate on environmental engineering. The degree provides a multidisciplinary education based on the traditional engineering principles, chemistry, biology, and hydrogeology.

CIVIL ENGINEERING—B.S.E.

The B.S.E. degree in Civil Engineering requires a minimum of 128 semester hours of course work. A minimum of 50 upper-division semester hours is required. The minimum requirements are for a student who has successfully completed at least a year (each) of high school chemistry, physics, and computer programming along with precalculus, algebra, and trigonometry.

The B.S.E. degree program consists of the following categories:

First-Year Composition	6
General Studies/school requirements	55
Engineering core	18–19
Civil Engineering core	27
Design courses	6
Technical courses	15–16
Total	128

For information concerning First-Year Composition, General Studies/school requirements, and engineering core courses, see “School of Engineering,” page 218. The Civil Engineering core and the design and the technical course requirements are shown below. The four-year sequences presented afterwards show the specific course requirements for the Civil Engineering degree without a concentration, Civil Engineering with the construction engineering concentration, and the Civil Engineering degree with the environmental engineering concentration.

Civil Engineering Core

CEE	296	Civil Engineering Systems	4
CEE	321	Structural Analysis and Design	4
CEE	341	Fluid Mechanics for Civil Engineers	4
CEE	351	Geotechnical Engineering	4
CEE	361	Introduction to Environmental Engineering	4
CEE	372	Transportation Engineering	4
ECE	380	Probability and Statistics for Engineering Problem Solving *CS*	3
Total			27

Design Courses for the Degree Without a Concentration

Six semester hours from the following list are required.

CEE	423	Structural Design	3
CEE	441	Water Resources Engineering	3
CEE	452	Foundations	3
CEE	466	Sanitary Systems Design	3
CEE	475	Highway Geometric Design	3

Technical Courses for the Degree Without a Concentration

From 15 to 16 semester hours are required. The design elective courses that have not been selected to satisfy the design electives requirement may be used as technical electives.

A maximum of seven hours may be selected from outside civil engineering, with an advisor’s approval. Construction courses taken as technical electives may be selected from the following list: CON 341, 383, 495, and 496. Students must select technical and design electives from at least three different CEE areas of study.

Environmental Engineering

CEE	362	Unit Operations in Environmental Engineering	3
CEE	466	Sanitary Systems Design	3
CEE	467	Environmental Microbiology	4
CHM	231	Elementary Organic Chemistry *SQ*	3

Geotechnical/Geoenvironmental Engineering

CEE	452	Foundations	3

Structures/Materials Engineering

CEE	322	Steel Structures	3
CEE	323	Concrete Structures	3
CEE	423	Structural Design	3
CEE	432	Matrix and Computer Applications in Structural Engineering	3

Transportation/Materials Engineering

CEE	412	Pavement Analysis and Design	3
CEE	475	Highway Geometric Design	3
CEE	481	Civil Engineering Project Management	3
CEE	483	Highway Materials, Construction, and Quality	3

Water Resources Engineering

CEE	440	Engineering Hydrology	3
CEE	441	Water Resources Engineering	3

Design Courses for the Degree with the Construction Engineering Concentration

CEE 322	Steel Structures	3
CEE 452	Foundations	3
Total		6

Technical Courses for the Degree with the Construction Engineering Concentration

CEE 323	Concrete Structures	3
CEE 481	Civil Engineering Project Management	3
CEE 483	Highway Materials, Construction, and Quality	3
CON 341	Surveying	3
CON 496	Construction Contract Administration	3
Total		15

Design Courses for the Degree with the Environmental Engineering Concentration

CEE 441	Water Resources Engineering	3
CEE 466	Sanitary Systems Design	3
Total		6

Technical Courses for the Degree with the Environmental Engineering Concentration

BIO 320	Fundamentals of Ecology or BCH 361 Principles of Biochemistry (3) or CHM 302 Environmental Chemistry (3) or CHM 341 Elementary Physical Chemistry (3) or PUP 442 Environmental Planning (3) or PUP 475 Environmental Impact Assessment (3)	3
CEE 362	Unit Operations in Environmental Engineering	3
CEE 440	Engineering Hydrology	3
CEE 467	Environmental Microbiology	4
Technical elective*		3
Total		16

* This course is selected from the list of technical courses for the degree without a concentration.

Civil Engineering Program of Study
A Four-Year Sequence

First Year

First Semester

CHM 114	General Chemistry for Engineers *SQ* or CHM 116 General Chemistry *SQ* (4)	4
ECE 100	Introduction to Engineering Design *CS*	3
ENG 101	First-Year Composition	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
Total		14

Second Semester

CEE 296	Civil Engineering Systems	4
ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
ENG 102	First-Year Composition	3
MAT 271	Calculus with Analytic Geometry II *MA*	4
PHY 121	University Physics I: Mechanics *SQ*[1]	3
PHY 122	University Physics Laboratory I *SQ*[1]	1
Total		18

Second Year

First Semester

ECE 210	Engineering Mechanics I: Statics	3
MAT 272	Calculus with Analytic Geometry III *MA*	4
MAT 274	Elementary Differential Equations *MA*	3
PHY 131	University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY 132	University Physics Laboratory II *SQ*[2]	1
HU/SB and awareness area course[3]		3
Total		17

Second Semester

ECE 212	Engineering Mechanics II: Dynamics	3
ECE 313	Introduction to Deformable Solids	3
ECE 340	Thermodynamics or ECE 201 Electrical Networks I (4)	3
ECE 380	Probability and Statistics for Engineering Problem Solving *CS*	3
Basic science elective		3
Total		15–16

Third Year

First Semester

CEE 321	Structural Analysis and Design	4
CEE 341	Fluid Mechanics for Civil Engineers	4
ECE 300	Intermediate Engineering Design *L*	3
ECE 351	Civil Engineering Materials	3
ECE 384	Numerical Methods for Engineers	4
Total		18

Second Semester

CEE 351	Geotechnical Engineering	4
CEE 361	Introduction to Environmental Engineering	4
CEE 372	Transportation Engineering	4
HU/SB and awareness area course[3]		3
Total		15

Fourth Year

First Semester

Design elective		3
HU/SB and awareness area course[3]		3
Technical electives		9
Total		15

Second Semester

CEE 486	Integrated Civil Engineering Design *L*	3
Design elective		3
HU/SB and awareness area course[3]		3
Technical electives		6–7
Total		15–16
Minimum total		128

[1] Both PHY 121 and 122 must be taken to secure SQ credit.

[2] Both PHY 131 and 132 must be taken to secure SQ credit.

[3] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU or SB requirements. Students should consider the following list of electives to enhance communication and management skills: COM 100, 110, 320; CON 101; PUP 100, 200.

Construction Engineering Concentration
Program of Study
A Four-Year Sequence

First Year

First Semester
CHM 114 General Chemistry for Engineers *SQ* 4
or CHM 116 General Chemistry *SQ* (4)
ECE 100 Introduction to Engineering Design *CS* 3
ENG 101 First-Year Composition 3
MAT 270 Calculus with Analytic Geometry I *MA* 4
Total 14

Second Semester
CEE 296 Civil Engineering Systems 4
ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
ENG 102 First-Year Composition 3
MAT 271 Calculus with Analytic Geometry II *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[1] 3
PHY 122 University Physics Laboratory I *SQ*[1] 1
Total 18

Second Year

First Semester
ECE 210 Engineering Mechanics I: Statics 3
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3
PHY 131 University Physics II: Electricity and Magnetism *SQ*[2] 3
PHY 132 University Physics Laboratory II *SQ*[2] 1
HU/SB and awareness area course[3] 3
Total 17

Second Semester
ECE 201 Electrical Networks I 4
ECE 212 Engineering Mechanics II: Dynamics 3
ECE 313 Introduction to Deformable Solids 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
Basic science elective 3
Total 16

Third Year

First Semester
CEE 321 Structural Analysis and Design 4
CEE 341 Fluid Mechanics for Civil Engineers 4
ECE 300 Intermediate Engineering Design *L* 3
ECE 351 Civil Engineering Materials 3
ECE 384 Numerical Methods for Engineers 4
Total 18

Second Semester
CEE 351 Geotechnical Engineering 4
CEE 361 Introduction to Environmental Engineering 4
CEE 372 Transportation Engineering 4
HU/SB and awareness area course[3] 3
Total 15

Fourth Year

First Semester
CEE 322 Steel Structures 3
CEE 452 Foundations 3
CEE 481 Civil Engineering Project Management 3
CON 341 Surveying 3
HU/SB and awareness area course[3] 3
Total 15

Second Semester
CEE 323 Concrete Structures 3
CEE 483 Highway Materials, Construction, and Quality 3
CEE 486 Integrated Civil Engineering Design *L* 3
CON 496 Construction Contract Administration *L* 3
HU/SB and awareness area course[3] 3
Total 15
Graduation requirement total 128

1 Both PHY 121 and 122 must be taken to secure SQ credit.
2 Both PHY 131 and 132 must be taken to secure SQ credit.
3 Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU or SB requirements. Students should consider the following list of electives to enhance communication and management skills: COM 100, 110, 320; CON 101; PUP 100, 200.

Environmental Engineering Concentration
Program of Study
A Four-Year Sequence

First Year

First Semester
CHM 114 General Chemistry for Engineers *SQ* 4
or CHM 116 General Chemistry *SQ* (4)
ECE 100 Introduction to Engineering Design *CS* 3
ENG 101 First-Year Composition 3
MAT 270 Calculus with Analytic Geometry I *MA* 4
Total 14

Second Semester
CEE 296 Civil Engineering Systems 4
ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
ENG 102 First-Year Composition 3
MAT 271 Calculus with Analytic Geometry II *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[1] 3
PHY 122 University Physics Laboratory I *SQ*[1] 1
Total 18

Second Year

First Semester
ECE 210 Engineering Mechanics I: Statics 3
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3
PHY 131 University Physics II: Electricity and Magnetism *SQ*[2] 3
PHY 132 University Physics Laboratory II *SQ*[2] 1
HU/SB and awareness area course[3] 3
Total 17

Second Semester
CHM 231 Elementary Organic Chemistry *SQ* 3
ECE 212 Engineering Mechanics II: Dynamics 3
ECE 313 Introduction to Deformable Solids 3
ECE 340 Thermodynamics 3

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

ECE	380	Probability and Statistics for Engineering Problem Solving *CS*	3
Total			15

Third Year

First Semester

CEE	321	Structural Analysis and Design	4
CEE	341	Fluid Mechanics for Civil Engineers	4
ECE	300	Intermediate Engineering Design *L*	3
ECE	351	Civil Engineering Materials	3
ECE	384	Numerical Methods for Engineers	4
Total			18

Second Semester

CEE	351	Geotechnical Engineering	4
CEE	361	Introduction to Environmental Engineering	4
CEE	372	Transportation Engineering	4
BIO	320	Fundamentals of Ecology or BCH 361 Principles of Biochemistry (3) or CHM 302 Environmental Chemistry (3) or CHM 341 Elementary Physical Chemistry (3) or PUP 442 Environmental Planning (3) or PUP 475 Environmental Impact Assessment (3)	3
HU/SB and awareness area course[3]			3
Total			18

Fourth Year

First Semester

CEE	362	Unit Operations in Environmental Engineering	3
CEE	440	Engineering Hydrology	3
CEE	466	Sanitary Systems Design	3
CEE	467	Environmental Microbiology	4
HU/SB and awareness area course[3]			3
Total			16

Second Semester

CEE	441	Water Resources Engineering	3
CEE	486	Integrated Civil Engineering Design *L*	3
HU/SB and awareness area course[3]			3
Technical elective[4]			3
Total			12
Graduation requirement total			128

1 Both PHY 121 and 122 must be taken to secure SQ credit.

2 Both PHY 131 and 132 must be taken to secure SQ credit.

3 Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU or SB requirements. Students should consider the following list of electives to enhance communication and management skills: COM 100, 110, 320; CON 101; PUP 100, 200.

4 This course is selected from the list of technical courses for the degree without a concentration.

GRADUATION REQUIREMENTS

Each Sequence of mathematics, engineering core, civil engineering core, and the combined design and technical courses must be completed with an average grade of "C" or higher. CEE courses, except CEE 296, may not be taken before the engineering core courses are completed. Design and technical courses may not be taken before the civil engineering core courses are completed.

A maximum of two graduate courses may be taken for undergraduate credit by students whose cumulative GPA is 3.00 or higher with the approval of the instructor, advisor, department chair, and the dean of the college.

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 79.

Concurrent Studies in Architecture and Civil Engineering

Qualified lower-division students interested in combining undergraduate studies in architecture and civil engineering may prepare for upper-division and graduate courses in both programs by taking courses shown for option B under the Architectural Studies major. See "Architectural Studies—B.S.D.," page 129.

GRADUATE STUDY

The Department of Civil and Environmental Engineering also offers graduate programs leading to the M.S., M.S.E., and Ph.D. degrees. These programs provide a blend of classroom instruction and research. Many topics and relevant research projects are available for thesis programs. Students interested in these programs should contact the department for up-to-date literature.

CIVIL AND ENVIRONMENTAL ENGINEERING (CEE)

CEE Note 1. Students enrolled in CEE 580, 590, 592, 599, 792, and 799 are required to attend graduate student seminars at the times shown in the *Schedule of Classes.*

CEE Note 2. Each semester, every graduate student enrolled for more than eight semester hours is to enroll for at least one semester hour of CEE 592, 599, 792, or 799**.**

CEE 296 Civil Engineering Systems. (4)
fall and spring
Introduces civil engineering. Problem solving, economics, description of civil engineering systems, design concepts, ethics, professional responsibilities, and computer graphics. Lecture, computer labs, field trips. Pre- or corequisite: ECE 100.

CEE 321 Structural Analysis and Design. (4)
fall and spring
Statically determinate and indeterminate structures (trusses, beams, and frames) by classical and matrix methods. Introduces structural design. Lecture, recitation. Prerequisites: ECE 212, 313. Pre- or corequisites: ECE 380, 384.

CEE 322 Steel Structures. (3)
fall
Behavior of structural components and systems. Design of steel members and connections. Load and resistance factor design methods. Lecture, recitation. Prerequisite: CEE 321.

CEE 323 Concrete Structures. (3)
spring
Behavior of concrete structures and the design of reinforced and prestressed concrete members, including footings. Partial design of concrete building system. Lecture, recitation. Prerequisite: CEE 321.

CEE 340 Hydraulics and Hydrology. (3)
fall and spring
Applies hydraulic engineering principles to flow of liquids in pipe systems and open channels; hydrostatics; characteristics of pumps and turbines. Introduces hydrology. Not open to engineering students. Lecture, lab. Prerequisite: CON 221.

CEE 341 Fluid Mechanics for Civil Engineers. (4)
fall and spring
Fundamental principles and methods of fluid mechanics forming the analytical basis for water resources engineering. Conduit and open channel flow. 3 hours lecture, 1 hour lab. Prerequisites: ECE 212, 313. Pre- or corequisites: ECE 380, 384.

CEE 351 Geotechnical Engineering. (4)
fall and spring
Index properties and engineering characteristics of soils. Compaction, permeability and seepage, compressibility and settlement, and shear strength. Lecture, lab. Prerequisites: ECE 212, 313. Pre- or corequisites: ECE 380, 384.

CEE 361 Introduction to Environmental Engineering. (4)
fall and spring
Concepts of air and water pollution; environmental regulation, risk assessment, chemistry, water quality modeling, water and wastewater treatment systems designs. Lecture, lab. Prerequisites: ECE 212, 313. Pre- or corequisites: ECE 380, 384.

CEE 362 Unit Operations in Environmental Engineering. (3)
spring
Design and operation of unit processes for water and wastewater treatment. Prerequisite: CEE 361.

CEE 372 Transportation Engineering. (4)
fall and spring
Highway, rail, water, and air transportation. Operational characteristics and traffic control devices of each transport mode. Impact on urban form. Prerequisites: ECE 212, 313. Pre- or corequisites: ECE 380, 384.

CEE 412 Pavement Analysis and Design. (3)
fall
Design of flexible and rigid pavements for highways and airports. Surface, base, and subgrade courses. Cost analysis and pavement selection. Prerequisites: CEE 351; ECE 351.

CEE 423 Structural Design. (3)
fall
Analysis and design of reinforced concrete steel, masonry, and timber structures. Lecture, lab. Prerequisite: CEE 323. Pre- or corequisite: CEE 322.

CEE 432 Matrix and Computer Applications in Structural Engineering. (3)
spring
Matrix and computer applications to structural engineering and structural mechanics. Stiffness and flexibility methods, finite elements, and differences. Prerequisite: CEE 321.

CEE 440 Engineering Hydrology. (3)
fall
Descriptive hydrology; hydrologic cycle, models, and systems. Rainrunoff models. Hydrologic design. Concepts, properties, and basic equations of groundwater flow. Prerequisite: CEE 341.

CEE 441 Water Resources Engineering. (3)
spring
Applies the principles of hydraulics and hydrology to the engineering of water resources projects; design and operation of water resources systems; water quality. Prerequisite: CEE 341.

CEE 452 Foundations. (3)
fall
Applies soil mechanics to foundation systems, bearing capacity, lateral earth pressure, and slope stability. Prerequisite: CEE 351.

CEE 466 Sanitary Systems Design. (3)
fall
Capacity, planning and design of water supply, domestic and storm drainage, and solid waste systems. Prerequisite: CEE 361.

CEE 467 Environmental Microbiology. (4)
fall
Overview of the microbiology of natural and human-impacted environment, microbial detection methodologies, waterborne disease outbreaks, risk assessment, and regulations. Lecture, lab. Prerequisite: CEE 361 or MIC 220.

CEE 471 Intelligent Transportation Systems. (3)
selected semesters
Applies advanced technology to the vehicle and the roadway to solve traffic congestion, safety, and air quality problems. Prerequisite: CEE 372 or instructor approval.

CEE 475 Highway Geometric Design. (3)
spring
Design of the visible elements of the roadway. Fundamental design controls with application to rural roads, at-grade intersections, freeways, and interchanges. Lecture, recitation. Prerequisite: CEE 372.

CEE 481 Civil Engineering Project Management. (3)
once a year
Civil engineering project management and administration, planning and scheduling, cost estimating and bidding strategies, financial management, quality control and safety, and computer applications. Lecture, field trip. Prerequisites: CEE 321, 351, 372.

CEE 483 Highway Materials, Construction, and Quality. (3)
once a year
Properties of highway materials including aggregates, asphalt concrete, and portland cement concrete; construction practice; material delivery, placement, and compaction; quality control. Lecture, field trip. Prerequisites: CEE 321, 351, 372; ECE 351, 380.

CEE 486 Integrated Civil Engineering Design. (3)
fall and spring
Requires completion of a civil engineering design in a simulated practicing engineering environment. Limited to undergraduates in their final semester. Lecture, team learning. Prerequisites: CEE 321, 341, 351, 361, 372.
General Studies: L

CEE 512 Pavement Performance and Management. (3)
selected semesters
Pavement management systems, including data collection, evaluation, optimization, economic analysis, and computer applications for highway and airport design. Prerequisite: instructor approval.

CEE 514 Bituminous Materials and Mixture. (3)
selected semesters
Types of bituminous materials used in pavement mixtures. Chemical composition, physical properties, desirable aggregate characteristics, optimum asphalt contents, superpave asphalt binder, mixture design. Lecture, lab. Prerequisite: ECE 351.

CEE 515 Properties of Concrete. (3)
selected semesters
Materials science of concrete. Cement chemistry, mechanisms of hydration, interrelationships among micro- and macro-properties of cement-based materials. Mechanical properties, failure theories, fracture mechanics of concrete materials. Cement-based composite materials and the durability aspects. Lecture, lab. Prerequisite: ECE 350 or 351.

CEE 521 Stress Analysis. (3)
fall
Advanced topics in the analytical determination of stress and strain. Prerequisite: CEE 321.

CEE 524 Advanced Steel Structures. (3)
fall
Strength properties of steel and their effects on structural behavior. Elastic design of steel structures. Plastic analysis and design of beams, frames, and bents. Plastic deflections. Plastic design requirements. Multistory buildings. Prerequisite: CEE 322.

CEE 526 Finite Element Methods in Civil Engineering. (3)
fall
Finite element formulation for solutions of structural, geotechnical, and hydraulic problems. Prerequisite: CEE 432.

CEE 527 Advanced Concrete Structures. (3)
selected semesters
Ultimate strength design. Combined shear and torsion. Serviceability. Plastic analysis. Special systems. Prerequisite: CEE 323.

CEE 530 Prestressed Concrete. (3)
selected semesters
Materials and methods of prestressing. Analysis and design for flexure, shear, and torsion. Prestress losses due to friction, creep, shrinkage, and anchorage set. Statically indeterminate structures. Design of flat slabs, bridges, and composite beams. Prerequisite: CEE 323.

CEE 533 Structural Optimization. (3)
selected semesters
Linear and nonlinear programming. Problem formulation. Constrained and unconstrained optimization. Sensitivity analysis. Approximate techniques. FEM-based optimal design of mechanical and aerospace

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L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

structures. Cross-listed as MAE 521. Credit is allowed for only CEE 533 or MAE 521. Prerequisite: instructor approval.

CEE 536 Structural Dynamics. (3)
selected semesters
Structures and structural members subjected to dynamic loadings, response spectra theory applications to bridges and power plants, investigations of the responses of multidegree of freedom structures, and matrix and numerical methods of analysis. Lecture, recitation. Prerequisites: CEE 321; instructor approval.

CEE 537 Topics in Structural Engineering. (1–3)
selected semesters
Advanced topics, including nonlinear structural analysis, experimental stress analysis, advanced finite elements, plasticity and viscoelesticity, composites, and damage mechanics. Prerequisite: instructor approval.

CEE 540 Groundwater Hydrology. (3)
fall
Physical properties of aquifers, well pumping, subsurface flow modeling, unsaturated flow, numerical methods, land subsidence, and groundwater pollution. Prerequisite: CEE 440 or instructor approval.

CEE 541 Surface Water Hydrology. (3)
spring
Hydrologic cycle and mechanisms, including precipitation, evaporation, and transpiration; hydrograph analysis; flood routing; statistical methods in hydrology and hydrologic design. Prerequisite: CEE 440 or instructor approval.

CEE 543 Water Resources Systems. (3)
selected semesters
Theory and application of quantitative planning methodologies for the design and operation of water resources systems. Class projects using a computer, case studies. Prerequisite: instructor approval.

CEE 546 Free Surface Hydraulics. (3)
selected semesters
Derivation of 1-dimensional equations used in open channel flow analysis; computations for uniform and nonuniform flows, unsteady flow, and flood routing. Mathematical and physical models. Prerequisite: CEE 341.

CEE 547 Principles of River Engineering. (3)
selected semesters
Uses of rivers, study of watershed, and channel processes. Sediment sources, yield, and control; hydrologic analysis. Case studies. Prerequisite: CEE 341 or instructor approval.

CEE 548 Sedimentation Engineering. (3)
selected semesters
Introduces the transportation of granular sedimentary materials by moving fluids. Degradation, aggregation, and local scour in alluvial channels. Mathematical and physical models. Prerequisite: CEE 547 or instructor approval.

CEE 550 Soil Behavior. (3)
selected semesters
Physicochemical aspects of soil behavior, stabilization of soils, and engineering properties of soils. Prerequisite: CEE 351.

CEE 551 Advanced Geotechnical Testing. (3)
selected semesters
Odometer, triaxial (static and cyclic) back pressure saturated and unsaturated samples, pore pressure measurements, closed-loop computer-controlled testing, in-situ testing, and sampling. Lecture, lab. Prerequisite: CEE 351.

CEE 552 Geological Engineering. (3)
selected semesters
Geological investigations for engineering purposes, case histories, geologic structure, weathering, remote sensing, geophysics, and air photo interpretation for engineering site locations. Lecture, field trips. Prerequisite: CEE 351.

CEE 553 Advanced Soil Mechanics. (3)
selected semesters
Applies theories of elasticity and plasticity to soils, theories of consolidation, failure theories, and response to static and dynamic loading. Prerequisite: CEE 351.

CEE 554 Shear Strength and Slope Stability. (3)
selected semesters
Shear strength of saturated and unsaturated soils strength-deformation relationships, time-dependent strength parameters, effects of sampling, and advanced slope stability. Prerequisite: CEE 351.

CEE 555 Advanced Foundations. (3)
selected semesters
Deep foundations, braced excavations, anchored bulkheads, reinforced earth, and underpinning. Prerequisite: CEE 351.

CEE 557 Hazardous Waste: Site Assessment and Mitigation Measures. (3)
selected semesters
Techniques for hazardous waste site assessment and mitigation. Case histories presented by instructor and guest speakers. Prerequisites: graduate standing; instructor approval.

CEE 559 Earthquake Engineering. (3)
selected semesters
Characteristics of earthquake motions, selection of design earthquakes, site response analyses, seismic slope stability, and liquefaction. Prerequisite: CEE 351.

CEE 560 Soil and Groundwater Remediation. (3)
fall
Presents techniques for remediation of contaminated soils and groundwaters with basic engineering principles. Prerequisite: instructor approval.

CEE 561 Physical-Chemical Treatment of Water and Waste. (3)
fall
Theory and design of physical and chemical processes for the treatment of water and wastewaters. Prerequisite: CEE 361.

CEE 562 Environmental Biochemistry and Waste Treatment. (3)
spring
Theory and design of biological waste treatment systems. Pollution and environmental assimilation of wastes. Prerequisite: CEE 362.

CEE 563 Environmental Chemistry Laboratory. (3)
fall
Analyzes water, domestic and industrial wastes, laboratory procedures for pollution evaluation, and the control of water and waste treatment processes. Lecture, lab. Prerequisite: CEE 361.

CEE 565 Modeling and Assessment of Aquatic Systems. (3)
selected semesters
Development of predictive models of water quality; methods to assess environmental impacts; applications to water quality management. Prerequisite: CEE 361 or instructor approval.

CEE 566 Industrial/Hazardous Waste Treatment. (3)
selected semesters
Emphasizes treatment of local industrial/hazardous waste problems, including solvent recovery and metals. Lecture, project. Prerequisites: CEE 561, 563.

CEE 573 Traffic Engineering. (3)
selected semesters
Driver, vehicle, and roadway characteristics, laws and ordinances, traffic control devices, traffic engineering studies, and Transportation System Management measures. Prerequisite: CEE 372.

CEE 574 Highway Capacity. (3)
selected semesters
Highway capacity for all functional classes of highways. Traffic signalization, including traffic studies, warrants, cycle length, timing, phasing, and coordination. Prerequisite: CEE 372.

CEE 575 Traffic Flow Theory and Safety Analysis. (3)
selected semesters
Traffic flow theory; distributions, queuing, delay models, and car-following. Highway safety; accident records systems, accident analysis, identifying problem locations, and accident countermeasures. Prerequisite: CEE 573 or 574.

CEE 577 Urban Transportation Planning. (3)
selected semesters
Applies land use parameters traffic generation theory, traffic distribution and assignment models, transit analysis, and economic factors to the solution of the urban transportation problem. Prerequisite: CEE 372.

CEE 580 Practicum. (1–12)
selected semesters
See CEE Note 1.

CEE 590 Reading and Conference. (1–12)
selected semesters
See CEE Note 1.

CEE 591 Seminar. (1–12)
selected semesters
Topics may include the following:
- Transportation Systems Pro-Seminar

CEE 592 Research. (1–12)
selected semesters
See CEE Notes 1, 2.

CEE 598 Special Topics. (1–4)
selected semesters
Topics may include the following:
- Intelligent Transportation Systems

CEE 599 Thesis. (1–12)
selected semesters
See CEE Notes 1, 2.

CEE 792 Research. (1–15)
selected semesters
See CEE Notes 1, 2.

CEE 799 Dissertation. (1–15)
selected semesters
See CEE Notes 1, 2.

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

Department of Computer Science and Engineering

cse.asu.edu

480/965-3190

GWC 206

Charles J. Colbourn, Chair

Professors: Ashcroft, Colbourn, Collofello, Farin, Golshani, Kambhampati, Lee, Lewis, Nielson, Panchanathan, Tsai, J. Urban, S. Urban, Yau

Associate Professors: Baral, Bhattacharya, Dasgupta, Dietrich, Faltz, Gupta, Huey, Liu, Miller, O’Grady, Pheanis, Sen, Xue

Assistant Professors: Bazzi, Cam, Candan, Chatha, Gannod, Konjevod, Richa, Ryu, Sarjoughian, Wagner

Lecturers: Chen, DeLibero, Nakamura, Navabi

Computers have a significant impact on our daily lives, and this impact is likely to be even greater in the future as computer professionals continue to develop more powerful, smaller, faster, and less expensive computing systems. Computer science and computer engineering deal with the study, design, development, construction, and application of modern computing machinery. Other important topics include computing techniques and appropriate languages for general information processing; for scientific computation; for the recognition, storage, retrieval, and processing of data of all kinds; and for the automatic control and simulation of processes.

The curricula offered by the Department of Computer Science and Engineering prepare the student to be a participant in this rapidly changing area of technology by presenting in-depth treatments of the fundamentals of computer science and computer engineering. The department offers two undergraduate degrees: a B.S. degree in Computer Science and a B.S.E. degree in Computer Systems Engineering. The following are shared objectives of the degree programs:

1. Graduates will understand current trends in information technology and be able to apply their understanding in the distributed management of information.
2. Graduates can apply the underlying principles of computer science, including mathematical and physical sciences and engineering principles.
3. Graduates will know and be able to apply system development processes, using modern tools, from the component level to the system level.
4. Graduates also will have the skills required to communicate effectively in both technical and nontechnical settings, to work effectively in teams and in a multicultural environment, to work ethically and professionally, and continue to learn independently and grow intellectually.

The Computer Systems Engineering program has the specific objective that its graduates will have the technical expertise necessary to analyze requirements and to design and implement effective solutions to problems that require the integration of hardware and software. The Computer Science program has the specific objective that its graduates will have the technical expertise necessary to analyze requirements, design, and implement effective solutions using computer science for a broad range of problems. The department strives to maintain a modern learning environment that fosters excellence, cooperation, and scholarship for faculty, students, and staff.

ADMISSION REQUIREMENTS

The admission standards for the undergraduate Computer Science and Computer Systems Engineering degree programs are changing for spring 2002.

The Preprofessional Program. Each student admitted to the Department of Computer Science and Engineering is designated a preprofessional student in either Computer Science or Computer Systems Engineering. The student follows the first- and second-year sequence of courses listed in the curriculum outline for his or her particular major. Included in the first- and second-year schedules are 13 emphasis courses:

CSE	120	Digital Design Fundamentals	3
CSE	200	Concepts of Computer Science	3
CSE	210	Object Oriented Design and Data Structures	3

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

CSE 225 Assembly Languages Programming and Microprocessors (Motorola) 4
or CSE 226 Assembly Languages Programming and Microprocessors (Intel) (4)
CSE 240 Introduction to Programming Languages 3
Choose among the course combinations below 6
ENG 101 First-Year Composition (3)
ENG 102 First-Year Composition (3)
—or—
ENG 105 Advanced First-Year Composition (3)
HU/SB elective chosen with an advisor (3)
—or—
ENG 107 English for Foreign Students (3)
ENG 108 English for Foreign Students (3)
MAT 243 Discrete Mathematical Structures 3
MAT 270 Calculus with Analytic Geometry I 4
MAT 271 Calculus with Analytic Geometry II 4
MAT 272 Calculus with Analytic Geometry III 4
PHY 121 University Physics I: Mechanics 3
PHY 122 University Physics I: Laboratory I 1
PHY 131 University Physics II: Electricity and Magnetism 3
PHY 132 University Physics II: Laboratory II 1

The Professional Program. Admission to the professional program is competitive and granted to those applicants demonstrating the highest promise for professional success in Computer Science and Engineering. The admissions committee considers overall transfer and ASU GPA numbers as well as the transfer and ASU GPA numbers in Computer Science and Engineering emphasis courses. All students seeking professional status must have completed or be in the process of completing all the emphasis courses and then follow the application procedure as described on the Computer Science and Engineering Web site. Completion of the specified courses does not guarantee admission to professional status. Only students who qualify for professional status in the College of Engineering and Applied Sciences and have been admitted to ASU are eligible to apply for the professional programs. Candidates are strongly encouraged to visit the Computer Science and Engineering Advising Center in GWC 302 before beginning the application process. All application materials can be found on the Web at cse.asu.edu.

DEGREE REQUIREMENTS

A minimum of 128 semester hours is required for the B.S. degree in Computer Science and the B.S.E. degree in Computer Systems Engineering. A minimum of 50 upper-division semester hours is required. In addition to the requirement for a cumulative GPA of 2.00 or higher, all computer science and computer systems engineering students must obtain a minimum grade of “C” in all CSE courses used for degree credit.

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See “University Graduation Requirements,” page 79.

DEGREES

Computer Science—B.S.

The faculty in the Department of Computer Science and Engineering offer a B.S. degree that prepares the student for a career in computer science. A student pursuing a B.S. degree must complete the First-Year Composition requirement, the General Studies requirement, department degree requirements, the computer science core courses, a senior-level breadth requirement in the major, technical electives, and unrestricted electives. For more information, visit the department in GWC 206, call 480/965-3190, send e-mail to cse.graduate.office@asu.edu, or access the department’s Web site at cse.asu.edu.

Software Engineering Concentration. Students pursuing the B.S. degree in Computer Science may choose to concentrate their studies on software engineering. The B.S. Degree in Computer Science with a concentration in software engineering provides recognition that the student has acquired in-depth knowledge and hands-on experience in software development and related subjects. This concentration requires the student to complete CSE 445, 460, 461, and 462 with a grade of “C” or higher in each.

The following table specifies departmental requirements for the B.S. degree in Computer Science.

First-Year Composition
Choose among the course combinations below 6
ENG 101 First-Year Composition (3)
ENG 102 First-Year Composition (3)
—or—
ENG 105 Advanced First-Year Composition (3)
HU/SB elective chosen with an advisor (3)
—or—
ENG 107 English for Foreign Students (3)
ENG 108 English for Foreign Students (3)
Total 6

General Studies/Department Requirements

Humanities and Fine Arts/Social and Behavioral Sciences
HU/SB electives 18

Literacy and Critical Inquiry
L elective 3
ECE 400 Engineering Communications *L* 3
or approved CSE L course (3)
Total 6

Natural Sciences/Basic Sciences
PHY 121 University Physics I: Mechanics *SQ*[1] 3
PHY 122 University Physics Laboratory I *SQ*[1] 1
PHY 131 University Physics II: Electricity and Magnetism *SQ*[2] 3
PHY 132 University Physics Laboratory II *SQ*[2] 1
Science elective[3] 4
Total 12

Mathematical Studies
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
MAT 243 Discrete Mathematical Structures 3
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 342 Linear Algebra 3
Total 21
General Studies/department requirement total 57

Computer Science Core
CSE 120 Digital Design Fundamentals 3

CSE 200 Concepts of Computer Science *CS* 3
CSE 210 Object-Oriented Design and Data Structures *CS* 3
CSE 225 Assembly Language Programming and Microprocessors (Motorola) 4
or CSE 226 Assembly Language Programming and Microprocessors (Intel) (4)
CSE 240 Introduction to Programming Languages 3
CSE 310 Data Structures and Algorithms 3
CSE 330 Computer Organization and Architecture 3
CSE 340 Principles of Programming Languages 3
CSE 355 Introduction to Theoretical Computer Science 3
CSE 360 Introduction to Software Engineering 3
CSE 430 Operating Systems 3

Total computer science core 34

400-level CSE computer science breadth requirement 18
Technical electives[4] 6
Unrestricted electives 7

Total 31
Total degree requirements 128

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[1] Both PHY 121 and 122 must be taken to secure SQ credit.

[2] Both PHY 131 and 132 must be taken to secure SQ credit.

[3] Each student must complete a four-credit laboratory science course that meets major requirements in the discipline of the course selected that satisfies the SQ portion of the General Studies requirement. See an advisor for the approved listing.

[4] Each student must complete six hours of courses chosen from the computer science technical elective list and approved by the student's advisor. See an advisor for the approved listing.

Computer Science
Program of Study
Typical Four-Year Sequence

First Year

First Semester
CSE 200 Concepts of Computer Science *CS* 3
ENG 101 First-Year Composition 3
MAT 270 Calculus with Analytic Geometry I *MA* 4
HU/SB and awareness area course[1] 3
Unrestricted elective 3

Total 16

Second Semester
CSE 120 Digital Design Fundamentals 3
CSE 210 Object-Oriented Design and Data Structures *CS* 3
ENG 102 First-Year Composition 3
MAT 271 Calculus with Analytic Geometry II *MA* 4
Unrestricted elective 4

Total 17

Second Year

First Semester
CSE 240 Introduction to Programming Languages 3
MAT 243 Discrete Mathematical Structures 3
MAT 272 Calculus with Analytic Geometry III *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[2] 3
PHY 122 University Physics Laboratory I *SQ*[2] 1
HU/SB and awareness area course[1] 3

Total 17

Second Semester
CSE 225 Assembly Language Programming and Microprocessors (Motorola) 4
or CSE 226 Assembly Language Programing and Microprocessors (Intel) (4)
MAT 342 Linear Algebra 3
PHY 131 University Physics II: Electricity and Magnetism *SQ*[3] 3
PHY 132 University Physics Laboratory II *SQ*[3] 1
HU/SB and awareness area course[1] 3
L elective 3

Total 17

Third Year

First Semester
CSE 310 Data Structures and Algorithms 3
CSE 330 Computer Organization and Architecture 3
CSE 360 Introduction to Software Engineering 3
HU/SB and awareness area course[1] 3
Laboratory science *SQ*[4] 4

Total 16

Second Semester
CSE 340 Principles of Programming Languages 3
CSE 355 Introduction to Theoretical Computer Science 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
HU/SB and awareness area course[1] 3
Technical elective 3

Total 15

Fourth Year

First Semester
CSE 430 Operating Systems 3
ECE 400 Engineering Communications *L* 3
or approved CSE L course (3)
400-level CSE computer science breadth electives 9

Total 15

Second Semester
400-level CSE computer science breadth electives 9
HU/SB and awareness area course[1] 3
Technical elective 3

Total 15

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[1] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU and SB requirements.

[2] Both PHY 121 and 122 must be taken to secure SQ credit.

[3] Both PHY 131 and 132 must be taken to secure SQ credit.

[4] Each student must complete a four-credit laboratory science course that meets major requirements in the discipline of the course selected that satisfies the SQ portion of the General Studies requirement. See an advisor for the approved listing.

Computer Systems Engineering—B.S.E.

The Department of Computer Science and Engineering offers a B.S.E. degree that prepares the student for a career in computer systems engineering. This degree program pro-

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L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/ quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

vides training in both engineering and computer science. Qualified students in this program may apply to participate in an industrial internship program offered through the Embedded Systems and Internetworking Consortium. Students who participate in this internship program receive academic credit (CSE 484) that applies to the technical elective requirement of the B.S.E. degree in Computer Systems Engineering. The following table specifies departmental requirements for the B.S.E. degree in Computer Systems Engineering.

First-Year Composition

Choose among the course combinations below 6
- ENG 101 First-Year Composition (3)
- ENG 102 First-Year Composition (3)

—or—

- ENG 105 Advanced First-Year Composition (3)
- HU/SB elective chosen with an advisor (3)

—or—

- ENG 107 English for Foreign Students (3)
- ENG 108 English for Foreign Students (3)

Total 6

General Studies/Department Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
HU and SB electives		12
Total		15

Literacy and Critical Inquiry

CSE 423	Microcomputer System Hardware *L* or CSE 438 Systems Programming *L* (3)	3
ECE 300	Intermediate Engineering Design *L*	3
Total		6

Natural Sciences/Basic Sciences

CHM 114	General Chemistry for Engineers *SQ* or CHM 116 General Chemistry *SQ* (4)	4
PHY 121	University Physics I: Mechanics *SQ*[1]	3
PHY 122	University Physics Laboratory I *SQ*[1]	1
PHY 131	University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY 132	University Physics Laboratory II *SQ*[2]	1
PHY 361	Introductory Modern Physics	3
Total		15

Mathematical Studies

MAT 243	Discrete Mathematical Structures	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
MAT 271	Calculus with Analytic Geometry II *MA*	4
MAT 272	Calculus with Analytic Geometry III *MA*	4
MAT 274	Elementary Differential Equations *MA*	3
MAT 342	Linear Algebra	3
Total		21
General Studies/department requirement total		57

Engineering Core

CSE 200	Concepts of Computer Science *CS*	3
CSE 225	Assembly Language Programming and Microprocessors (Motorola)	4
ECE 100	Introduction to Engineering Design *CS*	3
ECE 201	Electrical Networks I	4
ECE 210	Engineering Mechanics I: Statics	3
ECE 334	Electronic Devices and Instrumentation	4
Total		21

Computer Science Core

CSE 120	Digital Design Fundamentals	3
CSE 210	Object-Oriented Design and Data Structures *CS*	3
CSE 240	Introduction to Programming Languages	3
CSE 310	Data Structures and Algorithms	3
CSE 330	Computer Organization and Architecture	3
CSE 340	Principles of Programming Languages	3
CSE 355	Introduction to Theoretical Computer Science	3
CSE 360	Introduction to Software Engineering	3
CSE 421	Microprocessor System Design I	4
CSE 422	Microprocessor System Design II	4
CSE 430	Operating Systems	3
ECE 380	Probability and Statistics for Engineering Problem Solving *CS*	3
Technical electives[3]		6
Total		44
Degree requirement total		128

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[1] Both PHY 121 and 122 must be taken to secure SQ credit.

[2] Both PHY 131 and 132 must be taken to secure SQ credit.

[3] Each student must complete six hours of courses chosen from the computer science technical elective list and approved by the student's advisor. See an advisor for the approved listing.

Computer Systems Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester

CSE 200	Concepts of Computer Science *CS*	3
ECE 100	Introduction to Engineering Design *CS* or CSE 120 Digital Design Fundamentals (3)	3
ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles (3)	3
ENG 101	First-Year Composition	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
Total		16

Second Semester

CHM 114	General Chemistry for Engineers *SQ*	4
CSE 120	Digital Design Fundamentals or ECE 100 Introduction to Engineering Design *CS* (3)	3
CSE 210	Object-Oriented Design and Data Structures *CS*	3
ENG 102	First-Year Composition	3
MAT 271	Calculus with Analytic Geometry II *MA*	4
Total		17

Second Year

First Semester

CSE 225	Assembly Language Programming and Microprocessors (Motorola)	4
MAT 243	Discrete Mathematical Structures	3
MAT 272	Calculus with Analytic Geometry III *MA*	4
PHY 121	University Physics I: Mechanics *SQ*[1]	3
PHY 122	University Physics Laboratory I *SQ*[1]	1
Total		15

Second Semester

CSE 240	Introduction to Programming Languages	3
ECE 210	Engineering Mechanics I: Statics	3
MAT 274	Elementary Differential Equations *MA*	3

PHY	131	University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY	132	University Physics Laboratory II *SQ*[2]	1
HU/SB and awareness area course[3]			3
Total			16

Third Year

First Semester

CSE	310	Data Structures and Algorithms	3
CSE	330	Computer Organization and Architecture	3
CSE	360	Introduction to Software Engineering	3
ECE	300	Intermediate Engineering Design *L*	3
MAT	342	Linear Algebra	3
Total			15

Second Semester

CSE	340	Principles of Programming Languages	3
CSE	355	Introduction to Theoretical Computer Science	3
CSE	421	Microprocessor System Design I	4
ECE	380	Probability and Statistics for Engineering Problem Solving *CS*	3
HU/SB and awareness area course[3]			3
Total			16

Fourth Year

First Semester

CSE	422	Microprocessor System Design II	4
CSE	430	Operating Systems	3
ECE	201	Electrical Networks I	4
PHY	361	Introductory Modern Physics	3
HU/SB and awareness area course[3]			3
Total			17

Second Semester

CSE	423	Microcomputer System Hardware *L* or CSE 438 Systems Programming *L* (3)	3
ECE	334	Electronic Devices and Instrumentation	4
HU/SB and awareness area course[3]			3
Technical electives			6
Total			16

[1] Both PHY 121 and 122 must be taken to secure SQ credit.
[2] Both PHY 131 and 132 must be taken to secure SQ credit.
[3] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU and SB requirements.

COMPUTER SCIENCE AND ENGINEERING (CSE)

CSE 100 Principles of Programming with C++. (3)
fall, spring, summer
Principles of problem solving using C++, algorithm design, structured programming, fundamental algorithms and techniques, and computer systems concepts. Social and ethical responsibility. Lecture, lab. Prerequisite: MAT 170.
General Studies: CS

CSE 110 Principles of Programming with Java. (3)
fall, spring, summer
Concepts of problem solving using Java, algorithm design, structured programming, fundamental algorithms and techniques, and computer systems concepts. Social and ethical responsibility. Lecture, lab. Prerequisite: MAT 170.

CSE 120 Digital Design Fundamentals. (3)
fall, spring, summer
Number systems, conversion methods, binary and complement arithmetic, Boolean algebra, circuit minimization, ROMs, PLAs, flipflops, synchronous sequential circuits. Lecture, lab. Cross-listed as EEE 120. Credit is allowed for only CSE 120 or EEE 120. Prerequisite: computer literacy.

CSE 180 Computer Literacy. (3)
fall, spring, summer
Introduces personal computer operations and their place in society. Problem-solving approaches using databases, spreadsheets, and word processing. May be taken for credit on either Windows or Macintosh, but not both. Lecture, demonstration. Prerequisite: nonmajor.
General Studies: CS

CSE 181 Applied Problem Solving with Visual BASIC. (3)
fall, spring, summer
Introduces systematic definition of problems, solution formulation, and method validation. Requires computer solution using Visual BASIC for projects. Lecture, lab. Prerequisites: MAT 117; nonmajor.
General Studies: CS

CSE 185 Internet and the World Wide Web. (3)
fall and spring
Fundamental Internet concepts, World Wide Web browsing, publishing, searching, advanced Internet productivity tools.

CSE 200 Concepts of Computer Science. (3)
fall, spring, summer
Overview of algorithms, languages, computing systems, theory. Problem solving by programming with a high-level language (Java or other). Lecture, lab. Prerequisite: CSE 100 or 110 or one year of high school programming with Java or C++ or PASCAL.
General Studies: CS

CSE 210 Object-Oriented Design and Data Structures. (3)
fall, spring, summer
Object-oriented design, static and dynamic data structures (strings, stacks, queues, binary trees), recursion, searching, and sorting. Professional responsibility. Prerequisite: CSE 200.
General Studies: CS

CSE 225 Assembly Language Programming and Microprocessors (Motorola). (4)
fall, spring, summer
Assembly language programming, including input/output programming and exception/interrupt handling. Register-level computer organization, I/O interfaces, assemblers, and linkers. Motorola-based assignments. Lecture, lab. Cross-listed as EEE 225. Credit is allowed for only CSE 225 or EEE 225. Prerequisites: CSE 100 (or 110 or 200); CSE 120 or EEE 120.

CSE 226 Assembly Language Programming and Microprocessors (Intel). (4)
fall and spring
CPU/memory/peripheral device interfaces and programming. System buses, interrupts, serial and parallel I/O, DMA, coprocessors. Intel-based assignments. Lecture, lab. Cross-listed as EEE 226. Credit is allowed for only CSE 226 or EEE 226. Prerequisites: CSE 100 (or 110 or 200); CSE 120 or EEE 120.

CSE 240 Introduction to Programming Languages. (3)
fall, spring, summer
Introduces the procedural (C++), applicative (LISP), and declarative (Prolog) languages. Lecture, lab. Prerequisite: CSE 210.

CSE 310 Data Structures and Algorithms. (3)
fall, spring, summer
Advanced data structures and algorithms, including stacks, queues, trees (B, B+, AVL), and graphs. Searching for graphs, hashing, external sorting. Lecture, lab. Prerequisites: CSE 210; MAT 243.

CSE 330 Computer Organization and Architecture. (3)
fall and spring
Instruction set architecture, processor performance and design; datapath, control (hardwired, microprogrammed), pipelining, input/output. Memory organization with cache, virtual memory. Prerequisite: CSE 225 (or 226) or EEE 225 (or 226).

CSE 340 Principles of Programming Languages. (3)
fall and spring
Introduces language design and implementation. Parallel, machine-dependent and declarative features; type theory; specification, recog-

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

nition, translation, run-time management. Prerequisites: CSE 225 (or 226) or EEE 225 (or 226); CSE 240, 310.

CSE 355 Introduction to Theoretical Computer Science. (3)
fall and spring
Introduces formal language theory and automata, Turing machines, decidability/undecidability, recursive function theory, and complexity theory. Prerequisite: CSE 310.

CSE 360 Introduction to Software Engineering. (3)
fall, spring, summer
Software life cycle models; project management, team development environments and methodologies; software architectures; quality assurance and standards; legal, ethical issues. Prerequisites: CSE 210, 240.

CSE 408 Multimedia Information Systems. (3)
fall
Design, use, and applications of multimedia systems. Introduces acquisition, compression, storage, retrieval, and presentation of data from different media such as images, text, voice, and alphanumeric. Prerequisite: CSE 310.

CSE 412 Database Management. (3)
fall and spring
Introduces DBMS concepts. Data models and languages. Relational database theory. Database security/integrity and concurrency. Prerequisite: CSE 310.

CSE 420 Computer Architecture I. (3)
once a year
Computer architecture. Performance versus cost tradeoffs. Instruction set design. Basic processor implementation and pipelining. Prerequisite: CSE 330.

CSE 421 Microprocessor System Design I. (4)
fall and spring
Assembly language programming and logical hardware design of systems using 8-bit microprocessors and microcontrollers. Fundamental concepts of digital system design. Reliability and social, legal implications. Lecture, lab. Prerequisite: CSE 225 or EEE 225.

CSE 422 Microprocessor System Design II. (4)
fall and spring
Design of microcomputer systems using contemporary logic and microcomputer system components. Requires assembly language programming. Prerequisite: CSE 421.

CSE 423 Microcomputer System Hardware. (3)
once a year
Information and techniques presented in CSE 422 are used to develop the hardware design of a multiprocessor, multiprogramming, microprocessor-based system. Prerequisite: CSE 422.
General Studies: L

CSE 428 Computer-Aided Processes. (3)
selected semesters
Hardware and software considerations for computerized manufacturing systems. Specific concentration on automatic inspection, numerical control, robotics, and integrated manufacturing systems. Prerequisite: CSE 330.

CSE 430 Operating Systems. (3)
fall and spring
Operating system structure and services, processor scheduling, concurrent processes, synchronization techniques, memory management, virtual memory, input/output, storage management, and file systems. Prerequisites: CSE 330, 340.

CSE 432 Operating System Internals. (3)
fall
IPC, exception and interrupt processing, memory and thread management, user-level device drivers, and OS servers in a modern microkernel-based OS. Prerequisite: CSE 430.

CSE 434 Computer Networks. (3)
fall and spring
Cryptography fundamentals; data compression; error handling; flow control; multihop routing; network protocol algorithms; network reliability, timing, security; physical layer basics. Prerequisite: CSE 330.

CSE 438 Systems Programming. (3)
once a year
Design and implementation of systems programs, including text editors, file utilities, monitors, assemblers, relocating linking loaders, I/O handlers, and schedulers. Prerequisite: CSE 421 or instructor approval.
General Studies: L

CSE 440 Compiler Construction I. (3)
once a year
Introduces programming language implementation. Implementation strategies such as compilation, interpretation, and translation. Major compilation phases such as lexical analysis, semantic analysis, optimization, and code generation. Prerequisites: CSE 340, 355.

CSE 445 Distributed Computing with Java and CORBA. (3)
fall and spring
Frameworks for distributed software components. Foundations of client-server computing and architectures for distributed object systems. Dynamic discovery and invocation. Lecture, projects. Prerequisite: CSE 360 or instructor approval.

CSE 446 Client-Server User Interfaces. (3)
spring
Client-server model and its use in creating and managing window interfaces. Toolkits and libraries including X11, Microsoft Foundation Classes, and Java Abstract Window Toolkit. Lecture, projects. Prerequisite: CSE 310 or instructor approval.

CSE 450 Design and Analysis of Algorithms. (3)
fall and spring
Design and analysis of computer algorithms using analytical and empirical methods; complexity measures, design methodologies, and survey of important algorithms. Prerequisite: CSE 310.

CSE 457 Theory of Formal Languages. (3)
once a year
Theory of grammar, methods of syntactic analysis and specification, types of artificial languages, relationship between formal languages, and automata. Prerequisite: CSE 355.

CSE 459 Logic for Computing Scientists. (3)
selected semesters
Propositional logic, syntax and semantics, proof theory versus model theory, soundness, consistency and completeness, first order logic, logical theories, automated theorem proving, ground resolution, pattern matching unification and resolution, Dijkstras logic, proof obligations, and program proving. Prerequisite: CSE 355.

CSE 460 Software Analysis and Design. (3)
fall and spring
Requirements analysis and design; architecture and patterns; representations of software; formal methods; component-based development. Lecture, projects. Prerequisite: CSE 360.

CSE 461 Software Engineering Project I. (3)
fall and spring
First of two-course software team-development sequence. Planning, management, design, and implementation using object-oriented technology, CASE tools, CMM-level-5 guidelines. Lecture, lab, oral and written communications. Prerequisite: CSE 360.

CSE 462 Software Engineering Project II. (3)
fall and spring
Second of two-course software team-development sequence. Software evolution, maintenance, reengineering, reverse engineering, component-based development, and outsourcing. Lecture, lab, oral and written communications. Prerequisite: CSE 461.

CSE 470 Computer Graphics. (3)
fall and spring
Display devices, data structures, transformations, interactive graphics, 3-dimensional graphics, and hidden line problem. Prerequisites: CSE 310; MAT 342.

CSE 471 Introduction to Artificial Intelligence. (3)
fall and spring
State space search, heuristic search, games, knowledge representation techniques, expert systems, and automated reasoning. Prerequisites: CSE 240, 310.

CSE 473 Nonprocedural Programming Languages. (3)
selected semesters
Functional and logic programming using languages like Lucid and Prolog. Typical applications would be a Screen Editor and an Expert System. Prerequisite: CSE 355.

CSE 476 Introduction to Natural Language Processing. (3)
selected semesters
Principles of computational linguistics, formal syntax, and semantics, as applied to the design of software with natural (human) language I/O. Prerequisite: CSE 310 or instructor approval.

CSE 477 Introduction to Computer-Aided Geometric Design. (3)
once a year
Introduces parametric curves and surfaces, Bezier and B-spline interpolation, and approximation techniques. Prerequisites: CSE 210, 470; MAT 342.

CSE 484 Internship. (1–12)
selected semesters

CSE 507 Virtual Reality Systems. (3)
selected semesters
Computer generated 3D environments, simulation of reality, spatial presence of virtual objects, technologies of immersion, tracking systems. Lecture, lab. Prerequisite: CSE 408 or 470 or 508 or instructor approval.

CSE 508 Digital Image Processing. (3)
once a year
Digital image fundamentals, image transforms, image enhancement and restoration techniques, image encoding, and segmentation methods. Prerequisite: EEE 303 or instructor approval.

CSE 510 Database Management System Implementation. (3)
once a year
Implementation of database systems. Data storage, indexing, querying, and retrieval. Query optimization and execution, concurrency control, and transaction management. Prerequisite: CSE 412.

CSE 512 Distributed Database Systems. (3)
once a year
Distributed database design, query processing, and transaction processing. Distributed database architectures and interoperability. Emerging technology. Prerequisite: CSE 412.

CSE 513 Rules in Database Systems. (3)
selected semesters
Declarative and active rules. Logic as a data model. Evaluation and query optimization. Triggers and ECA rules. Current research topics. Prerequisite: CSE 412.

CSE 514 Object-Oriented Database Systems. (3)
selected semesters
Object-oriented data modeling, definition, manipulation. Identity and inheritance. Query languages. Schema evolution. Versioning. Distributed object management. Extended relational systems. Prerequisite: CSE 412.

CSE 515 Multimedia and Web Databases. (3)
spring
Data models for multimedia and Web data; query processing and optimization for inexact retrieval; advanced indexing, clustering, and search techniques. Prerequisites: CSE 408, 412.

CSE 517 Hardware Design Languages. (3)
once a year
Introduces hardware design languages. Modeling concepts for specification, simulation, and synthesis. Prerequisite: CSE 423 or EEE 425 or instructor approval.

CSE 518 Synthesis with Hardware Design Languages. (3)
selected semesters
Modeling VLSI design in hardware design languages for synthesis. Transformation of language-based designs to physical layout. Application of synthesis tools. Prerequisite: CSE 517.

CSE 520 Computer Architecture II. (3)
fall
Computer architecture description languages, computer arithmetic, memory-hierarchy design, parallel, vector, multiprocessors, and input/output. Prerequisites: CSE 420, 430.

CSE 521 Microprocessor Applications. (4)
selected semesters
Microprocessor technology and its application to the design of practical digital systems. Hardware, assembly language programming, and interfacing of microprocessor-based systems. Lecture, lab. Prerequisite: CSE 421.

CSE 523 Microcomputer Systems Software. (3)
selected semesters
Developing system software for a multiprocessor, multiprogramming, microprocessor-based system using information and techniques presented in CSE 421, 422. Prerequisite: CSE 422.

CSE 526 Parallel Processing. (3)
selected semesters
Real and apparent concurrency. Hardware organization of multiprocessors, multiple computer systems, scientific attached processors, and other parallel systems. Prerequisite: CSE 330 or 423.

CSE 531 Distributed and Multiprocessor Operating Systems. (3)
once a year
Distributed systems architecture, remote file access, message-based systems, object-based systems, client/server paradigms, distributed algorithms, replication and consistency, and multiprocessor operating systems. Prerequisite: CSE 432 or instructor approval.

CSE 532 Advanced Operating System Internals. (3)
selected semesters
Memory, processor, process and communication management, and concurrency control in the Windows NT multiprocessor and distributed operating system kernels and servers. Prerequisites: CSE 432, 531 (or 536).

CSE 534 Advanced Computer Networks. (3)
fall and spring
Advanced network protocols and infrastructure, applications of high-performance networks to distributed systems, high-performance computing and multimedia domains, special features of networks. Prerequisite: CSE 434.

CSE 536 Advanced Operating Systems. (3)
spring
Protection and file systems. Communication, processes, synchronization, naming, fault tolerance, security, data replication, and coherence in distributed systems. Real-time systems. Prerequisite: CSE 430.

CSE 539 Applied Cryptography. (3)
spring
Use of cryptography for secure protocols over networked systems, including signatures, certificates, timestamps, electrons, digital cash, and other multiparty coordination. Prerequisite: CSE 310 or instructor approval.

CSE 540 Compiler Construction II. (3)
selected semesters
Formal parsing strategies, optimization techniques, code generation, extensibility and transportability considerations, and recent developments. Prerequisite: CSE 440.

CSE 545 Programming Language Design. (3)
selected semesters
Language constructs, extensibility and abstractions, and runtime support. Language design process. Prerequisite: CSE 440.

CSE 550 Combinatorial Algorithms and Intractability. (3)
once a year
Combinatorial algorithms, nondeterministic algorithms, classes P and NP, NP-hard and NP-complete problems, and intractability. Design techniques for fast combinatorial algorithms. Prerequisite: CSE 450.

CSE 555 Theory of Computation. (3)
once a year
Rigorous treatment of regular languages, context-free languages, Turing machines and decidability, reducibility, and other advanced topics in computability theory. Prerequisite: CSE 355 or instructor approval.

CSE 562 Software Process Automation. (3)
once a year
Representing the software process; creating a measured and structured working environment; using, constructing, and adapting component-based tools. Prerequisite: CSE 360.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

CSE 563 Software Requirements and Specification. (3)
selected semesters
Examines the definitional stage of software development; analysis of specification representations, formal methods, and techniques emphasizing important application issues. Prerequisite: CSE 460.

CSE 564 Software Design. (3)
once a year
Examines software design issues and techniques. Includes a survey of design representations and a comparison of design methods. Prerequisite: CSE 460.

CSE 565 Software Verification, Validation, and Testing. (3)
once a year
Test planning, requirements-based and code-based testing techniques, tools, reliability models, and statistical testing. Prerequisite: CSE 460.

CSE 566 Software Project, Process, and Quality Management. (3)
once a year
Project management, risk management, configuration management, quality management, and simulated project management experiences. Prerequisite: CSE 360.

CSE 570 Advanced Computer Graphics I. (3)
once a year
Hidden surface algorithms, lighting models, and shading techniques. User interface design. Animation techniques. Fractals and stochastic models. Raster algorithms. Prerequisite: CSE 470.

CSE 571 Artificial Intelligence. (3)
once a year
Definitions of intelligence, computer problem solving, game playing, pattern recognition, theorem proving, and semantic information processing; evolutionary systems; heuristic programming. Prerequisite: CSE 471.

CSE 573 Advanced Computer Graphics II. (3)
once a year
Modeling of natural phenomena: terrain, clouds, fire, water, and trees. Particle systems, deformation of solids, antialiasing, and volume visualization. Lecture, lab. Prerequisite: CSE 470.

CSE 574 Planning and Learning Methods in AI. (3)
once a year
Reasoning about time and action, plan synthesis and execution, improving planning performance, applications to manufacturing intelligent agents. Prerequisite: CSE 471 (or its equivalent).

CSE 576 Topics in Natural Language Processing. (3)
selected semesters
Comparative parsing strategies, scoping and reference problems, nonfirst-order logical semantic representations, and discourse structure. Prerequisite: CSE 476 or instructor approval.

CSE 577 Advanced Computer-Aided Geometric Design I. (3)
once a year
General interpolation; review of curve interpolation and approximation; spline curves; visual smoothness of curves; parameterization of curves; introduces surface interpolation and approximation. Prerequisites: both CSE 470 and 477 or only instructor approval.

CSE 578 Advanced Computer-Aided Geometric Design II. (3)
selected semesters
Coons patches and Bezier patches; triangular patches; arbitrarily located data methods; geometry processing of surfaces; higher dimensional surfaces. Prerequisites: both CSE 470 and 477 or only instructor approval.

CSE 579 NURBS: Nonuniform Rational B-Splines. (3)
selected semesters
Projective geometry, NURBS-based modeling, basic theory of conics and rational Bezier curves, rational B-splines, surfaces, rational surfaces, stereographic maps, quadrics, IGES data specification. Prerequisites: CSE 470, 477.

CSE 593 Applied Project. (1–12)
selected semesters

CSE 598 Special Topics. (1–4)
selected semesters

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

Department of Electrical Engineering

www.eas.asu.edu/ee
480/965-3424
ENGRC 552

Stephen M. Goodnick, Chair

Regents’ Professors: Balanis, Ferry, Heydt

Professors: Backus, Crouch, El-Ghazaly, Goodnick, Gorur, Higgins, Hoppensteadt, Hui, Karady, Kiaei, Kozicki, Lai, Palais, Pan, Roedel, Schroder, Shen, Si, Spanias, Tao, Thornton, Y. Zhang

Associate Professors: Aberle, Allee, Bird, Chakrabarti, Cochran, Diaz, El-Sharawy, Greeneich, Grondin, Holbert, Karam, Kim, Morrell, Rodriguez, Skromme, Tsakalis, Tylavsky

Assistant Professors: Ayyanar, Duman, Joo, Papandreou-Suppappola, Reisslein, Tepedelenlioglu, Vasileska, Yazdi, J. Zhang

The professional activities of electrical engineers directly affect the everyday lives of most of the world’s population. They are responsible for the design and development of radio and television transmitters and receivers, telephone networks and switching systems, computer systems, and electric power generation and distribution. Within the broad scope of these systems, the electrical engineer is concerned with a challenging and diverse array of design and development problems.

Electrical engineers design minuscule semiconductor integrated circuits that contain many thousands of elementary devices. These engineers design systems for automatically controlling mechanical devices and a variety of processes. These engineers are responsible for the design of satellite communication links as well as patient monitoring systems for hospitals. The development of the microprocessor has expanded the opportunities for electrical engineers to improve the design of familiar products since these devices are now incorporated in automobiles, consumer and office products, entertainment systems, and a vast variety of test and measurement instruments and machine tools.

Students who earn a B.S.E. degree in Electrical Engineering will be involved in a variety of electrical and electronic problems in the course of their careers. To ensure the necessary breadth of knowledge, the Electrical Engineering curriculum includes basic (core) engineering courses and courses in networks and electronic circuits, electromagnetic fields and waves, microprocessors, communication and control systems, solid-state electronics, electrical power systems, and other specialty courses.

ELECTRICAL ENGINEERING—B.S.E.

The goal of the Electrical Engineering undergraduate program is to prepare the graduates for entry-level positions as electrical engineers for the broad range of opportunities available in industrial, commercial, and governmental organizations, and to prepare the graduates for continued learning experiences either in a formal graduate program or in continuing education applications.

This goal is achieved through a curriculum designed to accomplish five objectives:

1. We will maintain a modern curriculum, which adapts to changes in technology and society.
2. Our program will foster a diverse student population entering and successfully graduating, and our graduates will function well in a diverse work force.
3. Our graduates will be self-motivated, creative people who can succeed in environments where technical innovation is important.
4. Our graduates will be sought after by our constituent industries and respected graduate programs.
5. Our graduates will be technically competent.

The curriculum in Electrical Engineering builds upon the base provided by the engineering core. Beyond the engineering core, the curriculum includes a number of required electrical engineering and technical elective courses. Approved technical elective courses serve to provide students with an opportunity either to broaden their background in electrical engineering or to study, in greater depth, technical subjects in which they have special interests. Successful completion of the curriculum leaves the student prepared to embark on a career in electrical engineering or to pursue advanced education in graduate school.

The engineering design experience is structured around four backbone courses employing engineering teams: ECE 100 Introduction to Engineering Design (freshman year), ECE 300 Intermediate Engineering Design (junior year), EEE 488 Senior Design Laboratory I, and EEE 489 Senior Design Laboratory II. The integrated experience is strengthened with required courses: EEE 120 Digital Design Fundamentals, EEE 225 Assembly Language Programming and Microprocessors (Motorola), EEE 226 Assembly Language Programming and Microprocessors (Intel), EEE 303 Signals and Systems, and EEE 360 Energy Conversion and Transport. Students focus on design pertaining to specific electrical engineering areas in their senior technical electives before the culminating, capstone design experience in EEE 488 and EEE 489.

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Electrical Engineering. A minimum of 50 upper-division semester hours is required.

GRADUATION REQUIREMENTS

A student must earn a grade of "C" or higher in the mathematics and physics courses listed in the program of study. Each mathematics and physics course in the program of study must be completed with a "C" or higher before enrolling in any course that requires that mathematics or physics course as a prerequisite. The student must also have an overall GPA of at least 2.00 for the following group of courses: CSE 100; ECE 201, 300, 334, 352; all courses with an EEE prefix; and all other courses used as technical electives.

In addition to fulfilling school and major requirements, students must satisfy all university graduation requirements. See "University Graduation Requirements," page 79.

COURSE REQUIREMENTS

The specific course requirements for the B.S.E. degree in Electrical Engineering follow.

First-Year Composition[1]

Choose among the course combinations below 6
- ENG 101 First-Year Composition (3)
- ENG 102 First-Year Composition (3)

—or—

- ENG 105 Advanced First-Year Composition (3)
- Elective (requires departmental approval) (3)

—or—

- ENG 107 English for Foreign Students (3)
- ENG 108 English for Foreign Students (3)

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
HU courses		6–9
SB course(s)		3–6
Minimum total		15

Literacy and Critical Inquiry

ECE 300	Intermediate Engineering Design *L*	3
EEE 488	Senior Design Laboratory I	2
EEE 489	Senior Design Laboratory II	2
Total		7

Natural Sciences/Basic Sciences

CHM 114	General Chemistry for Engineers *SQ* or CHM 116 General Chemistry *SQ* (4)	4
PHY 121	University Physics I: Mechanics *SQ*[1, 2]	3
PHY 122	University Physics Laboratory I *SQ*[1, 2]	1
PHY 131	University Physics II: Electricity and Magnetism *SQ*[1, 3]	3
PHY 132	University Physics Laboratory II *SQ*[1, 3]	1
PHY 241	University Physics III[1]	3
Total		15

Mathematical Studies

ECE 100	Introduction to Engineering Design *CS*	3
MAT 270	Calculus with Analytic Geometry I *MA*[1]	4
MAT 271	Calculus with Analytic Geometry II *MA*[1]	4
MAT 272	Calculus with Analytic Geometry III *MA*[1]	4
MAT 274	Elementary Differential Equations *MA*[1]	3
MAT 342	Linear Algebra[1]	3

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

MAT	362	Advanced Mathematics for Engineers and Scientists I[1]	3
Total			24
General Studies/school requirements total			61

Engineering Core

ECE	201	Electrical Networks I	4
ECE	214	Engineering Mechanics	4
ECE	334	Electronic Devices and Instrumentation	4
ECE	352	Properties of Electronic Materials	4
EEE	225	Assembly Language Programming and Microprocessors (Motorola) or EEE 226 Assembly Language Programming and Microprocessors (Intel) (4)	4
Total			20

[1] A minimum grade of "C" is required.

[2] Both PHY 121 and 122 must be taken to secure SQ credit.

[3] Both PHY 131 and 132 must be taken to secure SQ credit.

Electrical Engineering Major

The following courses are required to fulfill the Electrical Engineering major:

CSE	100	Principles of Programming with C++ *CS**	3
EEE	120	Digital Design Fundamentals	3
EEE	302	Electrical Networks II	3
EEE	303	Signals and Systems	3
EEE	340	Electromagnetic Engineering I	4
EEE	350	Random Signal Analysis	3
EEE	360	Energy Conversion and Transport	4
Total			23

* CSE 110 Principles of Programming with Java (3) can be substituted for CSE 100 with Department of Electrical Engineering approval.

The program in Electrical Engineering requires a total of 18 semester hours of technical electives. With department approval, a maximum of two technical electives may be taken outside electrical engineering. Qualified students may choose from approved courses in business, engineering, mathematics, and the sciences at or above the 300-level, including graduate courses. Students must have a GPA of not less than 3.00 and approval of the dean to enroll in EEE graduate-level courses. To ensure breadth of knowledge, students *must* select courses from at least three of the following seven areas. In addition, to ensure depth, two courses must be taken in one area.

Communications and Signal Processing

EEE	407	Digital Signal Processing	4
EEE	455	Communication Systems	4
EEE	459	Communication Networks	3

Computer Engineering

CSE	330	Computer Organization and Architecture	3
CSE	420	Computer Architecture I	3
CSE	421	Microprocessor System Design I	4
CSE	422	Microprocessor System Design II	4

Controls

EEE	480	Feedback Systems	4
EEE	482	Introduction to State Space Methods	3

Electromagnetics

EEE	440	Electromagnetic Engineering II	4
EEE	443	Antennas for Wireless Communications	3
EEE	445	Microwaves	4
EEE	448	Fiber Optics	4

Electronic Circuits

EEE	405	Filter Design	3
EEE	425	Digital Systems and Circuits	4
EEE	433	Analog Integrated Circuits	4

Power Systems

EEE	460	Nuclear Concepts for the 21st Century	3
EEE	463	Electrical Power Plant	3
EEE	470	Electric Power Devices	3
EEE	471	Power System Analysis	3
EEE	473	Electrical Machinery	3

Solid-State Electronics

EEE	434	Quantum Mechanics for Engineers	3
EEE	435	Microelectronics	3
EEE	436	Fundamentals of Solid-State Devices	3
EEE	437	Optoelectronics	3
EEE	439	Semiconductor Facilities and Cleanroom Practices	3

Electrical Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM	114	General Chemistry for Engineers *SQ* or CHM 116 General Chemistry *SQ* (4)	4
ECE	100	Introduction to Engineering Design[1] *CS* or EEE 120 Digital Design Fundamentals (3)	3
ENG	101	First-Year Composition	3
MAT	270	Calculus with Analytic Geometry I *MA*	4
Total			14

Second Semester

EEE	120	Digital Design Fundamentals[1] or ECE 100 Introduction to Engineering Design *CS* (3)	3
ENG	102	First-Year Composition	3
MAT	271	Calculus with Analytic Geometry II *MA*	4
PHY	121	University Physics I: Mechanics *SQ*[2]	3
PHY	122	University Physics Laboratory I *SQ*[2]	1
Total			14

Second Year

First Semester

CSE	100	Principles of Programming with C++ *CS*[3]	3
ECN	111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
MAT	272	Calculus with Analytic Geometry III *MA*	4
MAT	274	Elementary Differential Equations *MA*	3
PHY	131	University Physics II: Electricity and Magnetism *SQ*[4]	3
PHY	132	University Physics Laboratory II *SQ*[4]	1
Total			17

Second Semester

ECE	201	Electrical Networks I	4
EEE	225	Assembly Language Programming and Microprocessors (Motorola) or EEE 226 Assembly Language Programming and Microprocessors (Intel) (4)	4
MAT	362	Advanced Mathematics for Engineers and Scientists I	3

PHY 241 University Physics III	3
HU/SB and awareness area course[5]	3
Total	17

Third Year

First Semester

ECE 334 Electronic Devices and Instrumentation	4
EEE 302 Electrical Networks II	3
EEE 340 Electromagnetic Engineering I	4
MAT 342 Linear Algebra	3
HU/SB and awareness area course[5]	3
Total	17

Second Semester

ECE 300 Intermediate Engineering Design *L*	3
ECE 352 Properties of Electronic Materials	4
EEE 303 Signals and Systems	3
EEE 360 Energy Conversion and Transport	4
HU/SB and awareness area course[5]	3
Total	17

Fourth Year

First Semester

ECE 214 Engineering Mechanics	4
EEE 350 Random Signal Analysis	3
EEE 488 Senior Design Laboratory I *L*	2
Technical electives	7
Total	16

Second Semester

EEE 489 Senior Design Laboratory II *L*	2
HU/SB and awareness area course[5]	3
Technical electives	11
Total	16

1 Both ECE 100 and EEE 120 are required.

2 Both PHY 121 and 122 must be taken to secure SQ credit.

3 CSE 110 Principles of Programming with Java (3) can be substituted for CSE 100 with Department of Electrical Engineering approval.

4 Both PHY 131 and 132 must be taken to secure SQ credit.

5 Engineering students may not use aerospace studies (AES) or military science (MIS) courses to satisfy HU or SB requirements.

ELECTRICAL ENGINEERING (EEE)

EEE 120 Digital Design Fundamentals. (3)
fall, spring, summer
Number systems, conversion methods, binary and complement arithmetic, Boolean algebra, circuit minimization, ROMs, PLAs, flipflops, synchronous sequential circuits. Lecture, lab. Cross-listed as CSE 120. Credit is allowed for only CSE 120 or EEE 120. Prerequisite: computer literacy.

EEE 225 Assembly Language Programming and Microprocessors (Motorola). (4)
fall, spring, summer
Assembly language programming, including input/output programming and exception/interrupt handling. Register-level computer organization, I/O interfaces, assemblers, and linkers. Motorola-based assignments. Lecture, lab. Cross-listed as CSE 225. Credit is allowed for only CSE 225 or EEE 225. Prerequisites: CSE 100 (or 110 or 200); CSE 120 or EEE 120.

EEE 226 Assembly Language Programming and Microprocessors (Intel). (4)
fall and spring
CPU/memory/peripheral device interfaces and programming. System buses, interrupts, serial and parallel I/O, DMA, coprocessors. Intel-based assignments. Lecture, lab. Cross-listed as CSE 226. Credit is allowed for only CSE 226 or EEE 226. Prerequisites: CSE 100 (or 110 or 200); CSE 120 or EEE 120.

EEE 302 Electrical Networks II. (3)
fall, spring, summer
Analyzes linear and nonlinear networks. Analytical and numerical methods. Prerequisite: ECE 201. Pre- or corequisite: MAT 362.

EEE 303 Signals and Systems. (3)
fall, spring, summer
Introduces continuous and discrete time signal and system analysis, linear systems, Fourier, and z-transforms. Prerequisite: EEE 302. Pre- or corequisite: MAT 342.

EEE 340 Electromagnetic Engineering I. (4)
fall, spring, summer
Static and time varying vector fields; boundary value problems; dielectric and magnetic materials; Maxwell's equations; boundary conditions. Prerequisites: MAT 362; PHY 131, 132.

EEE 350 Random Signal Analysis. (3)
fall and spring
Probabilistic and statistical analysis as applied to electrical signals and systems. Pre- or corequisite: EEE 303.

EEE 360 Energy Conversion and Transport. (4)
fall and spring
Three-phase circuits. Energy supply systems. Magnetic circuit analysis, synchronous generators, transformers, induction and DC machines. Transmission line modeling and design. Lecture, lab. Prerequisite: EEE 302.

EEE 405 Filter Design. (3)
fall
Principles of active and passive analog filter design, frequency domain approximations, sensitivity and synthesis of filters. Prerequisite: EEE 303.

EEE 407 Digital Signal Processing. (4)
fall and spring
Time and frequency domain analysis, difference equations, z-transform, FIR and IIR digital filter design, discrete Fourier transform, FFT, and random sequences. Lecture, lab. Prerequisites: EEE 303; MAT 342.

EEE 425 Digital Systems and Circuits. (4)
fall and spring
Digital logic gate analysis and design. Propagation delay times, fan out, power dissipation, noise margins. Design of MOS and bipolar logic families, including NMOS, CMOS, standard and advanced TTL, ECL, and BiCMOS. Inverter, combinational and sequential logic circuit design, MOS memories, VLSI circuits. Computer simulations using PSPICE. Lecture, lab. Prerequisite: ECE 334.

EEE 433 Analog Integrated Circuits. (4)
spring
Analysis, design, and applications of modern analog circuits using integrated bipolar and field effect transistor technologies. Lecture, lab. Prerequisite: ECE 334.

EEE 434 Quantum Mechanics for Engineers. (3)
fall
Angular momentum, wave packets, Schroedinger wave equation, probability, problems in one dimension, principles of wave mechanics, scattering, tunneling, central forces, angular momentum, hydrogen atom, perturbation theory, variational techniques. Prerequisites: ECE 352; EEE 340.

EEE 435 Microelectronics. (3)
spring
Introduces basic CMOS processing and fabrication tools. Covers the fundamentals of thermal oxidation, CVD, implantation, diffusion, and process integration. Internet lecture, internet or on-campus lab. Fee. Pre- or corequisite: EEE 436.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

EEE 436 Fundamentals of Solid-State Devices. (3)
fall and spring
Semiconductor fundamentals, pn junctions, metal-semiconductor contacts, metal-oxide-semiconductor capacitors and field-effect transistors, bipolar junction transistors. Prerequisite: ECE 352.

EEE 437 Optoelectronics. (3)
selected semesters
Basic operating principles of various types of optoelectronic devices which play important roles in commercial and communication electronics; light-emitting diodes, injection lasers, and photodetectors. Prerequisite: EEE 436.

EEE 439 Semiconductor Facilities and Cleanroom Practices. (3)
fall
Microcontamination, controlled environments, cleanroom layout and systems, modeling, codes and legislation, ultrapure water, production materials, personnel and operations, hazard management, advanced concepts. Prerequisite: EEE 435 or instructor approval.

EEE 440 Electromagnetic Engineering II. (4)
spring
Second half of an introductory course in electromagnetic theory and its application in electrical engineering. Analytical and numerical solution of boundary value problems. Advanced transmission lines; waveguides; antennas; radiation and scattering. Lecture, lab. Prerequisite: EEE 340 (or its equivalent).

EEE 443 Antennas for Wireless Communications. (3)
spring
Fundamental parameters; radiation integrals; wireless systems; wire, loop, and microstrip antennas; antenna arrays; smart antennas; ground effects; multipath. Prerequisite: EEE 340.

EEE 445 Microwaves. (4)
fall
Waveguides; circuit theory for waveguiding systems; microwave devices, systems, and energy sources; striplines and microstrips; impedance matching transformers; measurements. Lecture, lab. Prerequisite: EEE 340.

EEE 448 Fiber Optics. (4)
fall
Principles of fiber-optic communications. Lecture, lab. Prerequisites: EEE 303, 340.

EEE 455 Communication Systems. (4)
fall and spring
Signal analysis techniques applied to the operation of electrical communication systems. Introduction to and overview of modern digital and analog communications. Lecture, lab. Prerequisite: EEE 350.

EEE 459 Communication Networks. (3)
spring
Fundamentals of communication networks. Study of Seven-Layer OSI model. Focus on functionality and performance of protocols used in communication networks. Prerequisite: EEE 350.

EEE 460 Nuclear Concepts for the 21st Century. (3)
spring
Radiation interactions, damage, dose, and instrumentation. Cosmic rays, satellite effects; soft errors; transmutation doping. Fission reactors, nuclear power. TMI, Chernobyl. Radioactive waste. Prerequisite: PHY 241 or 361.

EEE 463 Electrical Power Plant. (3)
fall
Nuclear, fossil, and solar energy sources. Analysis and design of steam supply systems, electrical generating systems, and auxiliary systems. Power plant efficiency and operation. Prerequisites: ECE 201, 340 (or PHY 241).

EEE 470 Electric Power Devices. (3)
fall
Analyzes devices used for short circuit protection, including circuit breakers, relays, and current and voltage transducers. Protection against switching and lightning over voltages. Insulation coordination. Prerequisite: EEE 360.

EEE 471 Power System Analysis. (3)
spring
Review of transmission line parameter calculation. Zero sequence impedance, symmetrical components for fault analysis, short circuit calculation, review of power flow analysis, power system stability, and power system control concepts. Prerequisite: EEE 360.

EEE 473 Electrical Machinery. (3)
fall
Operating principles, constructional details, and design aspects of conventional DC and AC machines, transformers and machines used in computer disc drives, printers, wrist watches, and automobiles. Prerequisite: EEE 360.

EEE 480 Feedback Systems. (4)
fall and spring
Analysis and design of linear feedback systems. Frequency response and root locus techniques, series compensation, and state variable feedback. Lecture, lab. Prerequisite: EEE 303.

EEE 482 Introduction to State Space Methods. (3)
fall
Discrete and continuous systems in state space form controllability, stability, and pole placement. Observability and observers. Pre- or corequisite: EEE 480.

EEE 488 Senior Design Laboratory I. (2)
fall and spring
Capstone senior project. Design process: research, concept, feasibility, simulation, specifications, benchmarking, and proposal generation. Technical communications and team skills enrichment. Lecture, lab. Prerequisites: ECE 300, 334; EEE 303, 340; senior status. Pre- or corequisite: ECE 352; EEE 360.
General Studies: L (if credit also earned in EEE 489)

EEE 489 Senior Design Laboratory II. (2)
fall and spring
Capstone senior project. Implement, evaluate, and document EEE 488 design. Social, economic, and safety considerations. Technical communications and team skills enrichment. Lecture, lab. Prerequisite: EEE 488 in the immediately preceding semester.
General Studies: L (if credit also earned in EEE 488)

EEE 506 Digital Spectral Analysis. (3)
spring
Principles and applications of digital spectral analysis, least squares, random sequences, parametric, and nonparametric methods for spectral estimation. Prerequisites: EEE 407, 554.

EEE 507 Multidimensional Signal Processing. (3)
fall
Processing and representation of multidimensional signals. Design of systems for processing multidimensional data. Introduces image and array processing issues. Prerequisite: EEE 407 or instructor approval.

EEE 508 Digital Image Processing and Compression. (3)
spring
Fundamentals of digital image perception, representation, processing, and compression. Emphasizes image coding techniques. Signals include still pictures and motion video. Prerequisites: EEE 350 and 407 (or their equivalents).

EEE 511 Artificial Neural Computation Systems. (3)
selected semesters
Networks for computation, learning function representations from data, learning algorithms and analysis, function approximation and information representation by networks, applications in control systems and signal analysis. Prerequisite: instructor approval.

EEE 523 Advanced Analog Integrated Circuits. (3)
fall
Analysis and design of analog integrated circuits: analog circuit blocks, reference circuits, operational-amplifier circuits, feedback, and nonlinear circuits. Prerequisite: EEE 433 (or its equivalent).

EEE 524 Communication Transceiver Circuits Design. (3)
selected semesters
Communication transceivers and radio frequency system design; fundamentals of transceivers circuits; RF, IF, mixers, filters, frequency synthesizers, receivers, CAD tools, and lab work on IC design stations. Lecture, lab. Prerequisites: EEE 433 and 455 (or their equivalents). Pre- or corequisite: EEE 523.

EEE 525 VLSI Design. (3)
fall and spring
Analysis and design of Very Large Scale Integrated (VLSI) circuits. Physics of small devices, fabrication, regular structures, and system timing. Open only to graduate students.

EEE 526 VLSI Architectures. (3)
fall
Special-purpose architectures for signal processing. Design of array processor systems at the system level and processor level. High-level synthesis. Prerequisites: both CSE 330 and EEE 407 or only instructor approval.

EEE 527 Analog to Digital Converters. (3)
fall
Detailed introduction to the design of Nyquist rate, CMOS analog to digital converters. Prerequisite: EEE 523.

EEE 530 Advanced Silicon Processing. (3)
spring
Thin films, CVD, oxidation, diffusion, ion-implantation for VLSI, metallization, silicides, advanced lithography, dry etching, rapid thermal processing. Pre- or corequisite: EEE 435.

EEE 531 Semiconductor Device Theory I. (3)
fall
Transport and recombination theory, pn and Schottky barrier diodes, bipolar and junction field-effect transistors, and MOS capacitors and transistors. Prerequisite: EEE 436 (or its equivalent).

EEE 532 Semiconductor Device Theory II. (3)
spring
Advanced MOSFETs, charge-coupled devices, solar cells, photodetectors, light-emitting diodes, microwave devices, and modulation-doped structures. Prerequisite: EEE 531.

EEE 533 Semiconductor Process/Device Simulation. (3)
fall
Process simulation concepts, oxidation, ion implantation, diffusion, device simulation concepts, pn junctions, MOS devices, bipolar transistors. Prerequisite: EEE 436 (or its equivalent).

EEE 534 Semiconductor Transport. (3)
spring
Carrier transport in semiconductors. Hall effect, high electric field, Boltzmann equation, correlation functions, and carrier-carrier interactions. Prerequisites: EEE 434, 436 (or 531).

EEE 535 Electron Transport in Nanostructures. (3)
spring
Nanostructure physics and applications. Two-dimensional electron systems, quantum wires and dots, ballistic transport, quantum interference, and single-electron tunneling. Prerequisites: EEE 434, 436.

EEE 536 Semiconductor Characterization. (3)
spring
Measurement techniques for semiconductor materials and devices. Electrical, optical, physical, and chemical characterization methods. Prerequisite: EEE 436 (or its equivalent).

EEE 537 Semiconductor Optoelectronics I. (3)
fall
Electronic states in semiconductors, quantum theory of radiation, absorption processes, radiative processes, nonradiative processes, photoluminescence, and photonic devices. Prerequisites: EEE 434, 436 (or 531).

EEE 538 Semiconductor Optoelectronics II. (3)
selected semesters
Material and device physics of semiconductor lasers, light-emitting diodes, and photodetectors. Emerging material and device technology in III-V semiconductors. Prerequisite: EEE 537.

EEE 539 Introduction to Solid-State Electronics. (3)
fall
Crystal lattices, reciprocal lattices, quantum statistics, lattice dynamics, equilibrium, and nonequilibrium processes in semiconductors. Prerequisite: EEE 434.

EEE 541 Electromagnetic Fields and Guided Waves. (3)
selected semesters
Polarization and magnetization; dielectric, conducting, anisotropic, and semiconducting media; duality, uniqueness, and image theory; plane wave functions, waveguides, resonators, and surface guided waves. Prerequisite: EEE 440 (or its equivalent).

EEE 543 Antenna Analysis and Design. (3)
fall
Impedances, broadband antennas, frequency independent antennas, miniaturization, aperture antennas, horns, reflectors, lens antennas, and continuous sources design techniques. Prerequisite: EEE 443 (or its equivalent).

EEE 544 High-Resolution Radar. (3)
selected semesters
Fundamentals; wideband coherent design, waveforms, and processing; stepped frequency; synthetic aperture radar (SAR); inverse synthetic aperture radar (ISAR); imaging. Prerequisites: EEE 303 and 340 (or their equivalents).

EEE 545 Microwave Circuit Design. (3)
spring
Analysis and design of microwave attenuators, in-phase and quadrature-phase power dividers, magic tee's, directional couplers, phase shifters, DC blocks, and equalizers. Prerequisite: EEE 445 or instructor approval.

EEE 546 Advanced Fiber Optics. (3)
selected semesters
Theory of propagation in fibers, couplers and connectors, distribution networks, modulation, noise and detection, system design, and fiber sensors. Prerequisite: EEE 448 or instructor approval.

EEE 547 Microwave Solid-State Circuit Design I. (3)
spring
Applies semiconductor characteristics to practical design of microwave mixers, detectors, limiters, switches, attenuators, multipliers, phase shifters, and amplifiers. Prerequisite: EEE 545 or instructor approval.

EEE 548 Coherent Optics. (3)
selected semesters
Diffraction, lenses, optical processing, holography, electro-optics, and lasers. Prerequisite: EEE 440 (or its equivalent).

EEE 549 Lasers. (3)
selected semesters
Theory and design of gas, solid, and semiconductor lasers. Prerequisite: EEE 448 or instructor approval.

EEE 550 Transform Theory and Applications. (3)
selected semesters
Introduces abstract integration, function spaces, and complex analysis in the context of integral transform theory. Applications to signal analysis, communication theory, and system theory. Prerequisite: EEE 303.

EEE 551 Information Theory. (3)
selected semesters
Entropy and mutual information, source and channel coding theorems, applications for communication and signal processing. Prerequisite: EEE 554.

EEE 552 Digital Communications. (3)
spring
Complex signal theory, digital modulation, optimal coherent and incoherent receivers, channel codes, coded modulation, Viterbi algorithm. Prerequisite: EEE 554.

EEE 553 Coding and Cryptography. (3)
selected semesters
Introduces algebra, block and convolutional codes, decoding algorithms, turbo codes, coded modulation, private and public key cryptography. Prerequisite: EEE 554.

EEE 554 Random Signal Theory. (3)
fall
Applies statistical techniques to the representation and analysis of electrical signals and to communications systems analysis. Prerequisite: EEE 350 or instructor approval.

EEE 555 Modeling and Performance Analysis. (3)
selected semesters
Modeling and performance analysis of stochastic systems and processes such as network traffic queueing systems and communication channels. Prerequisite: EEE 554.

EEE 556 Detection and Estimation Theory. (3)
selected semesters
Combines the classical techniques of statistical inference and the random process characterization of communication, radar, and other modern data processing systems. Prerequisites: EEE 455, 554.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

EEE 558 Wireless Communications. (3)
fall
Cellular systems, path loss, multipath fading channels, modulation and signaling for wireless, diversity, equalization coding, spread spectrum, TDMA/FDMA/CDMA. Prerequisite: EEE 552.

EEE 571 Power System Transients. (3)
spring
Simple switching transients. Transient analysis by deduction. Damping of transients. Capacitor and reactor switching. Transient recovery voltage. Travelling waves on transmission lines. Lightning. Protection of equipment against transient overvoltages. Introduces computer analysis of transients. Prerequisite: EEE 471.

EEE 572 Advanced Power Electronics. (3)
fall
Analyzes device operation, including thyristors, gate-turn-off thyristors, and transistors. Design of rectifier and inverter circuits. Applications such as variable speed drives, HVDC, motor control, and uninterruptable power supplies. Prerequisite: EEE 470.

EEE 573 Electric Power Quality. (3)
spring
Sinusoidal waveshape maintenance; study of momentary events, power system harmonics, instrumentation, filters, power conditioners, and other power quality enhancement methods. Prerequisite: EEE 360 (or its equivalent).

EEE 574 Computer Solution of Power Systems. (3)
selected semesters
Algorithms for digital computation for power flow, fault, and stability analysis. Sparse matrix and vector programming methods, numerical integration techniques, stochastic methods, solution of the least squares problem. Prerequisite: EEE 471.

EEE 577 Power Engineering Operations and Planning. (3)
fall
Economic dispatch, unit commitment, dynamic programming, power system planning and operation, control, generation modeling, AGC, and power production. Prerequisite: EEE 471 or graduate standing.

EEE 579 Power Transmission and Distribution. (3)
spring
High-voltage transmission line electric design; conductors, corona, RI and TV noise, insulators, clearances. DC characteristic, feeders voltage drop, and capacitors. Prerequisite: EEE 470.

EEE 581 Filtering of Stochastic Processes. (3)
selected semesters
Modeling, estimation, and filtering of stochastic processes, with emphasis on the Kalman filter and its applications in signal processing and control. Prerequisites: EEE 482, 550, 554.

EEE 582 Linear System Theory. (3)
selected semesters
Controllability, observability, and realization theory for multivariable continuous time systems. Stabilization and asymptotic state estimation. Disturbance decoupling, noninteracting control. Prerequisite: EEE 482.

EEE 584 Internship. (3)
fall, spring, summer
Work performed in an industrial setting that provides practical experience and adds value to the classroom and research learning processes.

EEE 585 Digital Control Systems. (3)
selected semesters
Analysis and design of digital and sampled data control systems, including sampling theory, z-transforms, the state transition method, stability, design, and synthesis. Prerequisites: EEE 482, 550.

EEE 586 Nonlinear Control Systems. (3)
selected semesters
Stability theory, including phase-plane, describing function, Liapunov's method, and frequency domain criteria for continuous and discrete, nonlinear, and time-varying systems. Prerequisite: EEE 482.

EEE 587 Optimal Control. (3)
selected semesters
Optimal control of systems. Calculus of variations, dynamic programming, linear quadratic regulator, numerical methods, and Pontryagin's principle. Cross-listed as MAE 507. Credit is allowed for only EEE 587 or MAE 507. Prerequisite: EEE 482 or MAE 506.

EEE 588 Design of Multivariable Control Systems. (3)
selected semesters
Practical tools for designing robust MIMO controllers. State feedback and estimation, model-based compensators, MIMO design methodologies, CAD, real-world applications. Prerequisite: EEE 480 (or its equivalent).

EEE 606 Adaptive Signal Processing. (3)
fall
Principles/applications of adaptive signal processing, adaptive linear combiner, Wiener least-squares solution, gradient search, performance surfaces, LMS/RLS algorithms, block time/frequency domain LMS. Prerequisites: EEE 506, 554.

EEE 607 Speech Coding for Multimedia Communications. (3)
spring
Speech and audio coding algorithms for applications in wireless communications and multimedia computing. Prerequisite: EEE 407. Pre- or corequisite: EEE 506.

EEE 631 Heterojunctions and Superlattices. (3)
fall
Principles of heterojunctions and quantum well structures, band lineups, optical, and electrical properties. Introduces heterojunction devices. Prerequisites: EEE 436, 531.

EEE 632 Heterojunction Devices. (3)
selected semesters
Applies heterostructures, quantum wells, and superlattice to modulation-doped FETs, heterostructure bipolar transistors, lasers, detectors, and modulators. Prerequisites: EEE 434, 631 (or 537).

EEE 641 Advanced Electromagnetic Field Theory. (3)
selected semesters
Cylindrical wave functions, waveguides, and resonators; spherical wave functions and resonators; scattering from planar, cylindrical, and spherical surfaces; Green's functions. Prerequisite: EEE 541 (or its equivalent).

EEE 643 Advanced Topics in Electromagnetic Radiation. (3)
spring
High-frequency asymptotic techniques, geometrical and physical theories of diffraction (GTD and PTD), moment method (MM), radar cross section (RCS) prediction, Fourier transforms in radiation, and synthesis methods. Prerequisite: EEE 543.

EEE 647 Microwave Solid-State Circuit Design II. (3)
fall
Practical design of microwave free-running and voltage-controlled oscillators using Gunn and Impatt diodes and transistors; analysis of noise characteristics of the oscillator. Prerequisites: EEE 545, 547.

EEE 684 Internship. (1–2)
fall, spring, summer
Work performed in an industrial setting that provides practical experience and adds value to the classroom and research learning processes.

EEE 686 Adaptive Control. (3)
selected semesters
Main topics covered: adaptive identification, convergence, parametric models, performance and robustness properties of adaptive controllers, persistence of excitation, and stability. Prerequisites: both EEE 582 and 586 or only instructor approval.

EEE 731 Advanced MOS Devices. (3)
spring
Threshold voltage, subthreshold current, scaling, small geometry effects, hot electrons, and alternative structures. Prerequisite: EEE 531.

EEE 770 Advanced Topics in Power Systems. (3)
selected semesters
Power system problems of current interest, approached at an advanced technical level, for mature students. Prerequisites: EEE 577 and 579 (or their equivalents); instructor approval.

EEE 784 Internship. (3)
fall, spring, summer
Work performed in an industrial setting that provides practical experience and adds value to the classroom and research learning processes.

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see "Omnibus Courses," page 56.

Department of Industrial Engineering

www.eas.asu.edu/~imse
480/965-3185
GWC 502

Gary L. Hogg, Chair

Professors: Cochran, Dooley, Henderson, Hogg, Hubele, Montgomery, Runger, Wolfe

Associate Professors: Anderson-Rowland, Fowler, Mackulak, Moor, Mou, Roberts, Shunk, Villalobos, Ye

Assistant Professors: Carlyle, Gel, Kulahci, Wu

Lecturer: Borror

The industrial engineer (IE) provides leadership for American organizations in reestablishing competitiveness in the global marketplace through system integration and productivity improvement. No challenge can be greater than improving productivity, which is the application of knowledge and skills to provide improved goods and services to enhance the quality of life, both on and off the job. This improvement must be achieved without waste of physical and human resources while maintaining environmental balance. Industrial engineers are the "productivity people" who provide the necessary leadership and skills to integrate technology. This gives IEs a wide range of interests and responsibilities.

As in other engineering fields, industrial engineering is concerned with solving problems through the application of scientific and practical knowledge. What sets industrial engineering apart from other engineering disciplines is its broader scope. An IE relates to the total picture of productivity. An IE looks at the "big picture" of what makes society perform best—the right combination of human resources, natural resources, synthetic structures, and equipment. An IE bridges the gap between management and operations, dealing with and motivating people as well as determining what tools should be used and how they should be used.

An IE deals with people as well as things. In fact, industrial engineering is often called the "people-oriented profession." It is a primary function of the IE to integrate people and technology-oriented systems. Therefore, IEs are active in the fields of ergonomics and human factors.

To be competitive in this global economy, it is essential to emphasize and continually improve the quality of goods and services. Industrial engineering is the only engineering discipline offering course work in designing and implementing quality assurance systems.

The IE's skills are applicable to every kind of organization. IEs learn how to approach, think about, and solve productivity and integration problems regardless of their settings. IEs work in manufacturing facilities, banks, hospitals, government, transportation, construction, and social services. Within this wide variety of organizations, IEs get involved in projects such as designing and implementing quality control systems, independent work groups, the work flow in a medical laboratory, real-time production control systems, computer-based management information systems, and manufacturing operating systems, to name a few. A unique feature of most industrial engineering assignments is that they involve interdisciplinary teams. For example, the IE might be the leader of a team consisting of electrical and mechanical engineers, accountants, computer scientists, and planners. This IE program gives the student the skills necessary to direct these teams. These skills include team building, brainstorming, group dynamics, and interpersonal relationships.

IEs have a sound background in technology integration, management theory and application, engineering economics and cost analysis. IEs are well equipped to deal with problems never seen before, making them prime candidates for promotion through the management career path, especially in high-tech organizations. In fact, more than half of all practicing IEs are in management positions. This area of expertise has placed the IE in the leadership role in the establishment of a new field of activity called "management of technology."

Industrial engineers are well trained in the development and use of analytical tools, and their most distinctive skill is in the area of model building. IEs must quickly learn and understand the problems of their clients. In this context, good people skills and good analytic skills are essential. This industrial engineering program offers both.

INDUSTRIAL ENGINEERING—B.S.E.

The curriculum in Industrial Engineering builds upon mathematics, computer programming, and the engineering core. Beyond this foundation, the curriculum includes a number of required IE core courses, IE electives, and study area electives, enabling students to focus on a specific career objective.

By successfully completing this curriculum, the student is prepared to embark on a career in industrial engineering or to pursue advanced education in graduate school.

The career-focused study-areas are as follows:

1. *Industrial and Management Systems.* For a broad traditional IE career in the design and analysis of manufacturing and service systems.
2. *Information and Telecommunication Systems.* For a career in the application of integrated computer and telecommunication systems to manufacturing and service systems analysis and design.
3. *Global Industrial Engineering Leadership.* For a career in global manufacturing and service organizations.
4. *High-Tech Manufacturing.* For a career in the design and analysis of integrated manufacturing systems.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

5. *Preprofessional and Service Systems.* For a career in law, medicine or public service or careers in the design and analysis of health care, agribusiness, banking/financial, and government/public-administration systems.

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Industrial Engineering. A minimum of 50 upper-division hours is required. Students must attain a GPA of at least 2.00 for the courses in the major field.

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See “University Graduation Requirements,” page 79. For information concerning admission, degree, course, and graduation requirements for the School of Engineering, see pages 218– 221 of this catalog.

COURSE REQUIREMENTS

Students take 59 semester hours of university English proficiency and general studies course work, 19 hours of engineering core, 36 hours of industrial engineering courses, two hours of industrial engineering electives, and 12 hours of career-focused study area electives. Each study area has an associated list of recommended General Studies, IE electives, and study area courses. The course work for the undergraduate degree can be classified into the following categories:

First-Year Composition

Choose among the course combinations below 6
- ENG 101 First-Year Composition (3)
- ENG 102 First-Year Composition (3)

———*or*———

- ENG 105 Advanced First-Year Composition (3)
- Elective chosen with an advisor (3)

———*or*———

- ENG 107 English for Foreign Students (3)
- ENG 108 English for Foreign Students (3)

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 112 Microeconomic Principles *SB* 3
HU courses 6–9
SB course(s) 3–6

Minimum total 15

Literacy and Critical Inquiry

ECE 300 Intermediate Engineering Design *L* 3
IEE 490 Project in Design and Development *L* 3

Total 6

Natural Sciences/Basic Sciences

CHM 114 General Chemistry for Engineers *SQ* 4
or CHM 116 General Chemistry *SQ* (4)
PHY 121 University Physics I: Mechanics *SQ*[1] 3
PHY 122 University Physics Laboratory I *SQ*[1] 1
PHY 131 University Physics II: Electricity and Magnetism *SQ*[2] 3
PHY 132 University Physics Laboratory II *SQ*[2] 1
Basic science elective 3

Total 15

Mathematical Studies

MAT 242 Elementary Linear Algebra 2
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 17
General Studies/school requirements total 53

Engineering Core

ECE 100 Introduction to Engineering Design *CS* 3
ECE 201 Electrical Networks I 4
ECE 210 Engineering Mechanics I: Statics 3
ECE 212 Engineering Mechanics II: Dynamics 3
ECE 350 Structure and Properties of Materials 3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3

Total 19

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1 Both PHY 121 and 122 must be taken to secure SQ credit.
2 Both PHY 131 and 132 must be taken to secure SQ credit.

Industrial Engineering Major

The following courses are required:

ASE 485 Engineering Statistics *CS* 3
CSE 100 Principles of Programming with C++ *CS* 3
or CSE 110 Principles of Programming with Java (3)
CSE 200 Concepts of Computer Science 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
IEE 294 ST: Industrial Engineering Applications Seminar 2
IEE 300 Economic Analysis for Engineers 3
IEE 360 Manufacturing Processes 3
IEE 368 Facilities Analysis and Design 3
IEE 374 Quality Control *CS* 3
IEE 461 Production Control 3
IEE 475 Simulating Stochastic Systems *CS* 3
IEE 476 Operations Research Techniques/Applications *CS* 4

Total 36

Industrial Engineering Electives Area

Students select two semester hours of industrial engineering electives. IEE 361 Manufacturing Processes Lab is highly recommended. For course information, see the list of recommended courses in the department advising office.

Career-Focused Study Area Electives

Students select a minimum of 12 semester hours from the following recommended electives in one of the five career-focused study areas.

Industrial and Management Systems

IEE 305 Information Systems Engineering *CS* 3
IEE 431 Engineering Administration 3
Any approved engineering or business elective 3
Any approved engineering elective 3

Information and Telecommunication Systems

CSE 210 Object-Oriented Design and Data Structure 3
CSE 240 Introduction to Programming Languages 3
IEE 305 Information Systems Engineering *CS* 3
IEE 494 ST: Information Systems Development Tools 3

Global Industrial Engineering Leadership
ECN 306 Survey of International Economics *SB, G* 3
IBS 300 Principles of International Business *G*..........................3
IBS 400 Cultural Factors in International Business *C, G* 3
Any approved international business electives 3

High-Tech Manufacturing*
ECE 352 Properties of Electronic Materials 4
EEE 435 Microelectronics 3
EEE 436 Fundamentals of Solid-State Devices 3
MSE 355 Introduction to Materials Science and Engineering.......3
MSE 441 Analysis of Materials Failures 3
MSE 470 Polymers and Composites...3

Preprofessional and Service Systems*
Agribusiness Systems
AGB 340 Food Processing..3
AGB 341 Food Analysis..3
AGB 351 Management Science *CS*...3
AGB 364 Agribusiness Technologies I 3
AGB 414 Agribusiness Analysis *L*..3
AGB 440 Food Safety 3
AGB 442 Food and Industrial Microbiology 4

Banking and Financial Systems
FIN 300 Fundamentals of Finance 3
FIN 331 Financial Markets and Institutions................................3
FIN 361 Managerial Finance...3
FIN 431 Management of Financial Institutions 3

Government and Public Administration Systems
POS 310 American National Government *SB*..............................3
POS 316 State and Local Government *SB* 3
POS 320 Public Administration *SB*..3
POS 333 Interest Groups *SB* 3

Health Care Systems
HSA 498 PS: Health Care Finance 3
HSA 498 PS: Health Economics...3
HSA 498 PS: Health Service Administration and Policy 3
HSA 498 PS: Policy Issues in Health Care...................................3

Prelaw Systems
AJS 360 Substantive Criminal Law (ASU West) 3
COM 422 Advanced Argumentation 3
GLB 300 Gateway to Global Business (ASU West).....................3
POL 470 Law and Political Order (ASU West)............................3

Premedicine Systems
BIO 187 General Biology I *SG*..4
BIO 188 General Biology II *SQ* 4
BIO 351 Developmental Anatomy..3
CHM 331 General Organic Chemistry 3
CHM 332 General Organic Chemistry 3
CHM 335 General Organic Chemistry Lab 1
CHM 336 General Organic Chemistry Lab 1

* Certain focus study areas may require more than 12 semester hours due to class prerequisites.

Industrial Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester
CHM 114 General Chemistry for Engineers *SQ*............................4
or CHM 116 General Chemistry *SQ*[1]
ECE 100 Introduction to Engineering Design *CS* 3
ENG 101 First-Year Composition...3
MAT 270 Calculus with Analytic Geometry I *MA*........................4
HU/SB elective[2]..3
Total 17

Second Semester
ECN 112 Microeconomic Principles *SB*.......................................3
ENG 102 First-Year Composition...3
MAT 271 Calculus with Analytic Geometry II *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[3] 3
PHY 122 University Physics Laboratory I *SQ*[3] 1
HU/SB elective[2]..3
Total 17

Second Year

First Semester
CSE 100 Principles of Programming with C++ *CS* 3
or CSE 110 Principles of Programming with Java (3)
IEE 300 Economic Analysis for Engineers.................................3
MAT 242 Elementary Linear Algebra 2
MAT 272 Calculus with Analytic Geometry III *MA* 4
PHY 131 University Physics II: Electricity and Magnetism *SQ*[4] 3
PHY 132 University Physics Laboratory II *SQ*[4]...........................1
Total 16

Second Semester
CSE 200 Concepts of Computer Science.....................................3
ECE 350 Structure and Properties of Materials 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
IEE 294 ST: Industrial Engineering Applications Seminar 2
MAT 274 Elementary Differential Equations *MA*.........................3
Basic science elective[5]...3
Total 17

Third Year

First Semester
ASE 485 Engineering Statistics *CS*..3
ECE 210 Engineering Mechanics I: Statics..................................3
IEE 360 Manufacturing Processes 3
IEE 368 Facilities Analysis and Design 3
IEE 374 Quality Control *CS*..3
Industrial Engineering elective 2
Total 17

Second Semester
ECE 300 Intermediate Engineering Design *L* 3
ECE 212 Engineering Mechanics II: Dynamics...........................3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3
IEE 476 Operations Research Techniques/Applications *CS*........4
Study area elective 3
Total 16

Fourth Year

First Semester
ECE 201 Electrical Networks I 4
IEE 461 Production Control..3
IEE 475 Simulating Stochastic Systems *CS* 3
HU/SB elective[2]..3
Study area elective 3
Total 16

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

Second Semester

IEE 490 Project in Design and Development	3
HU/SB elective[2]	3
Study area electives	6
Total	12

[1] Students who have taken no high school chemistry should take CHM 113 and 116.

[2] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to satisfy HU or SB requirements.

[3] Both PHY 121 and 122 must be taken to secure SQ credit.

[4] Both PHY 131 and 132 must be taken to secure SQ credit.

[5] This elective must be an earth science or life science course; if physics or chemistry, the course must be of a more advanced level than CHM 114 or 116 or PHY 131.

INDUSTRIAL ENGINEERING (IEE)

IEE 294 Special Topics. (1–4)
fall and spring
Topics may include the following:
- Industrial Engineering Applications Seminar. (2)

IEE 300 Economic Analysis for Engineers. (3)
fall and spring
Economic evaluation of alternatives for engineering decisions, emphasizing the time value of money. Prerequisites: ECE 100; MAT 270.

IEE 305 Information Systems Engineering. (3)
fall
Overview of computer and information systems applications. Topics include client/server; distributed computing; networks; process modeling; e-commerce; enterprise applications; internet. Prerequisite: CSE 200.
General Studies: CS

IEE 360 Manufacturing Processes. (3)
fall and spring
Production technique and equipment. Casting and molding, forming, machining, joining and assembly, computer-integrated manufacturing, rapid prototyping, and electronics manufacturing. Cross-listed as MAE 351. Credit is allowed for only IEE 360 or MAE 351. Prerequisite: ECE 350.

IEE 361 Manufacturing Processes Lab. (1)
fall and spring
Series of labs designed to illustrate concepts presented in IEE 360 on production technique and equipment. Corequisite: IEE 360 or MAE 351.

IEE 368 Facilities Analysis and Design. (3)
fall
Planning analysis and design of methods of the tangible physical assets of the firm. Emphasizes facilities location, materials handling, automation, computer integration, and utilization of financial resources. Applications in diverse fields. Lecture, lab. Prerequisite: IEE 300.

IEE 369 Work Analysis and Design. (3)
spring
Planning analysis and design of methods of accomplishing work. Emphasizes human factors, work planning, methods analysis and design, and work measurement. Applications in diverse fields. Lecture, lab.

IEE 374 Quality Control. (3)
fall
Control charting and other statistical process control techniques. Organization and managerial aspects of quality assurance, plus acceptance sampling plans. Prerequisite: ECE 380.
General Studies: CS

IEE 431 Engineering Administration. (3)
fall
Introduces quantitative and qualitative approaches to management functions, engineering administration, organizational analysis, decision making, and communication. Credit is allowed for only IEE 431 or 541. Prerequisite: senior standing.

IEE 437 Human Factors Engineering. (3)
fall
Study of the human psychological and physiological factors that underlie the design of equipment and the interaction between people and machines. Credit is allowed for only IEE 437 or 547.

IEE 461 Production Control. (3)
fall
Techniques for the planning, control, and evaluation of production systems. Project management, forecasting, inventory control, scheduling, enterprise requirements planning. Prerequisites: ASE 485; CSE 100; IEE 476.

IEE 463 Computer-Aided Manufacturing and Control. (3)
spring
Computer control in manufacturing, CIM, NC, logic controllers, group technology, process planning, and robotics. Credit is allowed for only IEE 463 or 543. Prerequisite: IEE 360 or MAE 351.
General Studies: CS

IEE 475 Simulating Stochastic Systems. (3)
fall and spring
Analyzes stochastic systems using basic queuing networks and discrete event simulation. Basic network modeling, shared resources, routing, assembly logic. Credit is allowed for only IEE 475 or 545. Prerequisite: CSE 200.
General Studies: CS

IEE 476 Operations Research Techniques/Applications. (4)
fall and spring
Industrial systems applications with operations research techniques. Resource allocation, product mix, production, shipping, task assignment, market share, machine repair, customer service. Credit is allowed for only IEE 476 or 546. Prerequisite: CSE 200.
General Studies: CS

IEE 490 Project in Design and Development. (3)
fall and spring
Individual or team capstone project in creative design and synthesis. Prerequisites: ECE 300; 475. Pre- or corequisite: IEE 461.
General Studies: L

IEE 494 Special Topics. (1–4)
fall and spring
Topics may include the following:
- Information Systems Development Tools. (3)

IEE 505 Information Systems Engineering. (3)
fall and spring
Studies information systems application engineering. Topics include information technology, data modeling, data organization, process mapping, application and database engineering, and user interface development. Prerequisites: CSE 200; graduate standing.

IEE 511 Analysis of Decision Processes. (3)
spring
Methods of making decisions in complex environments and statistical decision theory; effects of risk, uncertainty, and strategy on engineering and managerial decisions. Prerequisites: ECE 380; graduate standing.

IEE 520 Ergonomics Design. (3)
spring
Human physiological and psychological factors in the design of work environments and in the employment of people in man-machine systems. Open-shop lab assignments in addition to class work. Prerequisite: IEE 437 or graduate standing.

IEE 530 Enterprise Modeling. (3)
spring
Focuses on social, economic, and technical models of the enterprise with emphasis on the management of technological resources. Includes organization, econometric, financial, and large-scale mathematical models. Prerequisite: graduate standing.

IEE 531 Topics in Engineering Administration. (3)
spring in even years
Consideration given to philosophical, psychological, political, and social implications of administrative decisions. Prerequisite: graduate standing.

IEE 532 Management of Technology. (3)
fall
Topics include designing a technical strategy; technological forecasting; interfacing marketing engineering and manufacturing; designing

and managing innovation systems; creativity; application of basic management principles to technology management. Prerequisite: IEE 431 or 541.

IEE 533 Scheduling and Network Analysis Models. (3)
spring
Applies scheduling and sequencing algorithms, deterministic and stochastic network analysis, and flow algorithms. Prerequisites: ECE 380; IEE 476 (or 546).

IEE 541 Engineering Administration. (3)
fall
Introduces quantitative and qualitative approaches to management functions, engineering administration, organizational analysis, decision making, and communication. Credit is allowed for only IEE 541 or 431. Prerequisite: graduate standing.

IEE 543 Computer-Aided Manufacturing and Control. (3)
spring
Computer control in manufacturing, CIM, NC, logic controllers, group technology, process planning and robotics. Credit is allowed for only IEE 543 or 463. Prerequisite: graduate standing.

IEE 545 Simulating Stochastic Systems. (3)
fall and spring
Analyzes stochastic systems using basic queuing networks and discrete event simulation. Basic network modeling, shared resources, routing, assembly logic. Credit is allowed for only IEE 545 or 475. Prerequisites: CSE 200; IEE 476 (or 546). Pre- or corequisite: ASE 485 or 500.

IEE 546 Operations Research Techniques/Applications. (4)
fall and spring
Models and analyzes industrial systems applications with operations research techniques. Resource allocation, product mix, production, shipping, task assignment, market share, machine repair, customer service. Credit is allowed for only IEE 546 or 476. Prerequisites: ECE 380; graduate standing.

IEE 547 Human Factors Engineering. (3)
fall and spring
Study of people at work; designing for human performance effectiveness and productivity. Considerations of human physiological and psychological factors. Credit is allowed for only IEE 547 or 437. Prerequisite: graduate standing.

IEE 552 Strategic Technological Planning. (3)
spring
Studies concepts of strategy, strategy formulation process, and strategic planning methodologies with emphasis on engineering design and manufacturing strategy, complemented with case studies. Presents and uses an analytical executive planning decision support system throughout course. Prerequisite: graduate standing. Pre- or corequisites: IEE 545, 561, 572, 574.

IEE 560 Object-Oriented Information Systems. (3)
spring
Applies object-oriented technology and concepts to enterprise information systems. Topics include requirement analysis, object-oriented design and programming, rapid application development, object data management, and development of object-oriented distributed applications. Prerequisite: IEE 505.

IEE 561 Production Systems. (3)
spring
Understanding how factories operate, how performance is measured, and how operational changes impact performance metrics. Operational philosophies, increasing production efficiency through quantitative methods. Prerequisites: ASE 485; IEE 476.

IEE 562 Computer-Aided Manufacturing (CAM) Tools. (3)
spring
Current topics in automation, distributed control, control code generation, control logic validation, CAM integration, CAD/CAM data structures, planning for control systems. Topics vary by semester. Prerequisite: IEE 463 or 543.

IEE 563 Distributed Information Systems. (3)
fall and spring
Introduction to concepts and technologies that form the core of distributed enterprise information systems. Topics include client-server architectures, distributed objects and paradigms, internet, World Wide Web, distributed information sharing, network programming, and e-commerce and enterprise applications. Prerequisite: IEE 505.

IEE 564 Planning for Computer-Integrated Manufacturing. (3)
fall
Theory and use of IDEF methodology in planning for flexible manufacturing, robotics, and real-time control. Simulation concepts applied to computer-integrated manufacturing planning. Prerequisite: graduate standing.

IEE 565 Computer-Integrated Manufacturing Research. (3)
spring
Determination and evaluation of research areas in computer-integrated manufacturing, including real-time software, manufacturing information systems, flexible and integrated manufacturing systems, robotics, and computer graphics. Prerequisite: IEE 564.

IEE 566 Simulation in Manufacturing. (3)
spring in even years
Uses simulation in computer-integrated manufacturing with an emphasis on modeling material handling systems. Programming, declarative, and intelligence-based simulation environments. Prerequisite: IEE 475 or 545.

IEE 567 Simulation System Analysis. (3)
fall
Simulation modeling of processes involving discrete and continuous system components. Topics include random number generators, output analysis, variance reduction, and statistical issues related to simulation. Prerequisite: IEE 475 or 545.

IEE 569 Advanced Statistical Methods. (3)
fall in even years
Applies statistical modelling and inference techniques to problems in engineering and science. Topics may include multivariate methods, spatial modeling, and nonparametric methods. Prerequisite: ASE 485 or 500.

IEE 570 Advanced Quality Control. (3)
spring
Process monitoring with control charts (Shewhart, cusum, EWMA), feedback adjustment and engineering process control, process capability, autocorrelation, selected topics from current literature. Prerequisite: ASE 485 or 500.

IEE 571 Quality Management. (3)
fall
Total quality concepts, quality strategies, quality and competitive position, quality costs, vendor relations, the quality manual, and quality in the services. Prerequisite: graduate standing.

IEE 572 Design of Engineering Experiments. (3)
fall and spring
Analyzes variance and experimental design. Topics include general design methodology, incomplete blocks, confounding, fractional replication, and response surface methodology. Prerequisite: ASE 485.

IEE 573 Reliability Engineering. (3)
spring
Nature of reliability, time to failure densities, series/parallel/standby systems, complex system reliability, Bayesian reliability, and sequential reliability tests. Prerequisite: ECE 380.

IEE 574 Applied Deterministic Operations Research Models. (3)
fall and spring
Develops advanced techniques in operations research for the solution of complex industrial systems problems. Goal programming, integer programming, heuristic methods, dynamic and nonlinear programming. Prerequisite: IEE 476 or 546.

IEE 575 Applied Stochastic Operations Research Models. (3)
spring
Formulate and solve industrial systems problems with stochastic components using analytical techniques. Convolution, continuous-time Markov chains, queues with batching, priorities, balking, open/closed queuing networks. Prerequisites: ASE 485 (or 500); IEE 476 (or 546).

IEE 577 Applied Intelligent Systems. (3)
fall
Intelligent system technologies and their applications in industrial engineering. Topics include artificial neural networks, genetic algorithms, data mining, Bayesian decision making, knowledge-based

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L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

decision support, and their engineering applications. Prerequisite: IEE 505.

IEE 578 Regression Analysis. (3)
fall
Regression model building oriented toward engineers and physical scientists. Topics include linear regression, diagnostics, biased and robust fitting, nonlinear regression. Prerequisite: ASE 485 or 500.

IEE 579 Time Series Analysis and Forecasting. (3)
fall in odd years
Forecasting time series by regression-based, exponential smoothing, and ARIMA model techniques; uses digital computer programs to augment the theory. Prerequisite: ASE 485 or 500.

IEE 582 Response Surfaces and Process Optimization. (3)
spring
Classical response surface analysis and designs including steepest ascent, canonical analysis, and multiple responses. Other topics include process robustness studies, robust design, and mixture experiments. Prerequisite: IEE 572.

IEE 593 Applied Project. (1–12)
selected semesters

IEE 594 Conference and Workshop. (1)
fall and spring
Orientation to the developing work in the field with an emphasis on what the IE faculty are doing.

IEE 598 Special Topics. (1–4)
selected semesters
Topics may include the following:
- Advanced Topics in Deterministic Operations Research. (3)
- Advanced Topics in Scheduling. (3)
- Analysis of Massive Data Sets. (3)
- Computer and Human Vision. (3)
- DOE/SPC for Semiconductor Processes. (3)
- Enterprise Internet/Intranet. (3)
- Introduction to Rapid Prototyping. (3)
- Mechatronics. (3)
- Product Modeling. (3)
- Strategic Design of Manufacturing Systems. (3)
- Strategic Issues in Manufacturing. (3)

IEE 599 Thesis. (1–12)
selected semesters

IEE 672 Advanced Topics in Experimental Design. (3)
spring in even years
Multilevel and mixed-level factorials and fractions, design optimality, incomplete blocks, unbalanced designs, random effects and variance components, analysis of covariance. Prerequisite: IEE 572.

IEE 677 Regression and Generalized Linear Models. (3)
spring in odd years
Theory of linear models including least squares, maximum likelihood, likelihood-based inference. Generalized linear models including Poisson and logistic regression, generalized estimating equations. Prerequisite: IEE 578.

IEE 679 Time Series Analysis and Control. (3)
fall in even years
Identification, estimation, diagnostic checking techniques for ARIMA models, transfer functions, multiple time series models for feedback and feedforward control schemes. Prerequisite: IEE 579.

IEE 681 Reliability, Availability, and Serviceability. (3)
fall in even years
Organizing hardware and software, integrity and fault-tolerant design, maintenance design and strategy, Markov models, fault-free analysis, and military standards. Prerequisite: IEE 573.

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

Department of Mechanical and Aerospace Engineering

www.eas.asu.edu/~mae
480/965-3291
ECG 346

Robert E. Peck, Chair

Professors: Boyer, Chattopadhyay, Davidson, Evans, Fernando, Jankowski, Krajcinovic, Laananen, Liu, Mignolet, Peck, Reed, Roy, Saric, Shah, Sieradzki, Tseng, Wie, Yao

Associate Professors: Chen, Kuo, Lee, Phelan, Rankin, Squires, Wells

Assistant Professors: Calhoun, Chapsky, McNeill, Mikellides, Peralta, Sugar

The Department of Mechanical and Aerospace Engineering is the administrative home for two undergraduate majors: Aerospace Engineering and Mechanical Engineering. Consistent with the department’s mission to provide the best possible education to its students, a department goal is to attract and retain—from the metropolitan community, the state, and the country—outstanding and diverse students and to give each the opportunity to become competent in contemporary subjects that bear on an engineering career. This goal is achieved through a curriculum designed to accomplish the following four objectives:

1. *Technical Competency.* Graduates are able to model and predict the behavior of engineering systems by applying the fundamental principles from mathematics, physics, and chemistry and by using modern computational and experimental tools.
2. *Product Realization Ability.* Graduates are able to design components or systems at the conceptual and embodiment design level including the issues of production, manufacturability, and cost.
3. *Communication Skills.* Graduates can present and document effectively, using both oral and written communication, their work and ideas to a diverse audience.
4. *Professionalism.* Graduates are prepared for modern engineering practice by working in teams, keeping technologically abreast, and having an understanding of related ethical, environmental, and societal issues.

The Aerospace Engineering major provides students an education in technological areas critical to the design and development of aerospace vehicles and systems. Aerospace Engineering graduates are typically employed in aerospace industries or at government laboratories (e.g., NASA). The Mechanical Engineering major is perhaps one of the most broadly applicable programs in engineering, providing education for a wide variety of employment opportunities.

The two majors can serve as entry points to immediate professional employment or to graduate study. The emphasis in all fields is on the development of fundamental knowledge that will have long-lasting utility in a rapidly changing technical society.

DEGREE REQUIREMENTS

All degree programs in the department require that students attain a minimum GPA of 2.00 in the engineering core and in the major and take a minimum of 50 upper-division semester hours to be eligible for graduation. Also, the department may require additional or remedial course work for those students who have demonstrated a trend toward academic difficulties.

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See “University Graduation Requirements,” page 79.

COURSE REQUIREMENTS

General Studies

See “Course Requirements,” page 220, for General Studies, school, and engineering core course requirements.

Engineering Core

Students in the Department of Mechanical and Aerospace Engineering are required to take the following from among the choices shown under “Engineering Core Requirement,” page 221, as part of the engineering core requirements:

ECE	100	Introduction to Engineering Design *CS*	3
ECE	201	Electrical Networks I	4
ECE	210	Engineering Mechanics I: Statics	3
ECE	212	Engineering Mechanics II: Dynamics	3
ECE	300	Intermediate Engineering Design *L*	3
ECE	313	Introduction to Deformable Solids	3
ECE	340	Thermodynamics	3
ECE	350	Structure and Properties of Materials	3
Total			25

AEROSPACE ENGINEERING—B.S.E.

The goal of the Aerospace Engineering program is to provide students with an education in technological areas critical to the design and development of aerospace vehicles and systems. The program emphasizes aeronautical engineering with topics in required courses covering aerodynamics, aerospace materials, aerospace structures, propulsion, flight mechanics, aircraft performance, and stability and control. Astronautic topics such as orbital mechanics, attitude dynamics, spacecraft control, and rocket propulsion are also covered in required courses.

Design is integrated throughout the curriculum beginning with ECE 100 Introduction to Engineering Design and followed later by ECE 300 Intermediate Engineering Design, both of which focus on basic design theory as well as professional practice. These required courses are followed by topic-specific design content in aerospace engineering courses in the junior and senior years. The senior capstone design course integrates design and analysis topics from the earlier courses and completes the required design sequence. This sequence includes a minimum of one-half year of required design. In addition, many of the aerospace technical electives have design content.

Laboratory experience is provided in the areas of aerodynamics, aerospace structures, and vibrations. Laboratory facilities include four major wind tunnels, an integrated mechanical-testing laboratory, a controls laboratory, and a vibrations laboratory.

Aerospace Engineering Major

Aerospace Engineering students are required to take the following two courses in addition to those required for the major:

MAT	242	Elementary Linear Algebra	2
PHY	361	Introductory Modern Physics	3

The Aerospace Engineering major consists of the following courses:

ECE	384	Numerical Methods for Engineers	4
MAE	101	Introduction to Aerospace Engineering	2
MAE	317	Dynamic Systems and Control	3
MAE	319	Measurements and Data Analysis	3
MAE	361	Aerodynamics I	3
MAE	413	Aircraft Performance, Stability, and Control	3
MAE	415	Vibration Analysis	4
MAE	425	Aerospace Structures	4
MAE	444	Fundamentals of Aerospace Design	3
MAE	460	Gas Dynamics	3
MAE	462	Space Vehicle Dynamics and Control	3
MAE	463	Propulsion	3
MAE	464	Aerospace Laboratory	3
MAE	468	Aerospace Systems Design *L*	3
Area of study (technical electives)			6
Total			50

Aerospace Engineering Areas of Study

To further the design experience, all Aerospace Engineering students must choose at least one technical elective from the following list of courses:

MAE	426	Design of Aerospace Structures	3
MAE	465	Rocket Propulsion	3
MAE	466	Rotary Wing Aerodynamics and Performance	3
MAE	467	Aircraft Performance	3
MAE	469	Projects in Astronautics or Aeronautics	3

The remaining technical elective(s) may be selected from among any of the courses listed in the following course tables or from courses listed under the Mechanical Engineering areas of study. The courses are grouped so that the student may select an elective package of closely related courses. A student may, with prior approval of the advisor and department, select a general area and a corresponding set of courses not listed that would support a career objective not covered by the categories shown below. *Note:* MAE 371 may *not* be substituted for MAE 361, MAE 422 may

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

not be substituted for MAE 425, and MAE 441 may *not* be substituted for MAE 444.

Aerodynamics

MAE 372 Fluid Mechanics....3
MAE 435 Turbomachinery....3
MAE 461 Aerodynamics II....3
MAE 463 Propulsion....3
MAE 466 Rotary Wing Aerodynamics and Performance....3
MAE 471 Computational Fluid Dynamics....3
MAE 490 Projects in Design and Development *L*....3
MAT 421 Applied Computational Methods *CS*....3

Aerospace Materials

MAE 455 Polymers and Composites....3
MSE 355 Introduction to Materials Science and Engineering....3
MSE 420 Physical Metallurgy....3
MSE 440 Mechanical Properties of Solids....3
MSE 441 Analysis of Material Failures....3
MSE 450 X-ray and Electron Diffraction....3
MSE 471 Introduction to Ceramics....3

Aerospace Structures

MAE 404 Finite Elements in Engineering....3
MAE 426 Design of Aerospace Structures....3
MAE 455 Polymers and Composites....3
MAE 490 Projects in Design and Development *L*....3

Computer Methods

ASE 485 Engineering Statistics *CS*....3
CSE 310 Data Structures and Algorithms....3
CSE 422 Microprocessor System Design II....4
CSE 428 Computer-Aided Processes....3
IEE 463 Computer-Aided Manufacturing and Control *CS*....3
IEE 475 Simulating Stochastic Systems *CS*....3
MAE 404 Finite Elements in Engineering....3
MAE 406 CAD/CAM Applications in MAE....4
MAE 471 Computational Fluid Dynamics....3
MAE 541 CAD Tools for Engineers....3
MAT 421 Applied Computational Methods *CS*....3
MAT 423 Numerical Analysis I *CS*....3
MAT 425 Numerical Analysis II *CS*....3

Design

MAE 341 Mechanism Analysis and Design....3
MAE 404 Finite Elements in Engineering....3
MAE 406 CAD/CAM Applications in MAE....4
MAE 426 Design of Aerospace Structures....3
MAE 435 Turbomachinery....3
MAE 442 Mechanical Systems Design....3
MAE 446 Thermal Systems Design....3
MAE 455 Polymers and Composites....3
MAE 466 Rotary Wing Aerodynamics and Performance....3
MAE 467 Aircraft Performance....3
MAE 490 Projects in Design and Development *L*....3
MSE 440 Mechanical Properties of Solids....3
MSE 441 Analysis of Material Failures....3

Mechanical

Any course listed under the Mechanical Engineering concentrations except MAE 371, 422, and 441....3

Propulsion

MAE 382 Thermodynamics....3
MAE 388 Heat Transfer....3
MAE 434 Internal Combustion Engines....3
MAE 435 Turbomachinery....3
MAE 436 Combustion....3
MAE 461 Aerodynamics II....3
MAE 465 Rocket Propulsion....3
MAE 466 Rotary Wing Aerodynamics and Performance....3
MAE 471 Computational Fluid Dynamics....3
MAE 490 Projects in Design and Development *L*....3

System Dynamics and Control

CSE 428 Computer-Aided Processes....3
EEE 480 Feedback Systems....4
EEE 482 Introduction to State Space Methods....3
MAE 417 Control System Design....3
MAE 447 Robotics and Its Influence on Design....3
MAE 469 Projects in Astronautics or Aeronautics....3
MAE 490 Projects in Design and Development *L*....3

TYPICAL FOUR-YEAR SEQUENCE

The first two years are usually devoted to the General Studies and engineering core requirements. Thus, the degree programs in the department share essentially the same course schedule for that period of time. A typical schedule is given below.

Aerospace Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM 114 General Chemistry for Engineers *SQ*....4
or CHM 116 General Chemistry *SQ* (4)
ECE 100 Introduction to Engineering Design *CS*....3
or HU/SB elective[1]
ENG 101 First-Year Composition....3
MAE 101 Introduction to Aerospace Engineering....2
MAT 270 Calculus with Analytic Geometry I *MA*....4

Total....16

Second Semester

ENG 102 First-Year Composition....3
MAT 242 Elementary Linear Algebra....2
MAT 271 Calculus with Analytic Geometry II *MA*....4
PHY 121 University Physics I: Mechanics *SQ*[2]....3
PHY 122 University Physics Laboratory I *SQ*[2]....1
HU/SB and awareness area course[1]....3
or ECE 100 Introduction to Engineering Design *CS* (3)

Total....16

Second Year

First Semester

ECE 210 Engineering Mechanics I: Statics....3
ECE 350 Structure and Properties of Materials....3
MAT 272 Calculus with Analytic Geometry III *MA*....4
MAT 274 Elementary Differential Equations *MA*....3
PHY 131 University Physics II: Electricity and Magnetism *SQ*[3]....3
PHY 132 University Physics Laboratory II *SQ*[3]....1

Total....17

Second Semester

ECE 201 Electrical Networks I....4
ECE 212 Engineering Mechanics II: Dynamics....3
ECE 313 Introduction to Deformable Solids....3
ECE 340 Thermodynamics....3
ECE 384 Numerical Methods for Engineers....4

Total....17

Third Year

First Semester

ECE 300	Intermediate Engineering Design *L*	3
MAE 317	Dynamic Systems and Control	3
MAE 319	Measurements and Data Analysis	3
MAE 361	Aerodynamics I	3
MAE 425	Aerospace Structures	4
Total		16

Second Semester

MAE 413	Aircraft Performance, Stability, and Control	3
MAE 444	Fundamentals of Aerospace Design	3
MAE 460	Gas Dynamics	3
PHY 361	Introductory Modern Physics	3
HU/SB and awareness area course[1]		3
Total		15

Fourth Year

First Semester

MAE 415	Vibration Analysis	4
MAE 462	Space Vehicle Dynamics and Control	3
MAE 463	Propulsion	3
MAE 464	Aerospace Laboratory	3
HU/SB and awareness area course[1]		3
Total		16

Second Semester

MAE 468	Aerospace Systems Design *L*	3
HU/SB and awareness area courses[1]		6
Required design technical elective		3
Technical elective		3
Total		15

1 Engineering students may not use aerospace studies (AES) or military science (MIS) courses to satisfy HU or SB requirements.

2 Both PHY 121 and 122 must be taken to secure SQ credit.

3 Both PHY 131 and 132 must be taken to secure SQ credit.

MECHANICAL ENGINEERING —B.S.E.

Mechanical engineering is a creative discipline that draws upon a number of basic sciences to design the devices, machines, processes, and systems that involve mechanical work and its conversion from and into other forms. It includes the conversion of thermal, chemical, and nuclear energy into mechanical energy through various engines and power plants; the transport of energy via devices such as heat exchangers, pipelines, gears, and linkages; and the use of energy to perform a variety of tasks for the benefit of society, such as in transportation vehicles of all types, manufacturing tools and equipment, and household appliances. Furthermore, since all hardware products must be constructed of solid materials and because most products contain parts that transmit forces, mechanical engineering is involved in the structural integrity and materials selection for almost every product on the market.

Mechanical engineers are employed in virtually every kind of industry. They are involved in seeking new knowledge through research, in generating creative design and development, and in the production, control, management, and sales of the devices and systems needed by society. Therefore, a major strength of a mechanical engineering education is the flexibility it provides in future employment opportunities for its graduates.

The undergraduate curriculum includes the study of the principles governing the use of energy; the principles of design, instruments and control devices; and the application of these studies to the creative solution of practical, modern problems.

Design is integrated throughout the curriculum, beginning with ECE 100 Introduction to Engineering Design and followed later by ECE 300 Intermediate Engineering Design, both of which focus on basic design theory as well as professional practice. These required courses are followed by topic specific design content in mechanical engineering courses in the junior and senior years. The senior capstone design course combines the design topics from the earlier courses and completes the required design sequence. In addition, many of the mechanical technical electives have design content.

Laboratory experience is provided in the areas of thermofluid systems, mechanics of materials, and controls. Laboratory facilities include a thermal systems laboratory, an integrated mechanical-testing laboratory, a controls laboratory, and a manufacturing laboratory.

Mechanical Engineering Major

Mechanical Engineering students are required to select the following supplemental courses:

ECE 384	Numerical Methods for Engineers	4
MAT 242	Elementary Linear Algebra	2
PHY 361	Introductory Modern Physics	3

The Mechanical Engineering major requires the following departmental courses:

MAE 317	Dynamic Systems and Control	3
MAE 319	Measurements and Data Analysis	3
MAE 371	Fluid Mechanics	3
MAE 388	Heat Transfer	3
MAE 422	Mechanics of Materials	4
MAE 441	Principles of Design	3
MAE 443	Engineering Design	3
MAE 490	Projects in Design and Development *L*	3
MAE 491	Experimental Mechanical Engineering	3
Area of study (technical electives)		18
Total		46

Mechanical Engineering Areas of Study

Technical electives may be selected from among any of the following courses or from courses listed under the Aerospace Engineering areas of study. The courses are grouped to assist a student in identifying areas of specialization. Students preferring a broader technical background may choose courses from different areas. Generally, no more than two technical elective courses from outside the department are allowed. Credit for courses not on the list requires prior approval of the advisor and department. Mechanical Engineering students may not use MAE 361, 425, or 444 to fulfill degree requirements.

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See “General Studies,” page 83.

Aerospace
Any course listed under the Aerospace Engineering areas of study except MAE 361, 425, and 444 3

Biomechanical
BME 411 Biomedical Engineering I 3
BME 412 Biomedical Engineering II 3
BME 416 Biomechanics 3
BME 419 Biocontrol Systems 3
EEE 302 Electrical Networks II 3
EEE 434 Quantum Mechanics for Engineers 3

Computer Methods
ASE 485 Engineering Statistics *CS* 3
CSE 310 Data Structures and Algorithms 3
CSE 422 Microprocessor System Design II 4
CSE 428 Computer-Aided Processes 3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3
IEE 475 Simulating Stochastic Systems *CS* 3
MAE 404 Finite Elements in Engineering 3
MAE 406 CAD/CAM Applications in MAE 4
MAE 471 Computational Fluid Dynamics 3
MAE 541 CAD Tools for Engineers 3
MAT 421 Applied Computational Methods *CS* 3
MAT 423 Numerical Analysis I *CS* 3
MAT 425 Numerical Analysis II *CS* 3

Control and Dynamic Systems
CSE 428 Computer-Aided Processes 3
EEE 360 Energy Conversion and Transport 4
EEE 480 Feedback Systems 4
EEE 482 Introduction to State Space Methods 3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3
MAE 413 Aircraft Performance, Stability, and Control 3
MAE 417 Control System Design 3
MAE 462 Space Vehicle Dynamics and Control 3
MAE 467 Aircraft Performance 3

Design
MAE 341 Mechanism Analysis and Design 3
MAE 351 Manufacturing Processes 3
MAE 404 Finite Elements in Engineering 3
MAE 406 CAD/CAM Applications in MAE 4
MAE 413 Aircraft Performance, Stability, and Control 3
MAE 417 Control System Design 3
MAE 434 Internal Combustion Engines 3
MAE 435 Turbomachinery 3
MAE 442 Mechanical Systems Design 4
MAE 446 Thermal Systems Design 3
MAE 447 Robotics and Its Influence on Design 3
MAE 462 Space Vehicle Dynamics and Control 3
MAE 467 Aircraft Performance 3

Energy Systems
EEE 360 Energy Conversion and Transport 4
MAE 372 Fluid Mechanics 3
MAE 382 Thermodynamics 3
MAE 434 Internal Combustion Engines 3
MAE 435 Turbomachinery 3
MAE 436 Combustion 3
MAE 446 Thermal Systems Design 3

Engineering Mechanics
MAE 341 Mechanism Analysis and Design 3
MAE 402 Introduction to Continuum Mechanics 3
MAE 404 Finite Elements in Engineering 3
MAE 413 Aircraft Performance, Stability, and Control 3
MAE 415 Vibration Analysis 4
MAE 426 Design of Aerospace Structures 3
MAE 442 Mechanical Systems Design 4
MAE 460 Gas Dynamics 3
MAE 461 Aerodynamics II 3
MAE 471 Computational Fluid Dynamics 3
MAT 421 Applied Computational Methods *CS* 3
MAT 423 Numerical Analysis I *CS* 3
MSE 440 Mechanical Properties of Solids 3

Manufacturing
CSE 428 Computer-Aided Processes 3
IEE 300 Economic Analysis for Engineers 3
IEE 374 Quality Control *CS* 3
IEE 461 Production Control 3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3
MAE 341 Mechanism Analysis and Design 3
MAE 351 Manufacturing Processes 3
MAE 404 Finite Elements in Engineering 3
MAE 442 Mechanical Systems Design 4
MAE 447 Robotics and Its Influence on Design 3
MAE 455 Polymers and Composites 3
MSE 355 Introduction to Materials Science and Engineering 3
MSE 420 Physical Metallurgy 3
MSE 431 Corrosion and Corrosion Control 3
MSE 440 Mechanical Properties of Solids 3

Stress Analysis, Failure Prevention, and Materials
MAE 341 Mechanism Analysis and Design 3
MAE 404 Finite Elements in Engineering 3
MAE 426 Design of Aerospace Structures 3
MAE 447 Robotics and Its Influence on Design 3
MAE 455 Polymers and Composites 3
MSE 355 Introduction to Materials Science and Engineering 3
MSE 420 Physical Metallurgy 3
MSE 431 Corrosion and Corrosion Control 3
MSE 440 Mechanical Properties of Solids 3
MSE 450 X-ray and Electron Diffraction 3

Thermosciences
MAE 372 Fluid Mechanics 3
MAE 382 Thermodynamics 3
MAE 433 Air Conditioning and Refrigeration 3
MAE 434 Internal Combustion Engines 3
MAE 435 Turbomachinery 3
MAE 436 Combustion 3
MAE 446 Thermal Systems Design 3
MAE 460 Gas Dynamics 3
MAE 463 Propulsion 3
MAE 471 Computational Fluid Dynamics 3

Mechanical Engineering Program of Study Typical Four-Year Sequence

First Year

First Semester
CHM 114 General Chemistry for Engineers *SQ* 4
or CHM 116 General Chemistry *SQ* (4)
ECE 100 Introduction to Engineering Design *CS* 3
or HU/SB elective[1]
ENG 101 First-Year Composition 3
MAT 270 Calculus with Analytic Geometry I *MA* 4
HU/SB and awareness area course[1] 3

Total 17

Second Semester
ENG 102 First-Year Composition 3
MAT 242 Elementary Linear Algebra 2
MAT 271 Calculus with Analytic Geometry II *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[2] 3
PHY 122 University Physics Laboratory I *SQ*[2] 1

HU/SB and awareness area course[1] ... 3
or ECE 100 Introduction to Engineering Design *CS* (3)

Total ... 16

Second Year

First Semester

ECE	210	Engineering Mechanics I: Statics	3
ECE	350	Structure and Properties of Materials	3
MAT	272	Calculus with Analytic Geometry III *MA*	4
MAT	274	Elementary Differential Equations *MA*	3
PHY	131	University Physics II: Electricity and Magnetism *SQ*[3]	3
PHY	132	University Physics Laboratory II *SQ*[3]	1
Total			17

Second Semester

ECE	201	Electrical Networks I	4
ECE	212	Engineering Mechanics II: Dynamics	3
ECE	313	Introduction to Deformable Solids	3
ECE	340	Thermodynamics	3
ECE	384	Numerical Methods for Engineers	4
Total			17

Third Year

First Semester

ECE	300	Intermediate Engineering Design *L*	3
MAE	317	Dynamic Systems and Control	3
MAE	319	Measurements and Data Analysis	3
MAE	371	Fluid Mechanics	3
MAE	422	Mechanics of Materials	4
Total			16

Second Semester

MAE	388	Heat Transfer	3
MAE	441	Principles of Design	3
HU/SB and awareness area courses[1]			3
Technical elective			6
Total			15

Fourth Year

First Semester

MAE	491	Experimental Mechanical Engineering	3
PHY	361	Introductory Modern Physics	3
HU/SB and awareness area course[1]			3
Technical electives			6
Total			15

Second Semester

MAE	443	Engineering Design	3
MAE	490	Projects in Design and Development *L*	3
HU/SB and awareness area course[1]			3
Technical electives			6
Total			15

[1] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to satisfy HU or SB requirements.

[2] Both PHY 121 and 122 must be taken to secure SQ credit.

[3] Both PHY 131 and 132 must be taken to secure SQ credit.

MECHANICAL AND AEROSPACE ENGINEERING (MAE)

MAE 101 Introduction to Aerospace Engineering. (2)
fall and spring
Careers in aerospace engineering, problem solving, computer usage in aerospace engineering, contemporary issues of the aerospace industry, the aerospace engineering curriculum. Pre- or corequisite: ECE 100.

MAE 317 Dynamic Systems and Control. (3)
fall and spring
Modeling and representations of dynamic physical systems, including transfer functions, block diagrams, and state equations. Transient response. Principles of feedback control and linear system analysis, including root locus and frequency response. Prerequisite: ECE 212.

MAE 319 Measurements and Data Analysis. (3)
fall and spring
Theory of measurement systems, sensors, digital data acquisition, signal processing and statistical analysis. Computer simulations and real-time experiments designed to illustrate these topics. Lecture, lab. Prerequisite: ECE 201. Pre- or corequisite: MAE 317.

MAE 341 Mechanism Analysis and Design. (3)
once a year
Positions, velocities, and accelerations of machine parts; cams, gears, flexible connectors, and rolling contact; introduces synthesis. Prerequisite: ECE 212.

MAE 351 Manufacturing Processes. (3)
fall and spring
Production technique and equipment. Casting and molding, forming, machining, joining and assembly, computer-integrated manufacturing, rapid prototyping, and electronics manufacturing. Cross-listed as IEE 360. Credit is allowed for only IEE 360 or MAE 351. Prerequisite: ECE 350.

MAE 361 Aerodynamics I. (3)
once a year
Fluid statics, conservation principles, stream function, velocity potential, vorticity, inviscid flow, Kutta-Joukowski, thin-airfoil theory, and panel methods. Prerequisites: ECE 212, 340.

MAE 371 Fluid Mechanics. (3)
fall and spring
Introductory concepts of fluid motions; fluid statics; control volume forms of basic principles; viscous internal flows. Prerequisites: ECE 212, 340.

MAE 372 Fluid Mechanics. (3)
once a year
Applies basic principles of fluid mechanics to problems in viscous and compressible flow. Prerequisites: ECE 384; MAE 361 (or 371).

MAE 382 Thermodynamics. (3)
once a year
Applied thermodynamics; gas mixtures, psychrometrics, property relationships, power and refrigeration cycles, and reactive systems. Prerequisite: ECE 340.

MAE 388 Heat Transfer. (3)
fall and spring
Steady and unsteady heat conduction, including numerical solutions; thermal boundary layer concepts and applications to free and forced convection. Thermal radiation concepts. Prerequisites: ECE 384; MAE 361 (or 371).

MAE 402 Introduction to Continuum Mechanics. (3)
once a year
Applies the principles of continuum mechanics to such fields as flow-in porous media, biomechanics, electromagnetic continua, and magneto-fluid mechanics. Prerequisites: ECE 313; MAE 361 (or 371); MAT 242 (or 342).

MAE 404 Finite Elements in Engineering. (3)
once a year
Introduces ideas and methodology of finite element analysis. Applications to solid mechanics, heat transfer, fluid mechanics, and vibrations. Prerequisites: ECE 313; MAT 242 (or 342).

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

MAE 406 CAD/CAM Applications in MAE. (4)
once a year
Solution of engineering problems with the aid of state-of-the-art software tools in solid modeling, engineering analysis, and manufacturing; selection of modeling parameters; reliability tests on software. 3 hours lecture, 3 hours lab. Prerequisites: ECE 384; MAE 422, 441 (or 444).

MAE 413 Aircraft Performance, Stability, and Control. (3)
spring
Aircraft performance, cruise, climbing and turning flights, energy maneuverability, 6 DOF equations for aircraft, aerodynamic stability derivatives, flight stability/control. Prerequisites: MAE 317, 361.

MAE 415 Vibration Analysis. (4)
fall
Free and forced response of single and multiple degree of freedom systems, continuous systems; applications in mechanical and aerospace systems numerical methods. Lecture, lab. Prerequisites: ECE 212; MAE 319, 422 (or 425); MAT 242 (or 342).

MAE 417 Control System Design. (3)
once a year
Tools and methods of control system design and compensation, including simulation, response optimization, frequency domain techniques, state variable feedback, and sensitivity analysis. Introduces nonlinear and discrete time systems. Prerequisite: MAE 317.

MAE 422 Mechanics of Materials. (4)
fall and spring
Failure theories, energy methods, finite element methods, plates, torsion of noncircular members, unsymmetrical bending, shear center, and beam column. Lecture, lab. Prerequisites: ECE 313; MAT 242 (or 342). Pre- or corequisite: ECE 384.

MAE 425 Aerospace Structures. (4)
fall
Stability, energy methods, finite element methods, torsion, unsymmetrical bending and torsion of multicelled structures, design of aerospace structures. Lecture, lab. Prerequisites: ECE 313; MAT 242 (or 342).

MAE 426 Design of Aerospace Structures. (3)
once a year
Flight vehicle loads, design of semimonocoque structures, local buckling and crippling, fatigue, aerospace materials, composites, joints, and finite element applications. Prerequisite: MAE 422 or 425.

MAE 433 Air Conditioning and Refrigeration. (3)
once a year
Air conditioning processes; environmental control; heating and cooling loads; psychrometry; refrigeration cycles. Prerequisite: MAE 388 or MET 432 or instructor approval.

MAE 434 Internal Combustion Engines. (3)
once a year
Performance characteristics, combustion, carburetion and fuel-injection, and the cooling and control of internal combustion engines. Computer modeling. Lab. Prerequisite: MAE 388.

MAE 435 Turbomachinery. (3)
once a year
Design and performance of turbomachines, including steam, gas and hydraulic turbines, centrifugal pumps, compressors, fans, and blowers. Pre- or corequisite: MAE 361 or 371.

MAE 436 Combustion. (3)
once a year
Thermochemical and reaction rate processes; combustion of gaseous and condensed-phase fuels. Applications to propulsion and heating systems. Pollutant formation. Prerequisite: MAE 388.

MAE 441 Principles of Design. (3)
fall and spring
Conceptual and embodiment design of mechanical elements; form synthesis; material selection, failure modes, manufacturability tolerances, common mechanisms, and machine elements. Lecture, lab (project). Prerequisites: ECE 300, 350. Pre- or corequisites: MAE 319, 422 (or 425).

MAE 442 Mechanical Systems Design. (4)
spring
Applies design principles and techniques to the synthesis, modeling, and optimization of mechanical, electromechanical, and hydraulic systems. Prerequisites: MAE 317, 441 (or 444).

MAE 443 Engineering Design. (3)
fall and spring
Group projects to design engineering components and systems. Problem definition ideation, modeling, and analysis; emphasizes decision making and documentation activities. 6 hours lab. Prerequisite: MAE 441.

MAE 444 Fundamentals of Aerospace Design. (3)
spring
Design theory and design tools applied to aerospace engineering. Engineering drawings, solid modeling, RFP's, Federal Aviation Regulations and military specifications, aircraft sizing, rapid prototyping. Lab, projects. Prerequisites: ECE 300, 350; MAE 319, 361, 425. Pre- or corequisite: MAE 413.

MAE 446 Thermal Systems Design. (3)
once a year
Applies engineering principles and techniques to the modeling and analysis of thermal systems and components. Presents and demonstrates optimization techniques and their use. Prerequisite: ECE 300; MAE 388.

MAE 447 Robotics and Its Influence on Design. (3)
once a year
Robot applications, configurations, singular positions, and work space; modes of control; vision; programming exercises; design of parts for assembly. Prerequisite: MAE 317.

MAE 455 Polymers and Composites. (3)
fall
Relationship between chemistry, structure, and properties of engineering polymers. Design, properties, and behavior of fiber composite systems. Cross-listed as MSE 470. Credit is allowed for only MAE 455 or MSE 470. Prerequisites: ECE 313, 350.

MAE 460 Gas Dynamics. (3)
spring
Compressible flow at subsonic and supersonic speeds; duct flow; normal and oblique shocks, perturbation theory, and wind tunnel design. Prerequisites: ECE 384; MAE 361 (or 371).

MAE 461 Aerodynamics II. (3)
once a year
Transonic/hypersonic flows, wing theory, Navier-Stokes, laminar/turbulent shear flows, pressure drop in tubes, separation, drag, viscous/inviscid interaction, and wing design. Prerequisite: MAE 460.

MAE 462 Space Vehicle Dynamics and Control. (3)
fall
Attitude dynamics and control, launch vehicles, orbital mechanics, orbital transfer/rendezvous, space mission design, space structures, spacecraft control systems design. Prerequisite: MAE 317.

MAE 463 Propulsion. (3)
fall
Fundamentals of gas-turbine engines and design of components. Principles and design of rocket propulsion and alternative devices. Lecture, design projects. Prerequisites: ECE 384; MAE 382 (or 460).

MAE 464 Aerospace Laboratory. (3)
fall
Aerodynamic flow parameters; flow over airfoils and bodies of revolution; flow visualization; computer-aided data acquisition and processing; boundary layer theory. 1 hour lecture, 4 hours lab. Prerequisites: ECE 384; MAE 319, 460.

MAE 465 Rocket Propulsion. (3)
once a year
Rocket flight performance; nozzle design; combustion of liquid and solid propellants; component design; advanced propulsion systems; interplanetary missions; testing. Prerequisite: MAE 382 or 460.

MAE 466 Rotary Wing Aerodynamics and Performance. (3)
once a year
Introduces helicopter and propeller analysis techniques. Momentum, blade-element, and vortex methods. Hover and forward flight. Ground effect, autorotation, and compressibility effects. Prerequisites: both ECE 384 and MAE 361 or only instructor approval.

MAE 467 Aircraft Performance. (3)
once a year
Integrates aerodynamic and propulsive forces into aircraft performance design. Estimation of drag parameters for design. Engine, airfoil selection. Conceptual design methodology. Lecture, design projects. Prerequisite: MAE 361 or 371. Pre- or corequisite: MAE 444.

MAE 468 Aerospace Systems Design. (3)
fall and spring
Group projects related to aerospace vehicle design, working from mission definition and continuing through preliminary design. Prerequisites: MAE 413, 444. Pre- or corequisite: MAE 463.
General Studies: L

MAE 469 Projects in Astronautics or Aeronautics. (3)
fall and spring
Various multidisciplinary team projects available each semester. Projects include design of high-speed rotocraft autonomous vehicles, liquid-fueled rockets, microaerial vehicles, satellites. Prerequisite: instructor approval.

MAE 471 Computational Fluid Dynamics. (3)
once a year
Numerical solutions for selected problems in fluid mechanics. Prerequisites: ECE 384; MAE 361 (or 371).

MAE 490 Projects in Design and Development. (3)
fall and spring
Capstone projects in fundamental or applied aspects of engineering. Prerequisites: MAE 441, 491.
General Studies: L

MAE 491 Experimental Mechanical Engineering. (3)
fall and spring
Experimental and analytical studies of phenomena and performance of fluid flow, heat transfer, thermodynamics, refrigeration, and mechanical power systems. 6 hours lab. Prerequisites: MAE 319, 388.

MAE 498 Pro-Seminar. (1–3)
selected semesters
Special topics for advanced students. Applies the engineering disciplines to design and analysis of modern technical devices and systems. Prerequisite: instructor approval.

MAE 504 Laser Diagnostics. (3)
spring
Fundamentals of optics and the interaction of light with matter. Laser sources, laser spectroscopy, velocimetry, particle sizing, and surface characterization.

MAE 505 Perturbation Methods. (3)
selected semesters
Nonlinear oscillations, strained coordinates, renormalization, multiple scales, boundary layers, matched asymptotic expansions, turning point problems, and WKBJ method. Cross-listed as MAT 505. Credit is allowed for only MAE 505 or MAT 505.

MAE 506 Advanced System Modeling, Dynamics, and Control. (3)
spring
Lumped-parameter modeling of physical systems with examples. State variable representations and dynamic response. Introduces modern control. Prerequisite: ASE 582 or MAT 442.

MAE 507 Optimal Control. (3)
fall
Optimal control of systems. Calculus of variations, dynamic programming, linear quadratic regulator, numerical methods, and Pontryagin's principle. Cross-listed as EEE 587. Credit is allowed for only EEE 587 or MAE 507. Prerequisite: EEE 482 or MAE 506.

MAE 509 Robust Multivariable Control. (3)
spring
Characterization of uncertainty in feedback systems, robustness analysis, synthesis techniques, multivariable Nyquist criteria, computer-aided analysis and design. Prerequisites: MAE 417, 506.

MAE 510 Dynamics and Vibrations. (3)
fall
Lagrange's and Hamilton's equations, rigid body dynamics, gyroscopic motion, and small oscillation theory.

MAE 511 Acoustics. (3)
fall
Principles underlying the generation, transmission, and reception of acoustic waves. Applications to noise control, architectural acoustics, random vibrations, and acoustic fatigue.

MAE 512 Random Vibrations. (3)
spring
Reviews probability theory, random processes, stationarity, power spectrum, white noise process, random response of single and multiple DOF systems, and Markov processes simulation. Prerequisite: MAE 510 or instructor approval.

MAE 515 Structural Dynamics. (3)
spring
Free vibration and forced response of discrete and continuous systems, exact and approximate methods of solution, finite element modeling, and computational techniques. Prerequisite: MAE 510 or instructor approval.

MAE 518 Dynamics of Rotor-Bearing Systems. (3)
spring
Natural whirl frequency, critical speed, and response analysis of rigid and flexible rotor systems. Bearing influence and representation. Stability analysis. Methods of balancing.

MAE 520 Solid Mechanics. (3)
fall
Introduces tensors: kinematics, kinetics, and constitutive assumptions leading to elastic, plastic, and viscoelastic behavior. Applications.

MAE 521 Structural Optimization. (3)
selected semesters
Linear and nonlinear programming. Problem formulation. Constrained and unconstrained optimization. Sensitivity analysis. Approximate techniques. FEM-based optimal design of mechanical and aerospace structures. Cross-listed as CEE 533. Credit is allowed for only CEE 533 or MAE 521. Prerequisite: instructor approval.

MAE 523 Theory of Plates and Shells. (3)
fall
Linear and nonlinear theories of plates. Membrane and bending theories of shells. Shells of revolution. Prerequisite: MAE 520.

MAE 524 Theory of Elasticity. (3)
spring
Elastic behavior in two and three dimensions. Airy stress functions and displacement potentials. Elements of fracture. Prerequisite: MAE 520.

MAE 527 Finite Element Methods in Engineering Science. (3)
fall
Discretization, interpolation, elemental matrices, assembly, and computer implementation. Application to solid and fluid mechanics, heat transfer, and time-dependent problems. Prerequisite: ASE 582.

MAE 536 Combustion. (3)
selected semesters
Thermodynamics; chemical kinetics of combustion. Explosion and ignition theories. Reactive gas dynamics. Structure, propagation, and stability of flames. Experimental methods. Prerequisite: MAE 436 or instructor approval.

MAE 540 Advances in Engineering Design Theory. (3)
fall
Survey of research in engineering design process, artifact and design, knowledge, formal and informal logic, heuristic and numerical searches, theory of structure and complexity. Prerequisite: graduate standing.

MAE 541 CAD Tools for Engineers. (3)
fall
Elements of computer techniques required to develop CAD software. Data structures, including lists, trees, and graphs. Computer graphics, including 2- and 3-dimensional algorithms and user interface techniques.

MAE 544 Mechanical Design and Failure Prevention. (3)
fall
Modes of mechanical failure; applies principles of elasticity and plasticity in multiaxial state of stress to design synthesis; failure theories; fatigue; creep; impact. Prerequisite: MAE 443.

MAE 546 CAD/CAM Applications in MAE. (4)
once a year
Solution of engineering problems with the aid of state-of-the-art software tools in solid modeling, engineering analysis, and manufacturing; selection of modeling parameters; reliability tests on software. Open only to students without previous credit for MAE 406. 3 hours lecture, 3 hours lab. Prerequisites: ECE 384; MAE 422, 441 (or 444).

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

MAE 547 Mechanical Design and Control of Robots. (3)
selected semesters
Homogeneous transformations, 3-dimensional kinematics, geometry of motion, forward and inverse kinematics, workspace and motion trajectories, dynamics, control, and static forces.

MAE 548 Mechanism Synthesis and Analysis. (3)
spring
Algebraic and graphical methods for exact and approximate synthesis of cam, gear, and linkage mechanisms; design optimization; methods of planar motion analysis; characteristics of plane motion; spatial kinematics.

MAE 557 Mechanics of Composite Materials. (3)
spring
Analyzes composite materials and applications. Micromechanical and macromechanical behavior. Classical lamination theory developed with investigation of bending-extension coupling.

MAE 560 Propulsion Systems. (3)
selected semesters
Design of air-breathing gas turbine engines for aircraft propulsion; mission analysis; cycle analysis; engine sizing; component design.

MAE 561 Computational Fluid Dynamics. (3)
spring
Finite-difference and finite-volume techniques for solving the subsonic, transonic, and supersonic flow equations. Method of characteristics. Numerical grid-generation techniques. Prerequisite: MAE 571 or instructor approval.

MAE 563 Unsteady Aerodynamics. (3)
spring
Unsteady incompressible and compressible flow. Wings and bodies in oscillatory and transient motions. Kernel function approach and panel methods. Aeroelastic applications. Prerequisite: MAE 460 or 461.

MAE 564 Advanced Aerodynamics. (3)
fall
Perturbation method. Linearized subsonic and supersonic flows. Thin wing/slender body theories. Lifting surface theory. Panel method computation. Prerequisite: MAE 460 or 461.

MAE 566 Rotary-Wing Aerodynamics. (3)
fall
Introduces helicopter and propeller analysis techniques. Momentum, blade-element, and vortex methods. Hover and forward flight. Ground effect, autorotation, and compressibility effects. Prerequisite: MAE 361.

MAE 571 Fluid Mechanics. (3)
fall
Basic kinematic, dynamic, and thermodynamic equations of the fluid continuum and their application to basic fluid models.

MAE 572 Inviscid Fluid Flow. (3)
spring
Mechanics of fluids for flows in which the effects of viscosity may be ignored. Potential flow theory, waves, and inviscid compressible flows. Prerequisite: MAE 571.

MAE 573 Viscous Fluid Flow. (3)
fall
Mechanics of fluids for flows in which the effects of viscosity are significant. Exact and approximate solutions of the Navier-Stokes system, laminar flow at low and high Reynolds number. Prerequisite: MAE 571.

MAE 575 Turbulent Shear Flows. (3)
fall
Homogeneous, isotropic, and wall turbulence. Experimental results. Introduces turbulent-flow calculations. Prerequisite: MAE 571.

MAE 577 Turbulent Flow Modeling. (3)
spring
Reynolds equations and their closure. Modeling of simple and complex turbulent flows, calculations of internal and external flows, and application to engineering problems. Prerequisite: MAE 571.

MAE 581 Thermodynamics. (3)
fall
Basic concepts and laws of classical equilibrium thermodynamics; applications to engineering systems. Introduces statistical thermodynamics.

MAE 582 Statistical Thermodynamics. (3)
once a year
Kinetic and quantum theory. Statistical mechanics; ensemble theory. Structure and thermodynamics of noninteracting and interacting particles. Boltzmann integro-differential equation. Prerequisite: graduate standing.

MAE 585 Conduction Heat Transfer. (3)
fall
Basic equations and concepts of conduction heat transfer. Mathematical formulation and solution (analytical and numerical) of steady and unsteady, one- and multidimensional heat conduction and phase change problems. Prerequisites: ECE 384; MAE 388.

MAE 586 Convection Heat Transfer. (3)
spring
Basic concepts and governing equations. Analyzes laminar and turbulent heat transfer for internal and external flows. Natural and mixed convection. Prerequisite: MAE 388.

MAE 587 Radiation Heat Transfer. (3)
fall
Advanced concepts and solution methodologies for radiation heat transfer, including exchange of thermal radiation between surfaces, radiation in absorbing, emitting, and scattering media and radiation combined with conduction and convection. Prerequisite: MAE 388.

MAE 588 Two-Phase Flows and Boiling Heat Transfer. (3)
spring
Pool and flow boiling heat transfer, condensation heat transfer, various models of vapor-liquid mixture flows, gas-solid mixture flows, and experimental measurement techniques.

MAE 589 Heat Transfer. (3)
fall
Basic concepts; physical and mathematical models for heat transfer. Applications to conductive, convective, radiative, and combined mode heat transfer. Prerequisite: MAE 388.

MAE 594 Graduate Research Conference. (1)
fall and spring
Topics in contemporary research. Required every semester of all departmental graduate students registered for 9 or more semester hours. Not for degree credit.

MAE 598 Special Topics. (1–4)
fall and spring
Special topics courses, including the following, which are regularly offered, are open to qualified students. Topics may include the following:

- Advanced Spacecraft Control. (1–3)
- Aeroelasticity. (1–3)
- Aerospace Vehicle Guidance and Control. (1–3)
- Boundary Layer Stability. (1–3)
- Hydrodynamic Stability. (1–3)
- Plasticity. (1–3)
- Polymers and Composites. (1–3)

Omnibus Courses. For an explanation of courses offered but not specifically listed in this catalog, see “Omnibus Courses,” page 56.

Programs in Engineering Special Studies

480/965-1726

ECG 104

Ronald J. Roedel, Director

The major of Engineering Special Studies accommodates students whose educational objectives require more intensity of concentration on a particular subject or more curricular flexibility within an engineering discipline than the traditional departmental majors generally permit. The major is a School of Engineering program. Unlike the departmental major areas, however, there is not a separate faculty. The faculty teaching and advising in these programs are from the various departments within the School of Engineering.

For many students, engineering studies form the basis of preparation for professional engineering work where proficiency in the application of science and the physical and social technologies is brought to bear on problems of a large scope. The necessary breadth that these students seek often is not obtainable in traditional engineering fields. Rather, specially designed programs of course work that merge the required principles and approaches drawn from all fields of engineering and other pertinent disciplines are desired.

The B.S.E. degree in Engineering Special Studies is designed primarily for students intending to pursue engineering careers at a professional level in industry or graduate studies.

ENGINEERING SPECIAL STUDIES—B.S.E.

Premedical Engineering. In recent decades, the interrelation between engineering and medicine has become vigorous and exciting. Rapidly expanding technology dictates that engineering will continue to become increasingly involved in all branches of medicine. As this develops, so will the need for physicians trained in the engineering sciences—medical men and women with a knowledge of computer technology, transport phenomena, biomechanics, bioelectric phenomena, operations research, and cybernetics. This concentration is of special interest to students who desire entry into a medical college and who have medical interests in research, aerospace and undersea medicine, artificial organs, prostheses, biomedical engineering, or biophysics. Since both engineering and medicine have as their goal the well-being of humans, this program is compatible with any field of medical endeavor. This program is administered with the Department of Bioengineering.

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Engineering Special Studies with a concentration in Premedical Engineering. A minimum of 50 upper-division hours is required. Students must attain a GPA of at least 2.00 for the courses in the major field.

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 79.

Note: To fulfill medical school admission requirements, BIO 187 General Biology is required in addition to the degree requirements and is best taken in summer session before the Medical College Admission Test.

COURSE REQUIREMENTS

The course work for the undergraduate degree can be classified into the following categories (in semester hours):

First-Year Composition

Choose among the course combinations below 6

ENG 101 First-Year Composition (3)
ENG 102 First-Year Composition (3)

—or—

ENG 105 Advanced First-Year Composition (3)
Elective chosen with an advisor (3)

—or—

ENG 107 English for Foreign Students (3)
ENG 108 English for Foreign Students (3)

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111 Macroeconomic Principles *SB*[1] 3
or ECN 112 Microeconomic Principles *SB*[1] (3)
HU/SB and awareness area courses[2] 12

Total 15

Literacy and Critical Inquiry

BME 413 Biomedical Instrumentation *L* 3
BME 423 Biomedical Instrumentation Laboratory *L* 1
ECE 300 Intermediate Engineering Design *L* 3

Total 7

Natural Sciences

PHY 121 University Physics I: Mechanics *SQ*[3] 3
PHY 122 University Physics Laboratory I *SQ*[3] 1
PHY 131 University Physics II: Electricity and Magnetism *SQ*[4] 3
PHY 132 University Physics Laboratory II *SQ*[4] 1

Total 8

Mathematical Studies

ECE 100 Introduction to Engineering Design *CS* 3
ECE 384 Numerical Methods for Engineers 4
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 22
General Studies/school requirements total 52

Engineering Core

ECE 201 Electrical Networks I 4
ECE 210 Engineering Mechanics I: Statics 3
ECE 334 Electronic Devices and Instrumentation 4
ECE 340 Thermodynamics 3
ECE 350 Structure and Properties of Materials 3

Total 17

Engineering Special Studies Program Major—Premedical Engineering Concentration

BIO 188 General Biology II *SQ* 4
BME 201 Introduction to Bioengineering *L* 3
BME 318 Biomaterials 3
BME 331 Biomedical Engineering Transport: Fluids 3
BME 334 Bioengineering Heat and Mass Transfer 3
BME 416 Biomechanics 3
BME 417 Biomedical Engineering Capstone Design I 3
BME 435 Physiology for Engineers 4

L literacy and critical inquiry / **MA** mathematics / **CS** computer/statistics/quantitative applications / **HU** humanities and fine arts / **SB** social and behavioral sciences / **SG** natural science—general core courses / **SQ** natural science—quantitative / **C** cultural diversity in the United States / **G** global / **H** historical / See "General Studies," page 83.

BME 470 Microcomputer Applications in Bioengineering............4
BME 490 Biomedical Engineering Capstone Design II.................3
CHM 113 General Chemistry *SQ*..4
CHM 116 General Chemistry *SQ*..4
CHM 331 General Organic Chemistry 3
CHM 332 General Organic Chemistry 3
CHM 335 General Organic Chemistry Laboratory.........................1
CHM 336 General Organic Chemistry Laboratory.........................1
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
Technical elective..1

Total 53

[1] ECN 111 or 112 must be included to fulfill the HU and SB requirements.

[2] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to fulfill HU and SB requirements.

[3] Both PHY 121 and 122 must be taken to secure SQ credit.

[4] Both PHY 131 and 132 must be taken to secure SQ credit.

Premedical Engineering Program of Study Typical Four-Year Sequence

First Year

First Semester

CHM 113 General Chemistry *SQ*..4
ECE 100 Introduction to Engineering Design *CS*.........................3
ENG 101 First-Year Composition..3
MAT 270 Calculus with Analytic Geometry I *MA*........................4

Total 14

Second Semester

CHM 116 General Chemistry *SQ*..4
ENG 102 First-Year Composition..3
MAT 271 Calculus with Analytic Geometry II *MA*......................4
PHY 121 University Physics I: Mechanics *SQ*[1]...........................3
PHY 122 University Physics Laboratory I *SQ*[1]............................1

Total 15

Second Year

First Semester

BIO 188 General Biology II *SQ*...4
BME 201 Introduction to Bioengineering *L*..................................3
ECE 210 Engineering Mechanics I: Statics...................................3
MAT 272 Calculus with Analytic Geometry III *MA*......................4
PHY 131 University Physics II: Electricity and Magnetism *SQ*[2]..3
PHY 132 University Physics Laboratory II *SQ*[2]...........................1

Total 18

Second Semester

CHM 331 General Organic Chemistry 3
CHM 335 General Organic Chemistry Laboratory.........................1
ECE 201 Electrical Networks I 4
ECE 350 Structure and Properties of Materials 3
ECN 111 Macroeconomic Principles *SB*.......................................3
or ECN 112 Microeconomic Principles *SB* (3)
MAT 274 Elementary Differential Equations *MA*.........................3

Total 17

Third Year

First Semester

BME 331 Biomedical Engineering Transport: Fluids 3
BME 435 Physiology for Engineers...4
ECE 300 Intermediate Engineering Design *L* 3
ECE 340 Thermodynamics..3
ECE 384 Numerical Methods for Engineers..................................4

Total 17

Second Semester

BME 318 Biomaterials 3
BME 334 Bioengineering Heat and Mass Transfer........................3
CHM 332 General Organic Chemistry 3
CHM 336 General Organic Chemistry Laboratory.........................1
ECE 334 Electronic Devices and Instrumentation 4
HU/SB and awareness area course[3]..3

Total 17

Fourth Year

First Semester

BME 413 Biomedical Instrumentation *L*..3
BME 416 Biomechanics...3
BME 417 Biomedical Engineering Capstone Design I..................3
BME 423 Biomedical Instrumentation Laboratory *L*.....................1
HU/SB and awareness area courses[3] 6

Total 16

Second Semester

BME 470 Microcomputer Applications in Bioengineering............4
BME 490 Biomedical Engineering Capstone Design II.................3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
HU/SB and awareness area course[3]..3
Technical elective..1

Total 14
Total degree requirements..128

[1] Both PHY 121 and 122 must be taken to secure SQ credit.

[2] Both PHY 131 and 132 must be taken to secure SQ credit.

[3] Engineering students may not use aerospace studies (AES) or military science (MIS) courses to satisfy HU or SB requirements.