School of Engineering

(ECG 100) 602/965–1726

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 of technical educations, it also provides an opportunity for the development of many additional activities, aptitudes and interests, including moral, ethical, and professional concepts. In this era of rapid technological change, an engineering education serves our 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 our civilization as we know it may well 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 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 obtain a degree in engineering and who plan careers in which science, mathematics, and analytical methods are of special value;
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 a technical career;
4. those who desire pre-engineering 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

See pages 30–35, 47–48, 224–225, and 230 for information regarding requirements for admission, transfer, retention, disqualification, and reinstatement.

College students who are beginning their initial college work in the School of Engineering should present certain secondary school units in addition to the minimum university requirements. A total of three units is required in mathematics. College algebra, geometry, and trigonometry must 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 recommended.

Students who have omissions or deficiencies in subject matter preparation may be required to complete additional university credit course work that may not be applied toward an engineering degree. One or more of the courses—CHM 113 General Chemistry, CSE 181 Applied Problem Solving with BASIC, ENG 101 First-Year Composition*, MAT 118 Precalculus Algebra and Trigonometry, and PHY 105 Basic Physics—are taken to satisfy omissions or deficiencies.

DEGREES AND MAJORS

The Bachelor of Science (B.S.) and Bachelor of Science in Engineering (B.S.E.) degrees are composed of three parts: University General Studies, an engineering core, and a major. This combination is illustrated in the charts shown on pages 242–243.

The general studies courses satisfy a university requirement and include literacy and critical inquiry, humanities and fine arts, social and behavioral sciences, numeracy and natural sciences (see pages 49–51). In addition, there are requirements in the areas of cultural diversity in the United States, historical, and global awareness. These courses constitute approximately 28% of the degree program.

* See statement on English examinations under "Placement Examinations for Proficiency," page 40.

The engineering core is a specific and organized body of knowledge that serves as a foundation to engineering and for further specialized studies in a particular engineering major. These courses constitute approximately 33% of the degree program.

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 special and interdisciplinary studies (for example, manufacturing engineering and premedical engineering). In general, all curricula are extensions beyond the engineering core and cover a wide variety of subject areas within each field. About one-fourth of the major credits are reserved for the student's use as an area of emphasis. These credits are traditionally referred to as *technical electives.*

Majors and areas of emphasis are offered by the six engineering departments: Chemical, Bio and Materials Engineering; Civil Engineering; Computer Science and Engineering; Electrical Engineering; Industrial and Management Systems Engineering; and Mechanical and Aerospace Engineering. The majors of the Engineering Special Studies and Engineering Interdisciplinary Studies are administered by the Office of the Dean and are designed for those students whose educational objectives require more intensity of concentration or flexibility than is possible in the traditional departmental fields (see pages 277–280).

The first two years of study are concerned primarily with the general studies and the engineering core, with more time being spent on general studies.

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. This arrangement can be illustrated by the chart below.

The sequential arrangement of all course work for the B.S. and B.S.E. degrees into the three categories shown below is especially helpful to the beginning student. The semester-by-semester selection of courses varies from one field to another. An example of a typical freshman engineering schedule is shown below.

Typical Freshman Year

			Semester Hours
First Semester			
CHM	114	General Chemistry for Engineers[1] or CHM 116 General Chemistry (4)	4
ECE	105	Introduction to Languages of Engineering[2]	3
MAT	290	Calculus I[3]	5
HU or SB elective[4]		or ENG 101 First-Year Composition (3)[5]	6
Total			18
Second Semester			
ECE	106	Introduction to Computer-Aided Engineering	3
ENG	102	First-Year Composition or ENG 105 Advanced First-Year Composition (3)[5]	3
MAT	291	Calculus II[3]	5
PHY	121	University Physics I: Mechanics[6]	3
PHY	122	University Physics Laboratory I	1
HU or SB elective[4]			3
Total			18

[1] Chemical Engineering, Bioengineering, Materials Science and Engineering, and Pre-medical engineering students take CHM 113 and 116.

[2] Students with no computer background should enroll in CSE 181 Applied Problem Solving with BASIC before enrolling in ECE 105.

[3] MAT 270, 271, and 272 may be taken in lieu of MAT 290 and 291 (only 10 hours may be used to satisfy graduation requirements).

[4] See pages 53–71.

[5] Students not eligible for ENG 105 should complete ENG 101 in the first semester.

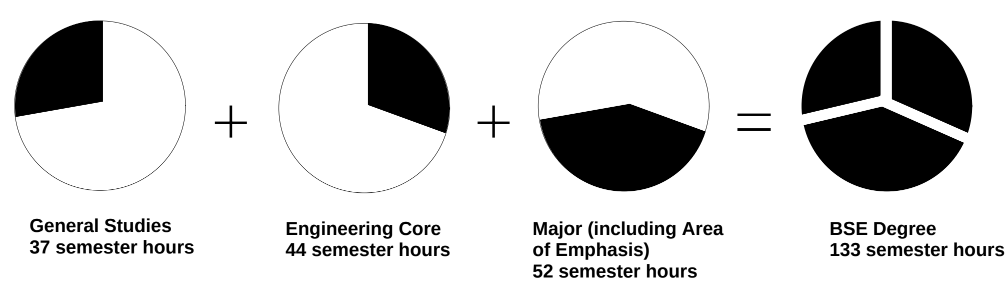
[6] Students who have not completed one unit of physics in high school should complete PHY 105 in the preceding semester.

Well-prepared students usually can complete the program of study leading to an undergraduate degree in engineering in four years or less by attending summer sessions. Many students, however, may 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 133 semester hours. Therefore, in cases of inadequate secondary preparation, poor health, or financial necessity requiring much time for outside work, the undergraduate program should be extended to five or more 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. It is the intent of the faculty that all students be prepared in the following areas:

1. *Competency in oral and written English.* This is considered to be essential for the engineering graduate. Although the requirement of specific course work may serve as a foundation for such competency, the development of communication skills should be demonstrated by student work in engineering courses. As a minimum and in addition to the 133 semester hour course requirements, all students must satisfy the university First-Year Composition requirements (see page 71).
2. *General studies.* This is to ensure that the engineering student acquires a satisfactory level of basic knowledge in the humanities and fine arts, social and behavioral sciences, literacy and critical inquiry, numeracy and natural sciences. These subjects are so selected as to give the engineer an increased awareness of social responsibilities, to provide an understanding of related factors in the decision-making process, and to provide a foundation for the study of engineering. *School of Engineering students must use caution in selecting their lower-division literacy and critical inquiry course (L1) because of accreditation requirements. The course selected should be one that is listed in the General Studies Courses table on pages 53–71 as satisfying both "L1" and "HU" or "L1" and "SB." Otherwise, the student must complete a total of 16 semester hours of humanities and social and behavioral sciences, instead of 15 semester hours, to satisfy the baccalaureate degree requirements in engineering. Because of accreditation requirements, aerospace studies (AES) and military science (MIS) courses are not acceptable for engineering degree credit as either humanities and fine arts or as a social and behavioral science.*
3. *Fundamental studies.* Studies in engineering and related subjects further develop the foundation for engineering and provide the base for specialized studies in a particular engineering discipline.



4. *Major studies.* These courses provide a depth of understanding for a more definitive body of knowledge appropriate to a particular aspect of societal concern. These studies include technical elective course work in an area of emphasis that may be selected by the student with the assistance of an advisor.

Also refer to the individual engineering department material for any additional specific departmental requirements.

The specific course requirements for the three parts of the B.S. and B.S.E. degrees are listed below.

B.S. and B.S.E. Degree Requirements

English Proficiency — *Semester Hours*

ENG 101, 102 First-Year Composition 6
or ENG 105 Advanced First-Year Composition (3)

General Studies

Literacy and Critical Inquiry[1]
(Six semester hours minimum)
ECE 400 Engineering Communications[2] 3
One L1 and HU or L1 and SB course[1] 3

Numeracy
(Six semester hours minimum)
ECE 106 Introduction to Computer-Aided Engineering[2] 3
MAT 290 Calculus I[2] 5
or MAT 270 Calculus with Analytic Geometry I (4)

Humanities and Fine Arts and Social and Behavioral Sciences[1]
(16 semester hours minimum)
At least one course must be of upper-division level; two courses must be from the same department; and two or more departments must be represented in total selection. If L1 course is also an HU or SB course, then 15 semester hours minimum are required.

ECN 111 Macroeconomic Principles[2] ... 3
or ECN 112 Microeconomic Principles (3)
HU course(s)[3] 6–10
SB course(s)[3] 3–7

Natural Sciences
(Eight semester hours minimum)
PHY 121 University Physics I: Mechanics[2] 3
PHY 122 University Physics Laboratory I[2] 1
PHY 131 University Physics II: Electricity and Magnetism[2] 3
PHY 132 University Physics Laboratory II[2] 1

Total general studies 37

NOTE: Six semester hours taken in two of the three awareness areas[1] are required in the final list of courses in the student's graduation program of study. These courses can be included in the HU and SB course selections.

[1] Refer to pages 53–71 for the specific requirements and the approved list.
[2] Required for graduation.
[3] Aerospace studies (AES) and military science (MIS) courses are not acceptable for engineering degree credit.

Engineering Core — *Semester Hours*

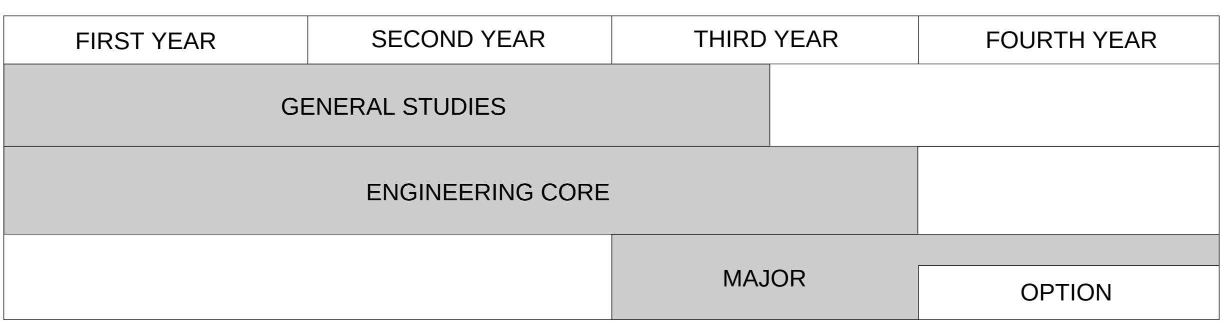
CHM 114 General Chemistry for Engineers 4
or CHM 116 General Chemistry (4)
ECE 105 Introduction to Languages of Engineering 3
ECE 210 Engineering Mechanics I: Statics 3
or PHY 321 Newtonian Mechanics (3)[1]
ECE 301 Electrical Networks I 4
MAT 274 Elementary Differential Equations 3
MAT 291 Calculus II 5
or MAT 271 (4) and MAT 272 (4)
Approved mathematics content electives[2] .. 4
Basic science elective[2] 3

Minimum five of the following six courses are required[2] 15
ECE 312 Engineering Mechanics II: Dynamics (3) or PHY 322 Analytical Mechanics (3)[1]
ECE 313 Introduction to Deformable Solids (3)
ECE 333 Electrical Instrumentation (3) or ECE 334 Electronic Devices and Instrumentation (4)
ECE 340 Thermodynamics (3) or CHM 441 General Physical Chemistry (3)
ECE 350 Structure and Properties of Materials (3) or CHM 442 General Physical Chemistry (3) or ECE 351 Engineering Materials (3) or ECE 352 Properties of Electronic Materials (3)

Microcomputer/Microprocessor elective (3)
Select one[2]:
BME 470 Microcomputer Applications in Bioengineering (3)
CEE 400 Microcomputer Applications in Civil Engineering (3)
CHE 461 Process Control (3)
CSE/EEE 225 Assembly Language Programming (Motorola) (3)
CSE/EEE 226 Assembly Language Programming (Intel) (3)
IEE 463 Computer-Aided Manufacturing and Control (3)
MAE 305 Measurements and Microcomputers (4)

Total required minimum engineering core 44

[1] Subject to department approval. If PHY 321 is selected, PHY 322 must also be completed.
[2] Courses to be selected are subject to department approval. See department requirements.



A summary of the degree requirements is as follows:

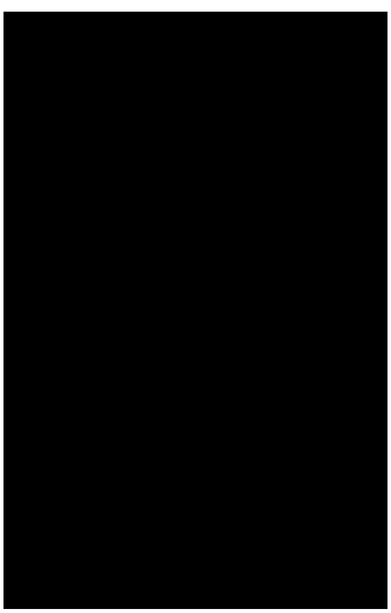
	Semester Hours
General studies	37
Engineering core	44
Major (including area of emphasis)	52
The requirements for each of the majors offered are described on the following pages.	
Total degree requirements	133
Plus university First-Year Composition requirements.	

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 52 semester hours of required 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, Mechanical Engineering, Engineering Special Studies, and Engineering Interdisciplinary Studies are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET). The Bachelor of Science program in Computer Science is accredited by the Computer Science Accreditation Commission (CSAC) of the Computing Sciences Accreditation Board (CSAB).



ANALYSIS AND SYSTEMS

ASE 100 College Adjustment and Survival. (2) F, S
Exploration of career goals and majors. Emphasis on organization and development of study skills, including time management, stress management, and use of the library.

399 Cooperative Work Experience. (1) F, S, SS
Usually involves two six-month work periods with industrial firms or government agencies alternated with full-time semester and summer sessions studies. Not open to students from other colleges on campus. May be repeated for credit. Prerequisites: at least 45 hours completed in major area with minimum 2.50 GPA; instructor approval.

485 Engineering Statistics. (3) F, S, SS
Statistical methods applied to engineering problems. Estimation, tests of hypotheses, regression, correlation, analysis of variance, and nonparametric statistics. Prerequisite: ECE 383. *General studies: N2.*

490 Project in Design and Development. (2–3) F, S, SS
Individual project in creative design and synthesis. Course may be repeated. Prerequisite: senior standing.

496 Professional Seminar. (0) F, S
Topics of interest to students in the engineering special and interdisciplinary studies.

500 Research Methods: Engineering Statistics. (3) F, S, SS
Statistical methods applied to engineering problems. Estimation, tests of hypotheses, regression, correlation, and analysis of variance and nonparametric statistics. Open only to students without previous credit in ASE 485. Prerequisite: ECE 383 or 500.

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

586 Partial Differential Equations in Engineering. (3) S
Development and solution of partial differential equations in engineering. Applications in solid mechanics, vibrations, and heat transfer. Prerequisites: ECE 386; MAT 242, 274.

Omnibus Courses: See page 44 for omnibus courses that may be offered.

ENGINEERING CORE

ECE 105 Introduction to Languages of Engineering. (3) F, S, SS
Computer programming using C, freehand drawing, visualization, and computer graphics. Lecture, recitation, lab. Prerequisites: CSE 181 or BASIC programming experience; algebra.

106 Introduction to Computer-Aided Engineering. (3) F, S
Computer-aided analysis and design, computer graphics, modeling, optimization, and graphic documentation. Lecture, recitation, lab. Prerequisites: ECE 105 and 1 year high school physics *or* corequisite of PHY 105 or 112 or 131. *General studies: N3.*

107 Freehand Drawing and Visualization. (1) F, S, SS
Representational drawing from direct observation to assist visualization, spatial awareness, and perception. Techniques include contour, gesture, and value drawing. Media include pencil and computer graphics. 3 hours lab.

210 Engineering Mechanics I: Statics. (3) F, S, SS
Force systems, resultants, equilibrium, distributed forces, area moments, fluid statics, internal stresses, friction, energy criterion for equilibrium, and stability. Lecture, recitation. Prerequisites: ECE 106; MAT 271 or 291; PHY 121, 122.

301 Electrical Networks I. (4) F, S, SS
Introduction to electrical networks. Component models, transient, and steady-state analysis. Lecture, recitation, lab. Prerequisite: ECE 106. Pre- or corequisites: MAT 274; PHY 131, 132.

312 Engineering Mechanics II: Dynamics. (3) F, S, SS
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.

313 Introduction to Deformable Solids. (3) F, S, SS
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; MAT 274.

333 Electrical Instrumentation. (3) F, S, SS
Survey of electronic devices and circuits as applied to instrumentation/measurements. Diodes/transistors/basic transistor amplifiers/op-amps/digital logic gates/electrical sensors/transducers as applied to electrical and electronic devices, circuits, and instruments. Lecture, lab. Prerequisite: ECE 301.

334 Electronic Devices and Instrumentation. (4) F, S, SS
Application of electric network theory to semiconductor discrete and integrated circuits. Electronic device and circuit applications, laboratory circuit design, testing, and verification. Lecture, recitation, lab. Prerequisite: ECE 301.

340 Thermodynamics. (3) F, S, SS
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. Pre- or corequisites: CHM 114 or 116; ECE 210; MAT 274; PHY 131.

350 Structure and Properties of Materials. (3) F, S, SS
Basic concepts of material structure and its relation to properties. Application to engineering problems. Prerequisites: CHM 114 or 116; PHY 121.

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

352 Properties of Electronic Materials. (3) F, S, SS
Introduction of Schrodinger wave equation, treatment of potential barrier problems in wave mechanics, hydrogen atom and the periodic table, bonds of crystals, free electron model, the band theory of solids, semiconductors, introduction of semiconductor devices, superconductor dielectric, and magnetic properties of electronic materials. Prerequisites: ECE 333 or 334; MAT 274.

383 Probability and Statistics for Engineers. (2) F, S, SS
Probability, random variables, discrete and continuous distributions, descriptive statistics, and sampling distributions. Prerequisite: MAT 272 or MAT 291. *General studies: N2.*

384 Numerical Analysis for Engineers I. (2) F, S
Numerical solution of algebraic and transcendental equations and systems of linear equations. Numerical integration. Curve fitting. Error bounds and error propagation. Emphasis on use of digital computer. Prerequisites: ECE 105; MAT 272 or 291.

385 Numerical Analysis for Engineers II. (2) S
Continuation of ECE 384. Numerical solution of partial differential equations and mixed equation systems. Introduction to experimental design and optimization techniques. Prerequisite: ECE 384.

386 Partial Differential Equations for Engineers. (2) F, S
Boundary value problems, separation of variables, and Fourier series as applied to initial-boundary value problems. Prerequisite: MAT 274.

400 Engineering Communications. (3) F, S, SS
Planning and preparing engineering publications and oral presentations, based on directed library research related to current engineering topics. Prerequisite: senior standing in an engineering field and completion of first-year English requirements plus sophomore critical writing course. *General studies: L2.*

500 Research Methods: Probability and Statistics for Engineers. (2) F, S, SS
Probability, random variables, discrete and continuous distributions, descriptive statistics, and sampling distributions. Open only to students without previous credit for ECE 383. Prerequisite: MAT 272 or 291.

Omnibus Courses: See page 44 for omnibus courses that may be offered.

SOCIETY, VALUES, AND TECHNOLOGY

STE 201 Introduction to Bioengineering. (3) F
Impact of bioengineering on society. Developing an awareness of the contributions of bioengineering to solve medical and biological problems. Cross-listed as BME 201. Prerequisite: ENG 102 or 105.

202 Global Awareness within Engineering Design. (3) F
Strategies for integrating long-term environmental, economic, and ethical considerations into engineering design. Biomedical, environmental, biotechnological, and materials engineering case studies. Lecture, critical discourse. Cross-listed as BME 202. Prerequisites: ECE 106; ECN 111 or 112; ENG 102. *General studies: L1.*

Omnibus Courses: See page 44 for omnibus courses that may be offered.

Chemical, Bio and Materials Engineering

James W. Mayer
Interim Chair
(ECG 202) 602/965–3313

Historically, materials have had a tremendous impact on the advancement of civilization, as reflected in the words “stone,” “bronze,” “iron,” and “paper” attached to the various ages in the development of society. Until recently an arbitrary distinction was made between chemically reactive materials and relatively inert solid phase materials. As our technological know-how advances, we recognize that the fundamental principles, the molecular level mechanisms, and the processing techniques are very similar regardless of the state, phase, or shape of the materials. Understanding of these principles and their application to real systems is the key to future progress as specially designed materials are sought for the solution of complex technological problems. Therefore, it is logical that the educational program of future scientists and engineers dealing with the engineered materials be comprehensive, covering all aspects of the materials world.

Similarly, the human body and other living systems process materials by analogous steps as do the chemical industries. These living systems are small, sophisticated integrated plants utilizing pumps, aerators, separators, and reactors involving fluid flow, thermodynamics, heat and mass transfer, and other familiar principles. Therefore, it is appropriate that chemical, bio-, and materials engineers work together in both education and research.

Students aspiring to be engineers in either the chemical, bio-, or materials engineering areas must prepare to solve a wide variety of problems utilizing chemistry, physics, mathematics, life sciences, and engineering sciences. As professionals in industry, they apply these fundamentals to creatively develop, economically design, and productively operate systems, constituent equipment, and specialized analytical facilities.

The department offers three B.S.E. degrees, in Chemical Engineering, in Bioengineering, and in Materials Science and Engineering. A B.S.E. degree program in pre-medical engineering is also available at ASU; it is described separately on pages 279–280.

CHEMICAL ENGINEERING—B.S.E.

PROFESSORS
BERMAN, CALE, GUILBEAU, HENRY, KUESTER, SATER, ZWIEBEL

ASSOCIATE PROFESSORS
BECKMAN, BELLAMY, BURROWS, RAUPP, RIVERA, TORREST

ASSISTANT PROFESSOR
GARCIA

PROFESSORS EMERITI
DORSON, REISER

Chemical engineers are generally concerned with chemical change. They 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 mass transfer, solution thermodynamics, reaction kinetics, and separation techniques to technological endeavors such as 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

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

General studies 39
Sixteen hours of HU and SB type courses must be included (see page 240, general studies, for special requirements) since CHE 351 and 352 must be taken to satisfy L1 elective.

Engineering core 44
CHE 461; CHM 116, 331, 441, 442; ECE 105, 210, 301, 313, 333, 384, 385; MAT 274, 291 (or 271 and 272)

Major 50
CHE 311, 312, 331, 332, 333, 342, 432, 442, 451, 462; CHM 113, 332, 335; 12 hours technical electives

In the above engineering core listing, ECE 394 ST: Conservation Principles, ST: Properties That Matter, ST: Systems, and ST: Differential Conservation may be substituted for CHM 441 and ECE 210, 301, 313, and 333. In the above list of courses, additional hours of approved technical elective courses may be substituted for CHE 311, 312 and 331 and CHM 442.

The technical elective courses must be selected from upper-division courses with an advisor's approval and must include the following: 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.

Students are required to enroll in CHE 496 Professional Seminar during at least one semester of each academic year in attendance. A total of five semesters of seminar credit is necessary to meet degree requirements.

The Department of Chemical, Bio and Materials Engineering also offers graduate programs leading to the M.S.E., M.S., and Ph.D. degrees. These programs provide a blend of classroom instruction and research. A wide variety of 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 Areas of Emphasis

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 of emphasis with suggested courses. A student may choose electives within the general department guidelines and does not have to select one of the areas listed.

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

Chemistry elective: CHM 361, 461.

Technical electives: AGB 425, 426; CHE 475, 476, 477.

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

Chemistry elective: CHM 361, 461.

Technical electives: BME 318, 414, 416, 435; CHE 411, 412, 413.

Environmental. Students interested in the management of hazardous wastes and air and water pollution should select from:

Chemistry elective: CHM 361, 461, 481.

Technical electives: CEE 362, 561, 563, 564; CHE 494, 533, 552, 553; EEE 461.

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

Chemistry elective: CHM 438, 453, 471.

Technical electives: BME 318; ECE 350, 352; MSE 431, 470, 471, 472.

Pre-medical. Students planning to attend medical school should select courses from those listed under the biomedical emphasis. In addition, BIO 181 and 182 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:

Energy conversion and conservation: CHE 552, 553, 554, 556; MAE 436, 437, 438.

Plant administration and management: CHE 528, 553; IEE 300, 431.

Simulation, control, and design: CHE 527, 528, 556, 562, 563.

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

Chemistry elective: CHM 471.

Technical electives: ECE 352; EEE 435, 436; MSE 472.

Chemical Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester			*Semester Hours*
CHE	496	Professional Seminar	0
CHM	113	General Chemistry	4
ECE	105	Introduction to Languages of Engineering	3
ENG	101	First-Year Composition	3
MAT	290	Calculus I	5
HU or SB elective*			3
Total			18

Second Semester			
CHE	496	Professional Seminar	0
CHM	116	General Chemistry	4
ECE	106	Introduction to Computer-Aided Engineering	3
ENG	102	First-Year Composition	3
MAT	291	Calculus II	5
PHY	121	University Physics I: Mechanics	3
PHY	122	University Physics Laboratory I	1
Total			19

Second Year

First Semester			
CHE	311	Material Balances	3
CHE	496	Professional Seminar	0
CHM	331	General Organic Chemistry	3
CHM	335	General Organic Chemistry Laboratory	1
MAT	274	Elementary Differential Equations	3
PHY	131	University Physics II: Electricity and Magnetism	3
PHY	132	University Physics Laboratory II	1
Total			14

Second Semester

CHE	312	Introduction to Thermodynamics	3
CHE	331	Transport Phenomena I: Fluids	3
CHE	496	Professional Seminar	0
CHM	332	General Organic Chemistry	3
ECE	210	Engineering Mechanics I: Statics	3
ECE	384	Numerical Analysis for Engineers I	2
HU or SB elective*			3
Total			17

Third Year

First Semester

CHE	332	Transport Phenomena II: Energy Transfer	3
CHE	342	Applied Chemical Thermodynamics	4
CHE	351	Measurements Laboratory	2
CHE	496	Professional Seminar	0
CHM	441	General Physical Chemistry	3
ECE	385	Numerical Analysis for Engineers II	2
HU or SB elective*			4
Total			18

Second Semester

CHE	333	Transfer Phenomena III: Mass Transfer	3
CHE	352	Transport Laboratories	2
CHE	496	Professional Seminar	0
CHM	442	General Physical Chemistry	3
ECE	301	Electrical Networks I	4
ECE	313	Introduction to Deformable Solids	3
HU or SB elective*			3
Total			18

Fourth Year

First Semester

CHE	432	Principles of Chemical Engineering Design	3
CHE	442	Chemical Reactor Design	3
CHE	451	Chemical Engineering Laboratory	2
CHE	461	Process Control	3
CHE	496	Professional Seminar	0
Technical elective			6
Total			17

Second Semester

CHE	462	Process Design	3
CHE	496	Professional Seminar	0
ECE	333	Electrical Instrumentation	3
ECE	400	Engineering Communications	3
HU or SB elective*			3
Technical elective			6
Total			18

Degree requirements: 133 semester hours plus English proficiency.

* See pages 53–71 for requirements and approved list.

BIOENGINEERING—B.S.E.

PROFESSORS
GUILBEAU, TOWE

ASSISTANT PROFESSORS
KIPKE, PIZZICONI, SWEENEY, YAMAGUCHI

PROFESSOR EMERITUS
DORSON

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. Bioengineering bridges the engineering, physical, life, and medical sciences. More specifically, the bioengineering program at ASU educates engineering students to use engineering principles and technology to develop instrumentation, materials, diagnostic and therapeutic devices, artificial organs, and other equipment needed in medicine and biology and to discover new fundamental principles regarding the functioning and structure of living systems. The multidisciplinary approach to solving problems in medicine and biology has evolved from exchanges of information between specialists in the concerned areas.

Because a depth of knowledge from at least two diverse disciplines is required in the practice of bioengineering, students desiring a career in bioengineering should plan for advanced study beyond the bachelor's degree. The Bioengineering major at ASU is especially designed for students desiring graduate study in bioengineering, a career in the medical-device industry, a career in biomedical research, a career in biotechnology research, or entry into a medical college.

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

Academic Requirements

In addition to the general studies requirement, CHM 116 General Chemistry and BIO 181 General Biology (basic science elective) must be selected in the engineering core. Also, in the engineering core, students must select ECE 313, 333, 340, and 350 and BME 470. The following courses are required in the undergraduate Bioengineering major. They have been selected to meet all university requirements and ABET accreditation requirements:

			Semester Hours
AGB/BME	435	Animal Physiology I	4
BIO	182	General Biology	4
BME	318	Biomaterials	3
BME	331	Transport Phenomena I: Fluids	3
BME	334	Heat and Mass Transfer	3
BME	411	Biomedical Engineering I or BME 412 Biomedical Engineering II (3)	3
BME	413	Physiological Instrumentation	3
BME	417	Biomedical Engineering Design	3
BME	423	Physiological Instrumentation Laboratory	1
BME	490	Biomedical Engineering Projects	2
BME	496	Professional Seminar	0
CHM	113	General Chemistry	4
Technical electives			18
Total			51

Bioengineering Areas of Emphasis

Students interested in a career in bioengineering may elect to emphasize either biochemical, bioelectrical, biomaterials engineering, biomechanical, bionuclear, biosystems, molecular and cellular bioengineering, or pre-medical engineering. Although organic chemistry and biochemistry are not required in the bioelectrical, biomechanical, bionuclear, and biosystems engineering areas of emphasis, students selecting these areas are encouraged to include organic and biochemistry in their advanced degree programs of study.

Biochemical Engineering. This emphasis is designed to strengthen the student's knowledge of chemistry and transport phenomena and is particularly well suited for students interested in biotechnology. Technical electives must include: CHM 331, 332, and 361 (or 461 or 462). The remaining technical electives must be upper-division engineering courses of suitable engineering science and design content.

Bioelectrical Engineering. This emphasis is designed to strengthen the student's knowledge of electrical systems, signal processing, and medical imaging. It emphasizes bioelectrical phenomena, medical instrumentation, noninvasive imaging, and electrophysiology. ECE 334 is taken instead of ECE 333 in the engineering core. Technical electives must include BME 414, and EEE 302 and 303. Remaining technical electives are selected from BME 412, 419, and 520, and any 400-level EEE course with acceptable engineering science and design content.

Biomaterials Engineering. This area of emphasis 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 and biotechnology applications in biomaterials engineering for the design and selection of soft and hard tissue biomaterials intended for clinical applications. Technical electives must include CHM 331, 332, and 361 and MSE 355 and 470. Remaining technical electives must be chosen from upper-division engineering or life or physical sciences courses having suitable science and design content and are subject to BME program approval.

Biomechanical Engineering. This emphasis is designed to strengthen the student's knowledge of mechanics, materials science, control theory and mechanical design. It emphasizes the design of orthopedic load bearing joint replacement devices, orthotic devices, and other mechanical devices important in the practice of medicine. It also provides the fundamentals for the study of neuromuscular control and the study of human motion. The following courses are required selections in the engineering core: ECE 384 (or MAT 242) and MAE 305. Technical electives may be selected from one of the following two groups:

Biomechanics: BME 416; ECE 312; MAE 404 (or MSE 440), 422, 441.

Biocontrols: BME 416, 419; ECE 312; MAE 317, 417 (or 447).

Bionuclear Engineering. This emphasis is designed to strengthen the student's knowledge of radiation interactions and shielding, health physics, radiation biology, radiation protection, and nuclear instrumentation. Technical electives include: BME 461, 465; PHY 361. Remaining technical electives are selected from BME 414 or any 400-level BME or EEE courses with acceptable engineering science and design content.

Biosystems Engineering. This emphasis is designed to strengthen the background of students interested in physiological systems analysis and design of artificial organs and medical devices that are based on chemical reactions and include momentum, heat, or mass transfer phenomena. Analyzing or designing flowing and reacting systems requires a background in transport phenomena, thermodynamics, and reaction engineering. Whether the system involves the microcirculation and physiological events or an artificial organ and extracorporeal circulation, there is a core of bioengineering sciences and design common to both applications. Technical electives must include: BME 419; CHE 342; ECE 312, 394 Conservation Principles.

Molecular and Cellular Bioengineering. This emphasis 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 biotechnology. Technical electives must include BIO 332 and CHM 331, 332, and 361. Other technical electives may be chosen from upper-division courses in engineering, life, and physical sciences with appropriate science and engineering design content and are subject to BME program approval.

Pre-medical Engineering. This emphasis is designed to meet the needs of students desiring entry into a medical or dental 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 CHM 331, 332, 335, and 336. Remaining technical electives must consist of BME prefix courses plus biology or biochemistry courses, which must meet engineering science and design content requirements.

Bioengineering Program of Study
Typical Four-Year Sequence

First Year

First Semester			*Semester Hours*
BME	496	Professional Seminar	0
CHM	113	General Chemistry	4
ECE	105	Introduction to Languages of Engineering	3
ECN	111	Macroeconomic Principles	3
ENG	101	First-Year Composition	3
MAT	290	Calculus I	5
Total			18

Second Semester			
BME	496	Professional Seminar	0
CHM	116	General Chemistry	4
ECE	106	Introduction to Computer-Aided Engineering	3
ENG	102	First-Year Composition	3
MAT	291	Calculus II	5
PHY	121	University Physics I: Mechanics	3
PHY	122	University Physics Laboratory I	1
Total			19

Second Year

First Semester			
BIO	181	General Biology	4
BME	496	Professional Seminar	0
MAT	274	Elementary Differential Equations	3
PHY	131	University Physics II: Electricity and Magnetism	3
PHY	132	University Physics Laboratory II	1
HU or SB elective[1]			3
L1 elective[1, 2]			3
Total			17

Second Semester			
BIO	182	General Biology	4
BME	331	Transport Phenomena I: Fluids	3
BME	496	Professional Seminar	0
ECE	210	Engineering Mechanics I: Statics	3
ECE	301	Electrical Networks I	4
HU or SB elective[1]			3
Total			17

Third Year

First Semester			
BME	435	Animal Physiology I	4
BME	496	Professional Seminar	0
ECE	313	Introduction to Deformable Solids	3

ECE	340	Thermodynamics or CHM 441 General Physical Chemistry (3)	3
ECE	350	Structure and Properties of Materials	3
ECE	384	Numerical Analysis for Engineers I or ECE 386 Partial Differential Equations for Engineers (2) or MAT 242 Elementary Linear Algebra (2)	2
Technical elective			3
Total			18

Second Semester

BME	318	Biomaterials	3
BME	334	Heat and Mass Transfer	3
BME	496	Professional Seminar	0
ECE	333	Electrical Instrumentation	3
ECE	383	Probability and Statistics for Engineers	2
HU or SB elective[1]			3
Total			14

Fourth Year

First Semester

BME	411	Biomedical Engineering I or BME 412 Biomedical Engineering II (3)	3
BME	413	Physiological Instrumentation	3
BME	423	Physiological Instrumentation Laboratory	1
BME	490	Biomedical Engineering Projects	2
BME	496	Professional Seminar	0
HU or SB elective[1]			3
Technical electives			6
Total			18

Second Semester

BME	417	Biomedical Engineering Design	3
BME	470	Microcomputer Applications	3
BME	496	Professional Seminar	0
ECE	400	Engineering Communications	3
Technical elective			9
Total			18

Degree requirements: 133 semester hours plus English proficiency.

[1] See pages 49–71 for the requirements and the approved list of courses.

[2] See page 244 for special requirements and selection of an L1 elective.

MATERIALS SCIENCE AND ENGINEERING—B.S.E.

REGENTS' PROFESSOR
WAGNER

PROFESSORS
CARPENTER, JACOBSON, KRAUSE, MAYER

ASSOCIATE PROFESSORS
DEY, HENDRICKSON

ASSISTANT PROFESSOR
ALFORD

PROFESSOR EMERITUS
STANLEY

Materials science is the engineering and scientific discipline that is concerned with the study of fundamental relationships between the structure of materials and their properties. The program provides students with the knowledge necessary to make decisions concerning the optimum utilization of existing materials or to develop and process new materials.

Essentially all major industries and many research laboratories are involved to some extent with the selection, utilization, and development of materials in designing and producing engineered systems. Students who major in Materials Science and Engineering find employment opportunities in a variety of industries and research facilities associated with aerospace, solid-state electronics, energy conversion, transportation, manufacturing and chemical processing. The responsibilities of a materials scientist or materials engineer include research and development of materials to meet some new demand brought about by advancing technology, to select the best choice of existing materials for a specific application, or to devise novel ways to process materials to improve performance. Materials scientists also develop new techniques for processing materials to reduce costs of products or to create new products. Also, materials scientists are often responsible for analyzing data on field tested materials to determine the effects of the environment on materials performance.

The tools of a materials scientist include highly sophisticated analytical and processing equipment. Instruments such as ion implanters, molecular beam epitaxy systems, and chemical vapor deposition chambers have become indispensable in materials processing. Since a considerable emphasis in materials science is placed on the microscopic world, instruments such as transmission and scanning electron microscopes, scanning tunneling microscopes, X-ray diffractometers, and Auger spectrometers are a necessary part of the field.

DEGREE REQUIREMENTS

The undergraduate curriculum requires that students take a series of interdisciplinary courses of fundamental importance to an understanding of all engineering materials. In addition, at the beginning of the third year, students are required to select a specialization in one of two areas: (1) materials processing and synthesis or (2) materials engineering. Students who elect to specialize in materials processing and synthesis select courses that emphasize thin film electronic materials while students who elect materials engineering select courses that emphasize the behavior of bulk solids.

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

General studies 37
See page 244 for School of Engineering requirements.

Engineering core 44
CHM 116, 441; ECE 105, 210 (or PHY 321), 301, 313, 333 (or 312 or PHY 322), 350, 383 (or 384 or 386); IEE 463 or MAE 305; MAT 242, 274, 291 (or 271 and 272); PHY 361

Major 52
CHM 113; MSE 353, 355, 430, 440, 450, 482, 490, 496

Three of the following four courses are required: MSE 420, 470, 471, and 472. In addition, course requirements for the two specialization areas are listed below.

Materials Processing and Synthesis. MSE 354, 453, and 454 and 11 hours of technical electives*.

Materials Engineering. MSE 420 lab, 431, 441, and 476, and 10 hours of technical electives*.

* Technical electives must include eight hours of engineering design content.

Materials Science and Engineering Areas of Emphasis

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.

Chemical Processing and Energy Systems. CHE 432, 442, 451; MAE 371, 372, 388, 430, 437, 438; MSE 530, 531, 533.

Electronic Materials. CHE 458, 548, 558; CHM 471; EEE 435, 539; MAE 437, 438; MSE 520, 521, 550, 562, 573; PHY 471, 481.

Manufacturing and Materials Processing. MAE 372, 403, 415, 422, 441, 442; MSE 441, 540, 549, 560.

Mechanical Metallurgy. MAE 305, 415, 422, 441, 442, 520, 522, 524, 527, 557; MSE 431, 441, 480, 520, 521, 540, 549, 550, 558, 560.

Physical Metallurgy. CHM 471; MAE 372, 388, 422; MSE 431, 441, 480, 520, 521, 550, 558, 559, 560, 561, 573; PHY 361, 362, 471, 481.

Polymers and Composites. CHM 331, 332, 438, 471; MAE 372, 520, 527; MSE 570.

Materials Science and Engineering Program of Study

Typical Four-Year Sequence

First Year

First Semester

		Semester Hours
CHM 113	General Chemistry	4
ECE 105	Introduction to Languages of Engineering	3
ENG 101	First-Year Composition	3
MAT 270	Calculus with Analytic Geometry I	4
HU or SB elective[1]		3
Total		17

Second Semester

CHM 116	General Chemistry	4
ECE 106	Introduction to Computer-Aided Engineering	3
ENG 102	First-Year Composition	3
MAT 271	Calculus with Analytic Geometry II	4
PHY 121	University Physics I: Mechanics	3
PHY 122	University Physics Laboratory I	1
Total		18

Second Year

First Semester

ECE 210	Engineering Mechanics I: Statics	3
	or PHY 321 Newtonian Mechanics (3)	
ECE 350	Structure and Properties of Materials	3
MAT 272	Calculus with Analytic Geometry III	4
MSE 496	Professional Seminar	0
PHY 131	University Physics II: Electricity and Magnetism	3
PHY 132	University Physics Laboratory II	1
HU or SB elective[1]		3
Total		17

Second Semester

ECE 301	Electrical Networks I	4
ECE 313	Introduction to Deformable Solids	3
MAT 242	Elementary Linear Algebra	2
MAT 274	Elementary Differential Equations	3
MSE 496	Professional Seminar	0
PHY 361	Introductory Modern Physics	3
L1 elective[1, 2]		3
Total		18

Third Year

First Semester

CHM 441	General Physical Chemistry	3
ECE 312	Engineering Mechanics II: Dynamics	3
	or ECE 333 Electrical Instrumentation (3) or PHY 322 Analytical Mechanics (3)	
IEE 463	Computer-Aided Manufacturing and Control	3
	or MAE 305 Measurements and Microcomputers (4)	
MSE 353	Introduction to Materials Processing and Synthesis	3
MSE 355	Introduction to Materials Science and Engineering	3
MSE 496	Professional Seminar	0
HU or SB elective[1]		3
Total		18

Second Semester

ECE 383	Probability and Statistics for Engineers	2
	or ECE 384 Numerical Analysis for Engineers I (2) or ECE 386 Partial Differential Equations for Engineers (2)	
MSE 354	Experiments in Materials Synthesis and Processing I	2
	or MSE 431 Corrosion and Corrosion Control (3)	
MSE 420	Physical Metallurgy	4
	or MSE 472 Integrated Circuit Materials Analysis (3)	
MSE 430	Thermodynamics of Materials	3
MSE 496	Professional Seminar	0
HU or SB elective[1]		3
Technical elective		3 or 4
Total		18

Fourth Year

First Semester

ECE 400	Engineering Communications	3
MSE 440	Mechanical Properties of Solids	3
MSE 450	X-Ray and Electron Diffraction	3
MSE 470	Polymers and Composites	3
	or MSE 453 Experiments in Materials Synthesis and Processing II (2)	
MSE 471	Introduction to Ceramics	3
	or MSE 453 Experiments in Materials Synthesis and Processing II (2)	
MSE 496	Professional Seminar	0
HU or SB elective[1]		3
Total		18

Second Semester

MSE 454	Advanced Materials Processing and Synthesis	3
	or MSE 441 Analysis of Material Failures (3)	
MSE 476	Nonmetallic Materials Laboratory[3]	1
MSE 482	Materials Engineering Design	3
MSE 490	Capstone Design Project	3
MSE 496	Professional Seminar	0
Technical elective		7
Total		17

Degree requirements: 133 semester hours plus English proficiency.

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[1] See pages 45–65 for the requirements and the approved list.

[2] See page 240 for special requirements and selection of an L1 elective.

[3] Materials Engineering option only.

CHEMICAL ENGINEERING

CHE 311 Material Balances. (3) F, S
Principles of physics and chemistry applied to the formulation of material balances. Prerequisites: CHM 116; ECE 106; MAT 271 or 291.

312 Introduction to Thermodynamics. (3) F, S
Energy balance calculations and introduction of thermodynamic principles. Prerequisite: CHE 311.

331 Transport Phenomena I: Fluids. (3) F, S
Transport phenomena, with emphasis on fluid systems. Cross-listed as BME 331. Prerequisites: CHE 311 (except BME majors); MAT 274; PHY 131.

332 Transport Phenomena II: Energy Transfer. (3) F, S
Continuation of transport principles, with emphasis on energy transport in stationary and fluid systems. Prerequisites: CHE 312, 331. Pre- or corequisite: ECE 385.

333 Transport Phenomena III: Mass Transfer. (3) F, S
The application of transport phenomena to mass transfer. The design of mass transfer equipment, including staged processes. Pre- or corequisites: CHE 332, 342.

342 Applied Chemical Thermodynamics. (4) F, S
Application of conservation and accounting principles with non-ideal property estimation techniques to model phase and chemical equilibrium processes. Lecture, recitation. Prerequisites: CHE 312; ECE 384.

351 Measurements Laboratory. (2) F
Introduction to laboratory practices and the use of measurement devices. Prerequisites: CHE 311, ENG 102. Pre- or corequisites: CHE 312 or ECE 340; CHM 335. *General studies: L1 (if credit also earned in CHE 352).*

352 Transport Laboratories. (2) S
The demonstration of transport phenomena principles with experiments in fluid flow, heat, and mass transfer. Pre- or corequisites: CHE 331, 332, 351. *General studies: L1 (if credit also earned in CHE 351).*

411 Biomedical Engineering I. (3) F
Review of diagnostic and prosthetic methods using engineering methodology. Introduction to transport, metabolic, and autoregulatory processes in the human body. Cross-listed as BME 411. Prerequisite: instructor approval.

412 Biomedical Engineering II. (3) S
Review of electrophysiology and nerve pacing applications, introduction to biomechanics and joint/limb replacement technology, cardiovascular and pulmonary fluid mechanics, and the application of mathematical modeling. Cross-listed as BME 412. Prerequisite: instructor approval.

413 Biomedical Instrumentation I. (3) F
Principles of medical instrumentation. Studies of medical diagnostic instruments and techniques for the measurement of physiologic variables in living systems. Cross-listed as BME 413. Prerequisites: AGB/BME 435 (grade of “C” or higher); ECE 333 or 334.

432 Principles of Chemical Engineering Design. (3) F
Multicomponent distillation, engineering economics, equipment sizing and costs, plant operation economics, and simulation and optimization techniques. Prerequisites: CHE 333, 342.

442 Chemical Reactor Design. (3) F, S
Application of kinetics to chemical reactor design. Prerequisite: CHE 342. Pre- or corequisite: CHE 333.

451 Chemical Engineering Laboratory. (2) F
Operation, control, and design of experimental and industrial process equipment; independent research projects. 6 hours lab. Pre- or corequisite: CHE 352, 432, 442.

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

461 Process Control. (3) F
Process dynamics, instrumentation, and feedback applied to automatic process control. Lecture, lab. Prerequisite: ECE 301. *General studies: N3.*

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

475 Biochemical Engineering. (3) N
Application of chemical engineering methods, mass transfer, thermodynamics, and transport phenomena to industrial biotechnology. Prerequisite: instructor approval.

476 Bioreaction Engineering. (3) N
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.

477 Bioseparation Processes. (3) N
Principles of separation of biologically active chemicals; the application, scaleup, and design of separation processes in biotechnology. Prerequisite: instructor approval.

490 Chemical Engineering Projects. (1–5) F, S, SS
Individual projects in chemical engineering operations and design. Prerequisite: instructor approval.

496 Professional Seminar. (0) F, S
Professional and ethical aspects with a discussion of employment opportunities and responsibilities. Lectures, field trips.

501 Introduction to Transport Phenomena. (3) F, S
Transport phenomena, with emphasis on fluid systems. Prerequisite: transition student with instructor approval.

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

503 Introduction to Mass Transport. (3) F, S
The application of transport phenomena to mass transfer. The design of mass transfer equipment, including staged processes. Prerequisite: transition student with instructor approval.

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

505 Introduction to Chemical Reactor Design. (3) F, S
Application of kinetics to chemical reactor design. Prerequisite: transition student with instructor approval.

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

517 Medical Transport Devices I. (3) N
Heat, mass, and momentum transfer concepts are developed from first principles and applied to the design and application of medical devices. Emphasis is an extracorporeal treatment of blood with channel dimensions which greatly exceed cellular dimensions. Cross-listed as BME 517. Prerequisites: partial differential equations; at least 1 course in heat, mass, or momentum transfer.

518 Introduction to Biomaterials. (3) F
Topics include structure property relationships for synthetic and natural biomaterials, biocompatibility, and uses of materials to replace body parts. Cross-listed as BME 518. Prerequisite: ECE 313 or instructor approval.

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

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

533 Transport Processes I. (3) F
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.

534 Transport Processes II. (3) S
Continuation of CHE/BME 533, emphasizing mass transfer. Cross-listed as BME 534. Prerequisite: BME/CHE 533.

535 Turbulent Mixing. (3) N
Turbulence and mixing in multicomponent systems with/without chemical reactions. Computational models applied to chemical processes. Prerequisite: CHE 533.

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

543 Thermodynamics of Chemical Systems. (3) F
Classical and statistical thermodynamics of nonideal physicochemical systems and processes; prediction of optimum operating conditions. Cross-listed as BME 543.

544 Chemical Reactor Engineering. (3) S
Reaction rates, thermodynamics, and transport principles applied to the design and operation of chemical reactors. Cross-listed as BME 544. Prerequisite: BME/CHE 543.

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

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

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

554 New Energy Technology. (3) N
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.

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

558 Electronic Materials. (3) N
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.

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

562 Chemical Systems Engineering. (3) N
Process dynamics, systems analysis, computer applications, and process control.

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

Omnibus Courses: See page 44 for omnibus courses that may be offered.

BIOENGINEERING

BME 201 Introduction to Bioengineering. (3) F
Impact of bioengineering on society. Developing an awareness of the contributions of bioengineering to solve medical and biological problems. Cross-listed as STE 201. Prerequisite: ENG 102 or 105.

202 Global Awareness within Engineering Design. (3) F
Strategies for integrating long-term environmental, economic, and ethical considerations into engineering design. Biomedical, environmental, biotechnological, and materials engineering case studies. Lecture, critical discourse. Cross-listed as STE 202. Prerequisites: ECE 106; ECN 111 or 112; ENG 102. *General studies: L1.*

318 Biomaterials. (3) S
Material properties of natural and artificial biomaterials. Tissue and blood biocompatibility. Uses of materials to replace body parts. Prerequisites: ECE 313, 350.

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

334 Bioengineering Heat and Mass Transfer. (3) S
Application of the principles of heat and mass transfer phenomena to solution of problems in medicine and medical device design. Prerequisites: BME 331 (grade of "C" or higher); ECE 340.

411 Biomedical Engineering I. (3) F
Review of diagnostic and prosthetic methods using engineering methodology. Introduction to transport, metabolic, and autoregulatory processes in the human body. Cross-listed as CHE 411. Prerequisite: instructor approval.

412 Biomedical Engineering II. (3) S
Review of electrophysiology and nerve pacing applications, introduction to biomechanics and joint/limb replacement technology, cardiovascular and pulmonary fluid mechanics, and the application of mathematical modeling. Cross-listed as CHE 412. Prerequisite: instructor approval.

413 Biomedical Instrumentation I. (3) F
Principles of medical instrumentation. Studies of medical diagnostic instruments and techniques for the measurement of physiologic variables in living systems. Cross-listed as CHE 413. Prerequisites: AGB/BME 435 (grade of "C" or higher); ECE 333 or 334.

414 Biomedical Instrumentation II. (3) S
Principles of applied biophysical measurements using bioelectric and radiological approaches. Prerequisites: BME 413 and ECE 333, or 334, MAT 274 *or* instructor approval.

415 Biomedical Transport Processes. (4) A
Principles of momentum, heat, and mass transfer with applications to medical and biological systems and medical device design. Prerequisites: MAT 274; PHY 131.

416 Biomechanics. (3) F
Mechanical properties of bone, muscle, and soft tissues. Static and dynamic analysis of human movement tasks such as locomotion. Pre- or corequisite: ECE 312, 313.

417 Biomedical Engineering Design. (3) S
Technical, regulatory, economic, legal, social, and ethical aspects of medical device systems engineering design. Prerequisites: BME 318 (grade of "C" or higher), 334 (grade of "C" or higher).

419 Biocontrol Systems. (3) S
Application of linear and nonlinear control systems techniques toward analysis of neuromusculoskeletal, cardiovascular, thermal, and mass transfer systems of the body. Prerequisites: ECE 301; MAT 274.

423 Biomedical Instrumentation Laboratory. (1) F
Laboratory experience with problems, concepts, and techniques of biomedical instrumentation in static and dynamic environments. Lab. Pre- or corequisites: AGB/BME 435 (grade of "C" or higher); BME/CHE 413; ECE 333 or 334.

435 Animal Physiology I. (4) F
Control and function of the nervous, muscular, cardiovascular, respiratory, and renal systems of domestic animals. Lecture, lab. Cross-listed as AGB 435. Prerequisites: BIO 181; CHM 113.

436 Animal Physiology II. (3) N
Control and function of the endocrine, digestive, and reproductive systems of domestic animals. Principles of adaptation of animals to their environment. Prerequisite: BME 435 (grade of "C" or higher) or ZOL 360.

437 Animal Physiology Laboratory. (1) N
Selected physiological experiments to accompany BME 436. Lab. Pre- or corequisite: BME 436.

461 Health Physics Principles and Radiation Measurements. (3) S
Sources, characteristics, dosimetry, shielding, and measurement techniques for cosmogenic, terrestrial, and anthropogenic radiation. Ionizing and nonionizing radiation theory. ALARA concept. Emphasis on instrumentation, detectors, and environmental monitoring. Lecture, lab. Prerequisite: ECE 301.

465 Clinical Nuclear Engineering I. (3) N
Fundamentals of clinical nuclear engineering and medical health physics practice. Radiation biology, dosimetry, and shielding for radiotherapy and diagnostic procedures. Cross-listed as EEE 465. Prerequisite: instructor approval.

470 Microcomputer Applications in Bioengineering. (3) S
Use of microcomputers for real-time data collection, analysis, and control of experiments involving actual and simulated physiological systems. Lecture, lab. Prerequisites: BME/AGB 435 and ECE 333 or 334.

490 Biomedical Engineering Projects. (1–5) F, S, SS
Individual projects in medical systems or medical device design and development.

496 Professional Seminar. (0) F, S
Professional and ethical aspects with a discussion of employment opportunities and responsibilities. Lecture, field trips.

511 Biomedical Engineering. (3) A
Diagnostic and prosthetic methods using engineering methodology. Transport, metabolic, and autoregulatory processes in the body.

512 Biomedical Engineering II. (3) A
Electrophysiology and nerve pacing applications, introduction to biomechanics and joint/limb replacement, technology, cardiovascular and pulmonary fluid mechanics, and mathematical modeling.

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

514 Biomedical Instrumentation. (3) F
Electrical, physical, and mechanical principles governing the operation of modern biomedical instrumentation. Prerequisites: ECE 334; MAT 274.

515 Biomedical Transport Processes. (3) N
Principles of momentum, heat, and mass transport with applications to medical and biological systems and medical device design. Cross-listed as CHE 515. Prerequisite: instructor approval.

516 Topics in Biomechanics. (3) S
Mechanical properties of bone, muscle, and soft tissues. Static and dynamic analysis of human movement tasks, including in-depth project. Prerequisites: ECE 312 and 313 *or* instructor approval.

517 Medical Transport Devices I. (3) N
Heat, mass, and momentum transfer concepts are developed from first principles and applied to the design and application of medical devices. Emphasis is an extracorporeal treatment of blood with channel dimensions which greatly exceed cellular dimensions. Cross-listed as CHE 517. Prerequisites: partial differential equations; at least 1 course in heat, mass, or momentum transfer.

518 Introduction to Biomaterials. (3) F
Topics include structure property relationships for synthetic and natural biomaterials, biocompatibility, and uses of materials to replace body parts. Cross-listed as CHE 518. Prerequisite: ECE 313 or instructor approval.

519 Topics in Biocontrol Systems. (3) F
Linear and nonlinear control systems analysis of neuromusculoskeletal, cardiovascular, thermal, and mass transfer systems of the body, including in-depth project. Prerequisite: MAT 274.

520 Bioelectric Phenomena. (3) N
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.

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

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

523 Physiological Instrumentation Lab. (1) F
Laboratory experience with problems, concepts, and techniques of biomedical instrumentation in static and dynamic environments. Lab. Pre- or corequisites: AGB/BME 435; BME/CHE 413; ECE 333 or 334.

524 Fundamentals of Applied Neural Control. (3) A
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.

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

532 Prosthetic and Rehabilitation Engineering. (3) A
Analysis and critical assessment of design and control strategies for state-of-the-art medical devices used in rehabilitation engineering. Pre- or corequisites: BME 416 (or EPE 610), 419, 435; ECE 312, 313.

533 Transport Processes I. (3) F
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 CHE 533.

534 Transport Processes II. (3) S
Continuation of BME/CHE 533, emphasizing mass transfer. Cross-listed as CHE 534. Prerequisite: BME/CHE 533.

543 Thermodynamics of Chemical Systems. (3) F
Classical and statistical thermodynamics of nonideal physicochemical systems and processes; prediction of optimum operating conditions. Cross-listed as CHE 543.

544 Chemical Reactor Engineering. (3) S
Reaction rates, thermodynamics, and transport principles applied to the design and operation of chemical reactors. Cross-listed as CHE 544. Prerequisite: BME/CHE 543.

551 Movement Biomechanics. (3) S
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 instructor approval.

566 Medical Imaging Instrumentation. (3) N
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: BME 465 or EEE 465 or instructor approval.

567 Radiation Shielding and Transport. (3) F
Shielding for radiation therapy, diagnostic radiology, cyclotrons, and nuclear reactors. Monte Carlo and empirical computational methods, regulations, and design problems. Cross-listed as EEE 567. Prerequisite: BME 465 or EEE 465.

568 Medical Tomography. (3) S
CT, SPECT, PET, and MRI. 3-dimensional *in vivo* measurements. Instrument design, physiological modeling, clinical protocols, reconstruction algorithms, and quantitation issues. Prerequisite: EEE 465.

569 Radiochemistry and Radiopharmaceutical Production. (3) N
Advanced principles of cyclotron design, targetry, operation, and utilization. Novel synthesis, tracer preparation, quality control, and biodistribution studies. Prerequisite: BME 465 or EEE 465.

Omnibus Courses: See page 44 for omnibus courses that may be offered.

MATERIALS SCIENCE AND ENGINEERING

MSE 353 Introduction to Materials Processing and Synthesis. (3) F
Principles of materials structure and properties with emphasis on applications in bulk and thin film materials processing and synthesis. Cross-listed as EEE 353. Prerequisites: CHM 116 and PHY 131 *or* equivalents.

354 Experiments in Materials Synthesis and Processing I. (2) S
Small groups of students complete three experiments selected from a list. Each is supervised by a selected faculty member. Lab. Cross-listed as EEE 354. Prerequisite: EEE/MSE 353 or equivalent.

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

420 Physical Metallurgy. (4) F
Crystal structure and defects. Phase diagrams, metallography, solidification and casting, deformation, and annealing. Lecture, lab. Prerequisite: ECE 350.

430 Thermodynamics of Materials. (3) N
Principles of statistical mechanics, statistical thermodynamics of single crystals, solutions, phase equilibrium, free energy of reactions, free electron theory, and thermodynamics of defects. Prerequisite: CHE 312 or ECE 340.

431 Corrosion and Corrosion Control. (3) S
Introduction to corrosion mechanisms and methods of preventing corrosion. Topics include the following: electrochemistry, polarization, corrosion rates, oxidation, coatings, and cathodic protection. Prerequisite: ECE 350.

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

441 Analysis of Material Failures. (3) S
Identification of types of failures. Analytical techniques. Fractography, SEM, nondestructive inspection, and metallography. Mechanical and electronic components. Prerequisite: ECE 350.

450 X-Ray and Electron Diffraction. (3) F
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.

453 Experiments in Materials Synthesis and Processing II. (2) F
A continuation of MSE 354, with emphasis on characterization. Small groups complete three experiments supervised by selected faculty members. Lab. Cross-listed as EEE 453. Prerequisites: EEE/MSE 353 and 354 *or* equivalents.

454 Advanced Materials Processing and Synthesis. (3) S
Case studies from published literature of current techniques in materials processing and synthesis. Student participation in classroom presentations. Lecture, recitation. Cross-listed as EEE 454. Prerequisites: EEE/MSE 353 and 354 *or* equivalents.

470 Polymers and Composites. (3) F
Relationship between chemistry, structure, and properties of engineering polymers. Design, properties, and behavior of fiber composite systems. Cross-listed as MAE 455. Prerequisite: ECE 350.

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

472 Integrated Circuit Materials Science. (3) N
Principles of materials science applied to semiconductor processing and fabrication in metals, ceramics, polymers, and semiconductors. Prerequisite: ECE 350.

476 Nonmetallic Materials Laboratory. (2) S
Experimental measurement of properties of polymeric, ceramic, and electronic materials. Structure characterization. Lecture, lab. Prerequisites: ECE 350; MSE 355.

480 Manufacturing Engineering. (3) F
Analysis and optimization of manufacturing processes. Prerequisite: ECE 350.

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

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

496 Professional Seminar. (0) F, S
Professional and ethical aspects with a discussion of employment opportunities and responsibilities. Lectures, field trips.

510 X-Ray and Electron Diffraction. (3) F
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.

511 Corrosion and Corrosion Control. (3) S
Introduction to corrosion mechanisms and methods of preventing corrosion. Topics include the following: electrochemistry, polarization, corrosion rates, oxidation, coatings, and cathodic protection. Prerequisite: transition student with instructor approval.

512 Analysis of Material Failures. (3) S
Identification of types of failures. Analytical techniques. Fractography, SEM, nondestructive inspection, and metallography. Mechanical and electronic components. Prerequisite: transition student with instructor approval.

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

514 Physical Metallurgy. (4) F
Crystal structure and defects. Phase diagrams, metallography, solidification and casting, and deformation and annealing. Lecture, lab. Prerequisite: transition student with instructor approval.

515 Thermodynamics of Materials. (3) N
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.

516 Mechanical Properties of Solids. (3) S
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.

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

518 Integrated Circuits Materials Science. (3) N
Principles of materials science applied to semiconductor processing and fabrication in metals, ceramics, polymers, and semiconductors. Prerequisite: transition student with instructor approval.

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

521 Defects in Crystalline Solids. (3) S
Introduction to the geometry, interaction, and equilibrium between dislocations and point defects. Relations between defects and properties will be discussed. Prerequisite: ECE 350 or instructor approval.

530 Materials Thermodynamics and Kinetics. (3) S
Thermodynamics of alloy systems, diffusion in solids, kinetics of precipitation, and phase transformations in solids. Prerequisites: CHE 312 or ECE 340; ECE 350.

531 Statistical Thermodynamics. (3) N
Kinetic and quantum theory. Statistical mechanics; ensemble theory. Structure and thermodynamics of non-interacting and interacting particles. Boltzmann integro-differential equation. Cross-listed as MAE 582. Prerequisite: MAE 581.

533 Direct Energy Conversion. (3) N
Advanced selected topics in direct energy conversion, theory, design, and applications. Cross-listed as MAE 537. Prerequisite: MAE 581.

540 Fracture, Fatigue, and Creep. (3) F
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 equivalent.

549 Manufacturing Analysis. (3) S
Analysis and optimization of manufacturing processes. Prerequisite: MSE 480.

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

556 Electron Microscopy Laboratory. (3) F
Laboratory support for MSE 558. Cross-listed as SEM 556. Pre- or corequisite: MSE/SEM 558.

557 Electron Microscopy Laboratory. (3) S
Lab support for MSE 559. Cross-listed as SEM 557. Pre- or corequisite: MSE/SEM 559.

558 Electron Microscopy I. (3) F
Microanalysis of the structure and composition of materials using images, diffraction and X-ray, and energy loss spectroscopy. Knowledge of elementary crystallography, reciprocal lattice, stereographic projections, and complex variables is required. Cross-listed as SEM 558. Prerequisite: instructor approval.

559 Electron Microscopy II. (3) S
Microanalysis of the structure and composition of materials using images, diffraction and X-ray, and energy loss spectroscopy. Knowledge of elementary crystallography, reciprocal lattice, stereographic projections, and complex variables is required. Cross-listed as SEM 559. Prerequisite: instructor approval.

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

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

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

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

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

572 Semiconductor Phase Diagrams. (3) A
Analysis of binary and ternary phase diagrams and application to semiconductor growth and vapor and liquid phase epitaxy. Prerequisite: MSE 521.

573 Magnetic Materials. (3) A
Emphasis on ferromagnetic and ferrimagnetic phenomena. Domains, magnetic anisotrophy, and magnetastriction. Study of commercial magnetic materials. Prerequisite: MSE 520 or equivalent.

Omnibus Courses: See page 44 for omnibus courses that may be offered.

Civil Engineering

Larry W. Mays
Chair
(ECG 252) 602/965–3589

PROFESSORS
W. HOUSTON, MAMLOUK, MATTHIAS, MAYS, O'BANNON, RUFF, SINGHAL, UPCHURCH

ASSOCIATE PROFESSORS
DUFFY, FAFITIS, HINKS, S. HOUSTON, RAJAN, ZANIEWSKI

ASSISTANT PROFESSORS
BAAJ, BAKER, FOX, MOBASHER

PROFESSORS EMERITI
BETZ, BLACKBURN, BORGO, KLOCK, LUNDGREN, PIAN

Civil engineers deal with some of the most critical and visible problems confronting the world's societies. Civil engineering projects are typically large and costly with potentially profound environmental, social, and economic impacts. Examples are rebuilding the decaying infrastructure (e.g., highways, bridges, urban water supply, and sewage disposal systems) of the United States and the construction of new infrastructures in the developing world. Civil engineers, as "society's engineers," play a leadership role in the planning, design, construction, operation, and management of these projects.

The Department of Civil Engineering offers challenging programs of study designed to provide students with the scientific and technical resources to pursue a broad and multifaceted range of careers. Areas of study in civil engineering are described below.

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

Geotechnical 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.

Hydraulic engineering. This area of study is involved with structures for the control of water such as dams, pipe networks, canals; flood control; irrigation; hydropower.

Structural engineering. This area of study considers the planning, analysis and design of steel and concrete bridges, buildings, dams; special offshore and space structures; composite materials.

Transportation engineering. This area of study involves the planning and design of transportation systems so that they provide safe, rapid, comfortable, convenient, and economical movement of people and goods; mass transit systems, railroads; airports; waterways and pipelines.

Water resources engineering. This area of study is concerned with surface and groundwater flow; planning and management of water supply; water distribution system modeling.

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

ENTRANCE REQUIREMENTS

See "Admission," and "Degrees and Majors," pages 241–242 for information regarding entrance requirements.

DEGREE REQUIREMENTS

The B.S.E. degree in Civil Engineering requires a minimum of 133 semester hours of course work, not including the university First-Year Composition requirement. The minimum requirements are for a student who has successfully completed at least a year (each) of high school chemistry, physics, computer programming, and precalculus algebra and trigonometry.

The B.S.E. degree program consists of three categories:

1. general studies and university First-Year Composition (see pages 49–71, 72);
2. engineering core (see pages 244–245); and
3. major (Civil Engineering).

The major consists of the Civil Engineering core, design electives, and technical electives.

Civil Engineering Core

Thirty-five hours are required. CEE courses, except CEE 296 and 321, may not be taken until all mathematics (MAT) and all engineering core courses (ECE), except ECE 383, 384, and 400, have been completed with an average grade of "C" or better. No CEE 400-level courses may be taken until ECE 383 and 384 have been completed.

			Semester Hours
CEE	296	Introduction to Civil Engineering	1
CEE	321	Structural Analysis	3
CEE	322	Steel Structures	3
CEE	323	Concrete Structures	3
CEE	341	Hydraulic Engineering	4
CEE	351	Soil Mechanics	4
CEE	361, 362	Environmental Engineering	6
CEE	372	Transportation Engineering	4
CEE	496	Topics in Civil Engineering Practice	1
IEE	300	Economic Analysis for Engineers	3
MAE	371	Fluid Mechanics	3

Civil Engineering Design Electives

Two courses (six semester hours) from the following list are required.

			Semester Hours
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

Civil Engineering Technical Electives

Eleven hours are required. The design elective courses that have not been selected to satisfy the design electives requirement (see above) may be used as technical electives.

A maximum of six hours may be selected outside civil engineering with advisor's approval. Courses in addition to those listed below are available and are indicated as CEE 498 on the three-year teaching plan of the department.

Construction. CON 341, 383, 495, 496. Only one of these courses may be selected for technical elective credit.

Environmental Engineering. Water treatment, industrial and domestic waste treatment and disposal, public health engineering, industrial hygiene. CEE 466; CHM 231; MIC 220 (or 205 and 206).

Geotechnical Engineering. Assessment of engineering properties and design utilizing soils and rocks as engineering materials. CEE 452.

Structural Engineering. Analysis and design of structures for buildings, bridges, space frames, structural mechanics. CEE 423, 432.

Transportation Engineering. Analysis and design of transportation facilities, transportation planning and economics, transportation in the urban environment. CEE 412, 471, 475.

Water Resources Engineering. Planning and design of facilities for collection, storage and distribution of water, water systems management, estimating availability of water resources. CEE 440, 441.

Civil Engineering Program of Study
A Four-Year Sequence

Freshman Year

First Semester — *Semester Hours*

CEE	296	Introduction to Civil Engineering	1
CHM	114	General Chemistry for Engineers[2]	4
ECE	105	Introduction to Languages of Engineering	3
ENG	101	First-Year Composition	3
MAT	270	Calculus with Analytic Geometry I	4
HU or SB elective[1]			3
Total			18

Second Semester

ECE	106	Introduction to Computer-Aided Engineering	3
ENG	102	First-Year Composition	3
MAT	271	Calculus with Analytic Geometry II	4
PHY	121	University Physics I: Mechanics	3
PHY	122	University Physics Laboratory I	1
HU or SB elective[1]			3
Total			17

Sophomore Year

First Semester

ECE	210	Engineering Mechanics I: Statics	3
MAT	272	Calculus with Analytic Geometry III	4
MAT	274	Elementary Differential Equations	3
PHY	131	University Physics II: Electricity and Magnetism	3
PHY	132	University Physics Laboratory II	1
L1 elective[1, 3]			3
Total			17

Second Semester

ECE	301	Electrical Networks I	4
ECE	312	Engineering Mechanics II: Dynamics	3
ECE	313	Introduction to Deformable Solids	3
ECE	340	Thermodynamics	3
ECE	383	Probability and Statistics for Engineers	2
ECN	111	Macroeconomic Principles or ECN 112 Microeconomic Principles (3)	3
Total			18

Junior Year

First Semester

CEE	321	Structural Analysis	3
ECE	351	Engineering Materials	3
ECE	384	Numerical Analysis for Engineers I	2
IEE	300	Economic Analysis for Engineers	3
MAE	371	Fluid Mechanics	3
Basic science elective[4]			3
Total			17

Second Semester

CEE	322	Steel Structures	3
CEE	341	Hydraulic Engineering	4
CEE	351	Geotechnical Engineering	4
CEE	361	Environmental Engineering	3
CEE	372	Transportation Engineering	4
Total			18

Senior Year

First Semester

CEE	323	Concrete Structures	3
CEE	362	Environmental Engineering	3
CEE	496	Topics in Civil Engineering Practice	1
Design elective			3
HU or SB elective[1]			3
Technical elective			6
Total			19

Second Semester

CEE	400	Microcomputer Applications in Civil Engineering	3
ECE	400	Engineering Communications	3
Design elective			3
HU or SB elective[1]			3
Technical elective			5
Total			17

Graduation requirements: 133 semester hours minimum plus English proficiency.

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[1] See pages 53–71 for the requirements and the approved list.

[2] Students who have taken no high school chemistry should take CHM 113 and 116.

[3] See page 244 for special requirements and selection of an L1 elective.

[4] Must be an earth science or life science course; if physics or chemistry, the course must be of a more advanced level than PHY 131 or CHM 114/116.

Seventeen semester hours of design and technical electives with an average grade of "C" or better is required. Two graduate courses may be taken for undergraduate credit by students whose cumulative GPA is 3.00 or better and with the approval of the instructor, advisor, department chair, and dean of the college.

Concurrent Studies in Architecture and Civil Engineering

Undergraduate. Qualified lower-division students interested in combining studies in architecture and civil engineering may prepare for upper-division and graduate courses in both programs by taking courses listed in option "B" of the School of Architecture (page 167).

Graduate. Qualified students may develop a program of study that leads to the concurrent degrees Master of Architecture and M.S.E. with a focus in Civil Engineering. The student's program of study is developed in conjunction with advisors in both departments. For specific details consult with advisors in the departments.

CIVIL ENGINEERING

CEE 296 Introduction to Civil Engineering. (1) F, S
Introduction to the profession. Description of areas of specialization. Degree requirements, academic standing, and advising procedures. Introduction to lab facilities. Prerequisite: freshman standing.

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

321 Structural Analysis. (3) F, S
Statically determinate and indeterminate structures by classical and matrix methods such as trusses, beams, and frames. 2 hours lecture, 2 hours recitation. Prerequisite: ECE 313.

322 Steel Structures. (3) F
Behavior of structural components and systems. Design of steel members and connections. Load and resistance factor design methods. Lecture, recitation. Prerequisites: CEE 321; completion of engineering core (except ECE 383, 384, and 400); minimum core grade requirements satisfied.

323 Concrete Structures. (3) S
Behavior of concrete structures and the design of reinforced and prestressed concrete members, including footings. Partial design of concrete building system. Lecture, recitation. Prerequisites: CEE 321; completion of engineering core (except ECE 383, 384, and 400); minimum core grade requirements satisfied.

340 Hydraulics and Hydrology. (3) F, S
Application of hydraulic engineering principles to flow of liquids in pipe systems and open channels; hydrostatics; characteristics of pumps and turbines. Introduction to hydrology. Not open to engineering students. Lecture, lab. Prerequisite: CON 221.

341 Hydraulic Engineering. (4) F, S
Fundamental principles and methods of fluid mechanics forming analytical basis for water resources engineering. Flow in conduits and open channels. Introduction to hydrology. Lecture, lab. Prerequisites: MAE 371; completion of engineering core (except ECE 383, 384, and 400); minimum core grade requirements satisfied.

351 Soil Mechanics. (4) F, S
Index properties and engineering characteristics of soils. Compaction, permeability and seepage, compressibility and settlement, and shear strength. Lecture, lab. Prerequisites: CEE 321; completion of engineering core (except ECE 383, 384, and 400); minimum core grade requirements satisfied.

361 Environmental Engineering. (3) F, S
Natural environment, water resources, hydrologic cycle, chemistry of natural waters, quality requirements and water treatment, and water distribution systems. Prerequisite: MAE 371.

362 Environmental Engineering. (3) S
Natural environment, the carbon cycle and biochemistry of wastes, principles of waste treatment, and drainage systems. Prerequisites: CEE 341, 361.

371 Introduction to Urban Planning. (3) N
Theoretical and practical aspects of city planning. Interrelationships among physical planning, environment, government, and society. Not acceptable as a technical elective for CEE students.

372 Transportation Engineering. (4) F, S
Highway, rail, water, and air transportation. Operational characteristics and traffic control devices of each transport mode. Impact on urban form. Prerequisites: CEE 321; completion of engineering core (except ECE 383, 384, and 400); minimum core grade requirements satisfied.

400 Microcomputer Applications in Civil Engineering. (3) S
Development of microcomputer literacy in civil engineering applications. Prerequisites: CEE 351, 361, 372; ECE 106.

412 Pavement Analysis and Design. (3) F
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.

423 Structural Design. (3) F
Analysis and design of reinforced concrete steel, masonry, and timber structures. Lecture, lab. Prerequisites: CEE 322, 323.

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

440 Engineering Hydrology. (3) F
Descriptive hydrology, including hydrologic cycle, systems, and models. Rain-runoff models. Hydrologic design. Concepts, properties, and basic equations of groundwater flow. Prerequisite: CEE 341.

441 Water Resources Engineering. (3) S
Application of 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.

450 Soil Mechanics in Construction. (3) F, S
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.

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

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

471 Planning and Design of Urban Systems. (3) N
For students in city planning, urban systems, civil engineering, and related areas working as interdisciplinary planning and design teams. Effect of economic base employment, and population on urban land use requirements. Location and required capacity of urban systems to serve urban land uses. Lecture, lab. Prerequisite: senior standing.

475 Highway Geometric Design. (3) F
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.

496 Topics in Civil Engineering Practice. (1) F, S
Professional engineering practice. Interviewing and résumé writing, professional registration requirements, continuing education, graduate study, financial planning, and employment. Prerequisite: senior standing.

512 Pavement Performance and Management. (3) F
Pavement management systems, including data collection, evaluation, optimization, economic analysis, and computer applications for highway and airport design. Prerequisite: CEE 412.

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

515 Properties of Concrete. (3) S
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.

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

524 Advanced Steel Structures. (3) F
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.

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

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

528 Stability of Structures. (3) N
Elastic and inelastic buckling of rolled and cold-formed columns and beams. Stability of plates, rigid frames, and trusses. Prerequisites: CEE 322; instructor approval.

529 Complex Structures. (3) N
Classical and numerical investigations of linear and nonlinear structures composed of flat and curved surfaces and linear or curvilinear elements. Prerequisite: instructor approval.

530 Prestressed Concrete. (3) F ’95
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.

531 Theory of Structures. (3) N
General theorems relating to elastic systems; deflection of trusses and beams; statically indeterminate trusses, beams, rings, arches, and frames by consistent deformation, least work, and elastic center; horizontally curved members in bending and torsion. Prerequisite: CEE 321.

533 Applied Optimal Design. (3) S ’95
Linear and nonlinear programming. Problem formulation. Design sensitivity analysis. FEM-based optimal design of structural and mechanical systems. Prerequisite: graduate standing or instructor approval.

536 Structural Dynamics. (3) F
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.

537 Topics in Structural Engineering. (1–3) F, S
Advanced topics, including, wind engineering, earthquake engineering, probabilistic concepts, and bridge and building engineering. Prerequisite: instructor approval.

540 Groundwater Hydrology. (3) F
Physical properties of aquifers; groundwater exploration, well construction, and pumping; subsurface flow modeling; land subsidence, groundwater pollution, and water rights. Prerequisite: CEE 341 or instructor approval.

541 Surface Water Hydrology. (3) S
Hydrologic cycle and mechanisms, including precipitation, evaporation, and transpiration; hydrograph analysis; flood routing; statistical methods in hydrology and hydrologic design. Prerequisite: CEE 341 or instructor approval.

542 Water Resources Systems Planning. (2) A
Philosophy of water resources planning; economic, social, and engineering interaction; introduction to the theory and application of quantitative planning methodologies in water resources planning. Guest lecturers, case studies. Prerequisite: instructor approval.

543 Water Resources Systems I. (3) A
Theory and application of quantitative planning methodologies for the design and operation of water resources systems; class projects using a computer; case studies. Pre- or corequisite: CEE 542 or instructor approval.

544 Water Resources Systems II. (3) F ’94
Advanced computer-oriented workshop in the application of quantitative planning techniques to the design and operation of water resources systems. Prerequisite: CEE 543.

545 Foundations of Hydraulic Engineering. (2) S ’95
Review of incompressible fluid dynamics. Flow in pipes and channels; unsteady and varied flows; wave motion. Prerequisite: CEE 341.

546 Free Surface Hydraulics. (2) F ’95
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.

547 Principles of River Engineering. (2) N
Uses of rivers, study of watershed, and channel processes. Sediment sources, yield, and control; hydrologic analysis. Case studies. Prerequisite: CEE 341 or instructor approval.

548 Sedimentation Engineering. (2) F ’94
Introduction to 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.

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

551 Advanced Soil Mechanics Laboratory. (3) F
Odometer, triaxial (static and cyclic) back pressure saturated and unsaturated samples, pore pressure measurements, resonant column, automatic data acquisition, and in-situ testing. Lecture, labs. Prerequisite: CEE 351.

552 Geological Engineering. (3) S
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.

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

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

555 Applied Soil Mechanics. (3) S
Deep foundations, braced excavations, anchored bulkheads, reinforced earth, underpinning, and dewatering. Prerequisite: CEE 452.

556 Seepage and Earth Dams. (3) F
Transient and steady state fluid flow through soil, confined and unconfined flow, pore water pressures, and application to earth dams. Prerequisite: CEE 351.

557 Topics in Geotechnical Engineering. (3) N
New and developing technology in geotechnical engineering. Prerequisites: graduate standing; instructor approval.

558 Numerical Methods. (3) N
Constitutive relations for soils and numerical techniques applied to geotechnical engineering, including computer applications. Prerequisites: CEE 351; computer programming; graduate standing.

559 Earthquake Engineering. (3) F
Characteristics of earthquake motions, selection of design earthquakes, site response analyses, seismic slope stability, and liquefaction. Prerequisites: CEE 351; graduate standing.

560 Hazardous Waste: Site Assessment and Mitigation Measures. (3) N
Techniques for hazardous waste site assessment and mitigation. Case histories presented by instructor and guest speakers. Prerequisite: graduate standing in Civil Engineering.

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

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

563 Environmental Chemistry Laboratory. (3) F
Analysis of water, domestic and industrial wastes, laboratory procedures for pollution evaluation, and the control of water and waste treatment processes. Lecture, lab. Prerequisite: CEE 361 or 362.

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

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

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

575 Traffic Flow Theory and Safety Analysis. (3) S
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.

576 Airport Engineering. (3) F
Planning and design of airport facilities. Effect of aircraft characteristics, air traffic control procedures and aircraft demand for runway and passenger handling facilities, on-site selection, runway configuration, and terminal design. Prerequisite: CEE 372.

577 Urban Transportation Planning. (3) F
Application of 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.

578 Highway Engineering, Planning, and Economics. (3) S
Highway transportation, including design, operation, planning, environmental impact, economic feasibility, and financing. Highways as a regional system. Prerequisite: CEE 372.

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. *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. Each civil engineering graduate student holding an appointment as a teaching or research assistant or associate is to enroll for one semester hour of CEE 580; such credit does not apply toward graduation.*

Omnibus Courses: See page 44 for omnibus courses that may be offered.

Computer Science and Engineering

Ben M. Huey
Acting Chair
(GWC 206) 602/965–3190

PROFESSORS
ASHCROFT, BARNHILL, BLACKLEDGE, COLLOFELLO, FARIN, FINDLER, LEWIS, NIELSON, J. URBAN, WOODFILL

ASSOCIATE PROFESSORS
DASGUPTA, FALTZ, FAUSTINI, FOLEY, GOLSHANI, HUEY, LINDQUIST, MILLER, O’GRADY, PHEANIS, ROCKWOOD, SEN

ASSISTANT PROFESSORS
CALLISS, DIETRICH, ELGOT-DRAPKIN, KAMBHAMPATI, S. URBAN

PROFESSOR EMERITUS
ROBBINS

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. in Computer Science and a B.S.E. in Computer Systems Engineering.

DEGREE REQUIREMENTS

Minimum Scholastic Requirements. 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.

Computer Science—B.S.

The Department of Computer Science and Engineering offers a B.S. degree that prepares the student for a career in computer science. A student pursuing a B.S. degree must complete an English proficiency requirement, the general studies requirements described below, the computer science core courses, a senior-level breadth requirement in the major, and a set of technical electives.

English Proficiency			*Semester Hours*
ENG	101, 102	First-Year Composition or ENG 105 Advanced First-Year Composition (3)	6
General Studies			
*Humanities and Fine Arts and Social and Behavioral Sciences** (18 semester hours minimum) These courses must include at least one upper-division course, at least two courses from the same department, and courses from at least two departments.			
Humanities and fine arts			6–12
Social and behavioral sciences			12–6
Literacy and Critical Inquiry			
ECE	400	Engineering Communications	3
One L1 course*			3
Numeracy			
ECE	383	Probability and Statistics for Engineers	2
MAT	270	Calculus with Analytic Geometry I or MAT 290 Calculus I (5)	4
Natural Science			
PHY	121	University Physics I: Mechanics	3
PHY	122	University Physics Laboratory I	1
PHY	131	University Physics II: Electricity and Magnetism	3
PHY	132	University Physics Laboratory II	1
Any physics courses requiring PHY 131 as a prerequisite or any laboratory science satisfying the S1 or S2 general studies requirements (except PHS 110; PHY 101, 105, 111, 112)			6
Total general studies			44

NOTE: Six semester hours taken in two of the three awareness areas* are required in the final list of courses in the student's graduation program of study. These can be included in the HU and SB course selections.

* See pages 53–71 for the requirements and the approved list.

Computer Science Core			*Semester Hours*
CSE	100	Introduction to Computer Science I	3
CSE	101	Introduction to Computer Science II	3
CSE	120	Digital Design Fundamentals	3
CSE	201	Application Languages Programming Laboratory	1–2
CSE	202	Functional Languages Programming Laboratory	2–1
CSE	225	Assembly Language Programming (Motorola) or CSE 226 Assembly Language Programming (Intel) (3)	3
CSE	310	Data Structures	3
CSE	325	System Design with Microprocessors (Motorola) or CSE 326 System Design with Microprocessors (Intel) (3)	3
CSE	330	Computer Organization and Architecture	3
CSE	340	Structure of Programming Languages	3
CSE	355	Introduction to Theoretical Computer Science	3
MAT	243	Discrete Mathematical Structures	3
MAT	271	Calculus with Analytic Geometry II or MAT 291 Calculus II (5)	4
MAT	272	Calculus with Analytic Geometry III or MAT 291 Calculus II (5)	4
MAT	342	Linear Algebra	3
Total computer science core			44

Computer science breadth requirement. Each student must complete 18 hours of CSE 400-level courses.	18
Technical electives. Each student must complete nine hours of courses chosen from the computer science technical elective list and approved by the student's advisor.	9
Unrestricted electives	7
Total degree requirements	128

Computer Science Program of Study
Typical Four-Year Sequence

Freshman Year

First Semester			*Semester Hours*
CSE	100	Introduction to Computer Science I	3
ENG	101	First-Year Composition	3
MAT	270	Calculus with Analytic Geometry I	4
HU or SB elective[1]			3
Laboratory science (S1)[1, 2]			3
Total			16
Second Semester			
CSE	101	Introduction to Computer Science II	3
CSE	120	Digital Design Fundamentals	3
ENG	102	First-Year Composition	3
MAT	271	Calculus with Analytic Geometry II	4
Laboratory science (S2)[1, 2]			3
Total			16

Sophomore Year

First Semester			
CSE	201	Application Languages Programming Laboratory	1
CSE	202	Functional Languages Programming Laboratory	1
MAT	243	Discrete Mathematical Structures	3
MAT	272	Calculus with Analytic Geometry III	4
PHY	121	University Physics I: Mechanics	3
PHY	122	University Physics Laboratory I	1
HU or SB elective[1]			3
Total			16
Second Semester			
CSE	225	Assembly Language Programming (Motorola)	3
CSE	310	Data Structures	3
PHY	131	University Physics II: Electricity and Magnetism	3
PHY	132	University Physics Laboratory II	1
HU or SB elective[1]			3
L1 elective[1]			3
Total			16

Junior Year

First Semester

CSE 201	Application Languages Programming Laboratory	1
CSE 325	System Design with Microprocessors (Motorola)	3
CSE 340	Structure of Programming Languages	3
MAT 342	Linear Algebra	3
HU or SB elective[1]		3
Unrestricted elective		3
Total		16

Second Semester

CSE 330	Computer Organization and Architecture	3
CSE 355	Introduction to Theoretical Computer Science	3
ECE 383	Probability and Statistics for Engineers	2
HU or SB elective[1]		3
Technical elective		3
Unrestricted elective		2
Total		16

Senior Year

First Semester

ECE 400	Engineering Communications	3
400-level CSE computer science breadth electives		9
Technical elective		3
Unrestricted elective		1
Total		16

Second Semester

HU or SB elective[1]		3
400-level CSE computer science breadth electives		9
Technical elective		3
Unrestricted elective		1
Total		16

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1 See pages 53–71 for the requirements and the approved list.

2 Any physics courses requiring PHY 131 as a prerequisite or any laboratory science course satisfying the S1 or S2 general studies requirements (except PHS 110; PHY 101, 105, 111, 112).

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 provides training in both engineering and computer science. The degree requirements for the School of Engineering on pages 242–244 show the requirements for English proficiency and general studies for the B.S.E. degree. The following list specifies the remaining requirements for the B.S.E. degree.

Engineering Core		*Semester Hours*
CHM 114	General Chemistry for Engineers or CHM 116	4
CSE 225	Assembly Language Programming (Motorola) or CSE 226 Assembly Language Programming (Intel) (3)	3
ECE 105	Introduction to Languages of Engineering	3
ECE 210	Engineering Mechanics I: Statics	3
ECE 301	Electrical Networks I	4
ECE 312	Engineering Mechanics II: Dynamics	3
ECE 333	Electrical Instrumentation	3
ECE 340	Thermodynamics	3
ECE 352	Properties of Electronic Materials	3
ECE 383	Probability and Statistics for Engineers	2
MAT 274	Elementary Differential Equations	3
MAT 291	Calculus II or MAT 271 (4) and 272 (4)	5
MAT 342	Linear Algebra	3
PHY 361	Introductory Modern Physics*	3
Total		45

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* Basic science elective.

Computer Science Core		*Semester Hours*
CSE 120	Digital Design Fundamentals	3
CSE 200	Concepts of Computer Science	4
CSE 201	Application Languages Programming Laboratory	1
CSE 202	Functional Languages Programming Laboratory	1
CSE 310	Data Structures	3
CSE 325	System Design with Microprocessors (Motorola) or CSE 326 System Design with Microprocessors (Intel) (3)	3
CSE 330	Computer Organization and Architecture	3
CSE 340	Structure of Programming Languages	3
CSE 355	Introduction to Theoretical Computer Science	3
CSE 421	Microprocessor System Design I	4
CSE 422	Microprocessor System Design II	4
CSE 423	Microcomputer System Hardware	3
MAT 243	Discrete Mathematical Structures	3
Technical electives		13
Total		51

The student selects technical electives from an approved list with approval of an advisor.

Computer Systems Engineering Program of Study

Typical Four-Year Sequence

Freshman Year

First Semester		*Semester Hours*
CHM 114	General Chemistry for Engineers	4
ECE 105	Introduction to Languages of Engineering	3
ENG 101	First-Year Composition	3
MAT 290	Calculus I	5
HU or SB elective[1]		3
Total		18

Second Semester

CSE 120	Digital Design Fundamentals	3
CSE 200	Concepts of Computer Science	4
ECE 106	Introduction to Computer-Aided Engineering	3
ENG 102	First-Year Composition	3
MAT 291	Calculus II	5
Total		18

Sophomore Year

First Semester

CSE 201	Application Languages Programming Laboratory	1
CSE 225	Assembly Language Programming (Motorola)	3
ECN 111	Macroeconomic Principles	3
MAT 243	Discrete Mathematical Structures	3
MAT 274	Elementary Differential Equations	3
PHY 121	University Physics I: Mechanics	3
PHY 122	University Physics Laboratory I	1
Total		17

Second Semester

CSE 202	Functional Languages Programming Laboratory	1
CSE 310	Data Structures	3
CSE 325	System Design with Microprocessors (Motorola)	3
ECE 210	Engineering Mechanics I: Statics	3
PHY 131	University Physics II: Electricity and Magnetism	3
PHY 132	University Physics Laboratory II	1
L1 elective[1, 2]		3
Total		17

Junior Year

First Semester

CSE 330	Computer Organization and Architecture	3
CSE 340	Structure of Programming Languages	3
ECE 312	Engineering Mechanics II: Dynamics	3

ECE	383	Probability and Statistics for Engineers	2
PHY	361	Introductory Modern Physics	3
HU or SB elective[1]			3
Total			17

Second Semester

CSE	355	Introduction to Theoretical Computer Science	3
CSE	421	Microprocessor System Design I	4
ECE	301	Electrical Networks I	4
MAT	342	Linear Algebra	3
HU or SB elective[1]			3
Total			17

Senior Year

First Semester

CSE	422	Microprocessor System Design II	4
ECE	333	Electrical Instrumentation	3
ECE	340	Thermodynamics	3
ECE	400	Engineering Communications	3
Technical elective			4
Total			17

Second Semester

CSE	423	Microcomputer System Hardware	3
ECE	352	Properties of Electronic Materials	3
HU or SB elective[1]			3
Technical electives			9
Total			18

[1] See pages 53–71 for the requirements and the approved list.

[2] See page 244 for special requirements and selection of an L1 elective.

COMPUTER SCIENCE AND ENGINEERING

CSE 100 Introduction to Computer Science I. (3) F, S, SS
Concepts of problem solving, algorithm design, structured programming, fundamental algorithms and techniques, and computer systems concepts. Social and ethical responsibility. Prerequisite: MAT 170.

101 Introduction to Computer Science II. (3) F, S, SS
Advanced programming techniques; file processing; implementing stacks, queues, linked lists, and binary search trees; large program development; team programming. Professional responsibility. Prerequisite: CSE 100. *General studies: N3.*

120 Digital Design Fundamentals. (3) F, S, SS
Number systems, conversion methods, binary and complement arithmetic, Boolean and switching algebra, circuit minimization, ROMs, PLAs, flipflops, synchronous sequential circuits, and register transfer design. Lecture, lab. Cross-listed as EEE 120. Prerequisite: CSE 100 or ECE 105.

180 Computer Literacy. (3) F, S, SS
Introduction to general problem-solving approaches using widely available software tools such as database packages, word processors, spreadsheets, and report generators. IBM PC or Macintosh. Nonmajors only. *General studies: N3.*

181 Applied Problem Solving with BASIC. (3) F, S, SS
Introduction to systematic definition of problems, solution formulation, and method validation. Computer solution using BASIC required for projects. Lecture, lab. Nonmajors only. Prerequisite: MAT 117. *General studies: N3.*

183 Applied Problem Solving with FORTRAN. (3) F
A human-oriented, systems approach to problem definition, formulation, and solution using FORTRAN. Computer solution required for projects. Nonmajors only. Prerequisite: MAT 170. *General studies: N3.*

200 Concepts of Computer Science. (4) A
Accelerated coverage of fundamentals of computer science using Pascal; professional responsibility. For students with a strong background in at least one other high-level programming language. Prerequisite: ECE 105 or equivalent. *General studies: N3.*

201 Application Languages Programming Laboratory. (1) F, S, SS
Each module introduces a programming language such as C, FORTRAN, PL/1, or COBOL. Includes programming exercises. May be repeated for different languages. Note: CSE 201 “C” and ECE 105 cannot both count for credit in one program of study. Prerequisite: CSE 101 or 200.

202 Functional Languages Programming Laboratory. (1) F, S, SS
Each module introduces a programming language such as APL, LISP, or PROLOG. Includes programming exercises. May be repeated for different languages. Prerequisite: CSE 101 or 200.

225 Assembly Language Programming (Motorola). (3) F, S, SS
Assembly language programming, register level computer organization, data structure and addressing modes, assemblers, and linkers. Motorola-based assignments. Cross-listed as EEE 225. Prerequisite: CSE/EEE 120. *General studies: N3.*

226 Assembly Language Programming (Intel). (3) F, S
Assembly language programming, register level computer organization, data structure and addressing modes, assemblers, and linkers. Intel-based assignments. Cross-listed as EEE 226. Prerequisite: CSE/EEE 120. *General studies: N3.*

310 Data Structures. (3) F, S, SS
Advanced treatment of representation, arrays, stacks, queues, lists, dynamic storage allocation, n-ary trees, strings, graphs, AVL trees; data abstraction; privacy, protection, and regulation. Prerequisites: CSE 101 or 200; MAT 243.

325 System Design with Microprocessors (Motorola). (3) F, S, SS
CPU, memory, and peripheral device interfaces and programming. Microcomputer systems, standard systems buses, serial and parallel I/O, direct memory access devices, communications; safety and reliability. Lecture, lab. Cross-listed as EEE 325. Prerequisite: CSE/EEE 225.

326 System Design with Microprocessors (Intel). (3) F, S, SS
CPU, memory, and peripheral device interfaces and programming. Microcomputer systems, standard system buses, serial and parallel I/O, direct memory access devices, communications; safety and reliability. Lecture, lab. Cross-listed as EEE 326. Prerequisite: CSE/EEE 226.

330 Computer Organization and Architecture. (3) F, S, SS
Hardwired timing and control, microcontrol, pipelining, memory media, organization, and management; vectored interrupts and DMA. Prerequisite: CSE/EEE 325 or 326.

340 Structure of Programming Languages. (3) F, S
Formal specifications for language syntax and dynamic runtime environments, and an introduction to language translation. Prerequisites: CSE 201 (or 202 or ECE 105), 225 (or 226), 310.

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

383 Applied FORTRAN Programming. (3) F, S
Advanced FORTRAN, including character handling, machine dependency, sorting and merging, plotting, tapes, disks, time-sharing terminals, and library programs. Lecture, lab. Nonmajors only. Prerequisite: CSE 183.

408 Multimedia Information Systems. (3) F
Design, use, and applications of multimedia systems. An introduction to acquisition, compression, storage, retrieval, and presentation of data from different media such as images, text, voice, and alphanumeric. Prerequisite: CSE 410.

410 Information Processing. (3) A
Primary and secondary file access organizations. Multi-attribute indexing. File processing. Introduction to database management and document retrieval. Social and ethical implications. Prerequisite: CSE 310.

412 Database Management. (3) F, S
Introduction to DBMS concepts. Data models and languages. Relational database theory. Database security/integrity and concurrency. Prerequisite: CSE 310.

420 Computer Architecture I. (3) S
Computer architecture. Performance versus cost trade-offs. Instruction set design. Basic processor implementation and pipelining. Prerequisite: CSE 330.

421 Microprocessor System Design I. (4) F, S
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. Pre- or corequisite: CSE/EEE 225 (or 226), 325 (or 326).

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

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

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

430 Operating Systems. (3) F, S
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.

434 Computer Networks. (3) A
Computer network protocols, hardware elements, and software algorithms. Error handling, routing, flow control, host-to-host communication, and local area networks. Prerequisite: CSE 330.

438 Systems Programming. (3) A
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.

440 Compiler Construction I. (3) F
Introduction to 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.

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

451 Switching Theory. (3) N
Combinational logic, functional decomposition, NAND (NOR) circuit analysis and synthesis, logic arrays, iterative networks, fault diagnosis, sequential circuit representation, and memory devices. Prerequisites: CSE 120; MAT 243.

457 Theory of Formal Languages. (3) A
Theory of grammar, methods of syntactic analysis and specification, types of artificial languages, relationship between formal languages, and automata. Cross-listed as MAT 401. Prerequisite: CSE 355.

459 Logic for Computing Scientists I. (3) F
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.

460 Software Project Management and Development I. (3) F, S
Software life cycle analysis; programming teams; requirements, specifications, documentation and milestones; design, testing, and maintenance tools and techniques. Ethical and professional responsibilities. Prerequisites: CSE 310, 340. Pre- or corequisite: CSE 355.

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

471 Introduction to Artificial Intelligence. (3) F, S
State space search, heuristic search, games, knowledge representation techniques, expert systems, and automated reasoning. Prerequisites: CSE 202 (LISP and PROLOG), 310.

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

474 Modeling for Computer Simulation. (3) A
Mathematical description of general dynamic systems (discrete event, discrete time, and continuous) in forms suitable for computer implementation. Prerequisites: CSE 310; ECE 383.

475 Simulation Theory and Languages. (3) A
Statistical background for simulation. Model construction and validation, and the analysis of results. Languages that support simulation. Prerequisite: CSE 474.

476 Introduction to Natural Language Processing. (3) F
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.

477 Introduction to Computer-Aided Geometric Design. (3) F, S
Introduction to parametric curves and surfaces, Bezier and B-spline interpolation, and approximation techniques. Prerequisites: CSE 101 (or 200), 470; MAT 342.

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

509 Digital Image Processing II. (3) S
Advanced analytical techniques applied to digital image processing, computer vision, and applications, including robotics. Prerequisite: CSE 508.

510 Advanced Database Management. (3) F, S
Advanced data modeling, deductive databases, object-oriented databases, distributed and multidatabase systems; emerging database technologies. Prerequisite: CSE 412.

512 Distributed Databases. (3) A
Fragmentation design. Query optimization. Distributed joins. Concurrency control. Distributed deadlock detection. Prerequisite: CSE 510.

513 Deductive Databases. (3) A
Logic as a data model. Query optimization emphasizing the top-down and bottom-up evaluation of declarative rules. Prerequisite: CSE 510.

514 Object-Oriented Database Systems. (3) A
Object-oriented data modeling, database and language integration, object algebras, extensibility, transactions, object managers, versioning/configuration, active data, nonstandard applications. Research seminar. Prerequisite: CSE 510.

516 Digital Testing and Reliability. (3) A
Fault modeling, test generation, and simulation for combinational and sequential circuits; memory testing, self-checking logic, fault-tolerant logic, and reliability analysis. Prerequisites: CSE 330 (or 423), 355 (or 451).

517 Digital Design Automation. (3) N
Typical computer-aided design system. Simulation techniques, test generation, microprogrammed control design aids, and specification sheet analysis. Applications. Prerequisite: CSE 520 or 524.

518 Hardware Design Languages. (3) N
Introduction to hardware design languages (HDL's). HDL description of integrated circuit components and systems. HDL description of computer organizations. Prerequisite: CSE 330.

520 Computer Architecture II. (3) F
Computer architecture description languages, computer arithmetic, memory-hierarchy design, parallel, vector, and multiprocessors, and input/output. Prerequisites: CSE 420, 430.

521 Microprocessor Applications. (4) S
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.

523 Microcomputer Systems Software. (3) F
Developing system software for a multiprocessor, multiprogramming, microprocessor-based system using information and techniques presented in CSE 421, 422. Prerequisite: CSE 422.

526 Parallel Processing. (3) N
Real and apparent concurrency. Hardware organization of multiprocessors, multiple computer systems, scientific attached processors, and other parallel systems. Prerequisite: CSE 330 or 423.

527 High-Level-Language Machines. (3) N
Advantages and disadvantages of high-level-language machines. Languages suitability. Microprogramming and interpretive execution. I/O operations. Examples. Prerequisite: CSE 520 or 524.

529 RISC Design Methodology. (3) N
Optimal computer architecture design methodology based on the symbiotic relationship of hardware and software disciplines. Prerequisite: CSE 330 or 423.

530 Operating System Internals. (3) F
Implementation of process management and synchronization, system call and interrupt handling, memory management, device drivers and file systems in UNIX. Prerequisites: CSE 430; knowledge of C language.

531 Distributed and Multiprocessor Operating Systems. (3) N
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 530 or instructor approval.

532 Advanced Operating System Internals. (3) F
Memory, processor, process and communication management, and concurrency control in the Mach multiprocessor and distributed operating system kernels and servers. Prerequisite: CSE 530 or instructor approval.

535 Performance Evaluation. (3) S
Topics in computer system measurement and evaluation, including hardware/software monitors, workload characterization, program behavior, adaptive scheduling, simulation models, and measurement interpretation. Prerequisite: CSE 430.

536 Theory of Operating Systems. (3) S
Protection. Communication and synchronization in distributed systems, distributed file systems, deadlock theory, virtual memory theory, and uniprocessor and multiprocessor thread management. Prerequisite: CSE 430.

540 Compiler Construction II. (3) S
Formal parsing strategies, optimization techniques, code generation, extensibility and transportability considerations, and recent developments. Prerequisite: CSE 440.

545 Programming Language Design. (3) N
Language constructs, extensibility and abstractions, and runtime support. Language design process. Prerequisite: CSE 440.

550 Combinatorial Algorithms and Intractability. (3) N
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.

554 Advanced Switching Theory. (3) S
Lattices, Boolean algebras, post algebras, Boolean differential calculus, multivalued logic, fuzzy logic, and finite state machines. Prerequisite: CSE 451.

555 Automata Theory. (3) N
Finite state machines, pushdown automata, linear bounded automata, Turing machines, register machines, rams, and rasps; relationships to computability and formal languages. Prerequisite: CSE 355.

556 Expert Systems. (3) S
Knowledge acquisition and representation, rule-based systems, frame-based systems, validation of knowledge bases, inexact reasoning, and expert database systems. Prerequisite: CSE 471.

560 Software Project Management and Development II. (3) F, S
Software project management, cost estimation, configuration management, and quality assurance. Advanced software engineering life cycle topics. Prerequisite: CSE 460.

563 Software Requirements and Specification. (3) F
Examination of the definitional stage of software development; analysis of specification representations and techniques emphasizing important application issues. Prerequisite: CSE 460.

564 Software Design. (3) S
Examination of software design issues and techniques. Includes a survey of design representations and a comparison of design methods. Prerequisite: CSE 460.

565 Software Validation. (3) F
Software reliability models and measures, program testing theory, fault tolerant software, program verification, reliable software design and development, and regression testing. Prerequisite: CSE 460.

566 Software Maintenance. (3) S
Survey of software maintenance problems, tools, metrics, and management approaches. Implications of software maintenance on software development. Prerequisite: CSE 460.

570 Advanced Computer Graphics I. (3) F
Hidden surface algorithms, lighting models, and shading techniques. User interface design. Animation techniques. Fractals and stochastic models. Raster algorithms. Prerequisite: CSE 470.

571 Artificial Intelligence. (3) S
Definitions of intelligence, computer problem solving, game playing, pattern recognition, theorem proving, and semantic information processing; evolutionary systems; heuristic programming. Prerequisite: CSE 471.

572 Pattern Recognition. (3) N
Pattern classification by distance functions and likelihood functions, deterministic and statistical approaches to trainable pattern classifiers, and syntactic pattern recognition. Prerequisite: ECE 383 or STP 326.

573 Advanced Computer Graphics II. (3) S
Modelling of natural phenomena: terrain, clouds, fire, water, and trees. Particle systems, deformation of solids, antialiasing, and volume visualization. Lecture, lab. Prerequisite: CSE 470.

576 Topics in Natural Language Processing. (3) S
Comparative parsing strategies, scoping and reference problems, non-first-order logical semantic representations, and discourse structure. Prerequisite: CSE 476 or instructor approval.

577 Advanced Computer-Aided Geometric Design I. (3) F
General interpolation; review of curve interpolation and approximation; spline curves; visual smoothness of curves; parameterization of curves; introduction to surface interpolation and approximation. Prerequisites: CSE 470 and 477 *or* instructor approval.

578 Advanced Computer-Aided Geometric Design II. (3) S
Coons patches and Bezier patches; triangular patches; arbitrarily located data methods; geometry processing of surfaces; higher dimensional surfaces. Prerequisites: CSE 470 and 477 *or* instructor approval.

Omnibus Courses: See page 44 for omnibus courses that may be offered.

Electrical Engineering

Peter E. Crouch
Chair
(ERC 552) 602/965–3424

REGENTS' PROFESSORS
BALANIS, FERRY

PROFESSORS
AKERS, BACKUS, CHANG, CROUCH, DeMASSA, HIGGINS, KARADY, KAUFMAN, KELLY, LUDERER, MARACAS, PALAIS, ROEDEL, SCHRODER, WANG

ASSOCIATE PROFESSORS
DAVIS, EL-GHAZALY, GORUR, GREENEICH, GRONDIN, KOZICKI, SADOWSKY, SHEN, SKROMME, SPANIAS, TYLAVSKY

ASSISTANT PROFESSORS
ABERLE, ALLEE, CHAKRABARTI, COCHRAN, EL-SHARAWY, HASHEMI-YEGANEH, HOLBERT, MORRELL, RODRIGUEZ, SI, SPECTOR, TSAKALIS

PROFESSORS EMERITI
AX, BARKSON, DONNELLY, RUSSELL, SCHWUTTKE, SIRKIS, THOMPSON, TICE, WELCH, ZIMMER

The professional activities of electrical engineers directly affect the lives of most of the world's population every day. 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. They design systems for automatically controlling mechanical devices and a variety of processes. They 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 majoring 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 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.

DEGREE REQUIREMENTS

Electrical Engineering Core

Students in Electrical Engineering fulfill the requirements of the engineering core by taking ECE 334 and 352 and EEE 225 or 226. No credit is given for ECE 333. Students may replace ECE 210 and 312 with PHY 321 and 322. Only ECE 313 may be deleted. The mathematics and basic science electives are met by taking the following courses:

			Semester Hours
MAT	342	Linear Algebra	3
MAT	362	Advanced Mathematics for Engineers and Scientists I	3
PHY	361	Introductory Modern Physics	3

In addition, the following courses are required to fulfill the electrical engineering core:

			Semester Hours
EEE	120	Digital Design Fundamentals	3
EEE	302	Electrical Networks II	3
EEE	303	Signals and Systems	3
EEE	325	System Design with Microprocessors (Motorola) or EEE 326 System Design with Microprocessors (Intel) (3)	3
EEE	340	Electromagnetic Engineering I	3
EEE	341	Electromagnetic Engineering II	4
EEE	350	Random Signal Analysis	3
EEE	360	Energy Conversion and Transport	4
EEE	490	Senior Design Laboratory	3
Total			29

Technical Electives in Electrical Engineering

The program in Electrical Engineering requires a total of 20 hours of technical electives. To ensure breadth of knowledge, students *must* select courses from not less than three of the following six areas. In addition, to ensure depth, two courses must be taken in one area.

Communications. EEE 407, 451, 455, 459.

Control. EEE 480, 482.

Electromagnetics. EEE 443, 445, 448.

Electronic Circuits. EEE 405, 425, 433.

Power Systems. EEE 463, 470, 471, 473.

Solid State Electronics. EEE 434, 435, 436, 439.

Of the remaining technical electives, two courses may be taken outside electrical engineering. With faculty-advisor approval, qualified students may choose two technical electives from other courses in 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 instructor to enroll in EEE graduate-level courses. In addition, these technical electives may be chosen from the approved list of courses from the College of Business.

Electrical Engineering Program of Study Typical Four-Year Sequence

Freshman Year

First Semester

			Semester Hours
CHM	114	General Chemistry for Engineers or CHM 116 General Chemistry (4)	4
ECE	105	Introduction to Languages of Engineering	3
ENG	101	First-Year Composition	3
MAT	290	Calculus I	5
HU or SB elective[1]			3
Total			18

Second Semester

ECE	106	Introduction to Computer-Aided Engineering	3
EEE	120	Digital Design Fundamentals	3
ENG	102	First-Year Composition	3
MAT	291	Calculus II	5
PHY	121	University Physics I: Mechanics	3
PHY	122	University Physics Laboratory I	1
Total			18

Sophomore Year

First Semester

ECE	210	Engineering Mechanics I: Statics	3
ECE	301	Electrical Networks I	4
EEE	225, 226	Assembly Language Programming	3
MAT	274	Elementary Differential Equations	3
PHY	131	University Physics II: Electricity and Magnetism	3
PHY	132	University Physics Laboratory II	1
Total			17

Second Semester

ECE	312	Engineering Mechanics II: Dynamics	3
ECE	334	Electronic Devices and Instrumentation	4
EEE	302	Electrical Networks II	3
EEE	325, 326	System Design with Microprocessors	3
MAT	342	Linear Algebra	3
MAT	362	Advanced Mathematics for Engineers and Scientists I	3
Total			19

Junior Year

First Semester

ECE	352	Properties of Electronic Materials	3
ECN	111	Macroeconomics	3
EEE	303	Signals and Systems	3
EEE	340	Electromagnetic Engineering I	3

PHY	361	Introductory Modern Physics	3
L1 elective[1, 2]			3
Total			18

Second Semester

ECE	340	Thermodynamics	3
EEE	341	Electromagnetic Engineering II	4
EEE	350	Random Signal Analysis	3
EEE	360	Energy Conversion and Transport	4
HU or SB elective[1]			3
Total			17

Senior Year

First Semester

EEE	490	Senior Design Laboratory	3
HU or SB elective[1]			3
Technical electives			11
Total			17

Second Semester

ECE	400	Engineering Communications	3
HU or SB elective[1]			3
Technical electives			9
Total			15

[1] See pages 53–71 for the requirements and the approved list.

[2] See page 244 for special requirements and selection of an L1 elective.

GRADUATION REQUIREMENTS

The attention of the student is directed to the retention and graduation requirements of the university and the School of Engineering. In addition to those requirements, a student must earn a grade of "C" or better in the mathematics and physics courses listed in the program of study. The student must also have an overall GPA of at least 2.00 for the following group of courses: ECE 301, 334, 352; all courses with an EEE prefix; all other courses used as technical electives.

ELECTRICAL ENGINEERING

EEE 120 Digital Design Fundamentals. (3) F, S, SS
Number systems, conversion methods, binary and complement arithmetic, Boolean and switching algebra, circuit minimization, ROMs, PLAs, flipflops, synchronous sequential circuits, and register transfer design. Lecture, lab. Cross-listed as CSE 120. Prerequisite: CSE 100 or ECE 105.

225 Assembly Language Programming (Motorola). (3) F, S, SS
Assembly language programming, register level computer organization, data structure and addressing modes, assemblers, and linkers. Motorola-based assignments. Cross-listed as CSE 225. Prerequisite: CSE/EEE 120. *General studies: N3.*

226 Assembly Language Programming (Intel). (3) F, S
Assembly language programming, register level computer organization, data structure and addressing modes, assemblers, and linkers. Intel-based assignments. Cross-listed as CSE 226. Prerequisite: CSE/EEE 120. *General studies: N3.*

302 Electrical Networks II. (3) F, S, SS
Analysis of linear and nonlinear networks. Analytical and numerical methods. Prerequisite: ECE 301.

303 Signals and Systems. (3) F, S, SS
Introduction to continuous and discrete time signal and system analysis, linear systems, Fourier, and z-transforms. Prerequisite: EEE 302. Pre- or corequisite: MAT 342.

325 System Design with Microprocessors (Motorola). (3) F, S, SS
CPU, memory, and peripheral device interfaces and programming. Microcomputer systems, standard systems buses, serial and parallel I/O, direct memory access devices, communications; safety and reliability. Lecture, lab. Cross-listed as CSE 325. Prerequisite: CSE/EEE 225.

326 System Design with Microprocessors (Intel). (3) F, S
CPU, memory, and peripheral device interfaces and programming. Microcomputer systems, standard system buses, serial and parallel I/O, direct memory access devices, communications; safety and reliability. Lecture, lab. Cross-listed as CSE 326. Prerequisite: CSE/EEE 226.

340 Electromagnetic Engineering I. (3) F, S, SS
Static and time varying vector fields; boundary value problems; dielectric and magnetic materials; Maxwell's equations; boundary conditions. Prerequisites: MAT 362; PHY 131.

341 Electromagnetic Engineering II. (4) F, S
Second half of an introductory course in electromagnetic theory and its application in electrical engineering. Plane waves in lossless and lossy media; polarization; reflection and refraction; transmission line theory; waveguides; cavities; antennas and radiating systems. Lecture, lab. Prerequisites: ECE 105, 301; EEE 340.

350 Random Signal Analysis. (3) F, S
Probablistic and statistical analysis as applied to electrical signals and systems. Prerequisite: EEE 303.

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

354 Experiments in Materials Synthesis and Processing I. (2) S
Small groups of students complete three experiments selected from a list. Each is supervised by a selected faculty member. Lab. Cross-listed as MSE 354. Prerequisite: EEE/MSE 353 or equivalent.

360 Energy Conversion and Transport. (4) F, S
Three phase circuits. Energy supply systems. Magnetic circuit analysis, synchronous generators, transformers, induction machines, and DC circuits. Load flow and short circuit calculations. Lecture, lab. Prerequisite: EEE 302.

405 Filter Design. (3) F
Principles of active and passive analog filter design, frequency domain approximations, sensitivity and synthesis of filters. Prerequisite: EEE 303.

407 Digital Signal Processing. (4) F
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.

425 Digital Systems and Circuits. (4) F, S
Digital logic gate analysis, propagation delay times, figures of merit, and noise margins. Application of MOS and bipolar logic families, including NMOS, CMOS, standard and advanced TTL and ECL, regenerative logic circuits, memories, and VLSI circuits; computer simulations using PSPICE. Lecture, lab. Prerequisite: ECE 334.

433 Analog Integrated Circuits. (3) S
Analysis, design, and applications of modern analog circuits using integrated bipolar and field effect transistor technologies. Prerequisite: ECE 334.

434 Quantum Mechanics for Engineers. (3) F
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. Prerequisite: EEE 340.

435 Microelectronics. (3) S
Practice of solid state device fabrication techniques, including thin film and integrated circuit fabrication principles. Lecture, lab. Pre- or corequisite: EEE 436.

436 Fundamentals of Solid State Devices. (3) F, S
Metal-semiconductor contacts, P-N junctions, light interacting devices, Schottky diodes, bipolar and field effect transistors, planar, and thin film integrated circuit (I-C) devices. Prerequisite: ECE 352.

437 Optoelectronics. (3) N
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. Prerequisites: ECE 352; EEE 436.

439 Semiconductor Facilities and Cleanroom Practices. (3) F
Microcontamination, controlled environments, cleanroom layout and systems, modelling, codes and legislation, ultrapure water, production materials, personnel and operations, hazard management, advanced concepts. Prerequisite: EEE 435 or instructor approval.

443 Antennas. (3) S
Fundamental parameters; engineering principles and radiation integrals; linear wire antennas; loops and arrays; numerical computations; measurements. Prerequisite: EEE 341 or equivalent.

445 Microwaves. (4) F
Waveguides; circuit theory for waveguiding systems; microwave devices, systems, and energy sources; striplines and microstrips; impedance matching transformers; measurements. Lecture, lab. Prerequisite: EEE 341 or equivalent.

448 Fiber Optics. (4) F
Principles of fiber-optic communications. Lectures, lab. Prerequisites: EEE 303, 340.

451 Error-Correcting Codes. (3) S
Application of modern algebra to the design of random error-detecting and error-correcting block codes. Prerequisite: CSE/EEE 120.

453 Experiments in Materials Synthesis and Processing II. (2) F
A continuation of EEE 354, with emphasis on characterization. Small groups complete 3 experiments supervised by selected faculty members. Lab. Cross-listed as MSE 453. Prerequisites: EEE/MSE 353 and 354 *or* equivalents.

454 Advanced Materials Processing and Synthesis. (3) S
Case studies from published literature of current techniques in materials processing and synthesis. Student participation in classroom presentations. Lecture, recitation. Cross-listed as MSE 454. Prerequisites: EEE/MSE 353 and 354 *or* equivalents.

455 Communication Systems. (4) F, S
Signal analysis techniques applied to the operation of electrical communication systems. An introduction to and overview of modern digital and analog communications. Lecture, lab. Prerequisite: EEE 303.

459 Data Communication Systems. (3) F
System characteristics. Communications media. Communication codes. Data validity checking. Line protocols, terminals, and system configurations. Examples. Prerequisite: EEE 303.

460 Nuclear Concepts for the 21st Century. (3) N
Neutron interactions with matter. Principles of neutron chain reacting systems. Neutron diffusion and moderation. Heat removal from nuclear reactors. Point reactor kinetics. Prerequisite: PHY 361.

461 Health Physics Principles and Radiation Measurements. (3) N
Sources, characteristics, dosimetry, shielding, and measurement techniques for natural and synthetic radiation. Philosophy of radiation protection. Emphasis on instrumentation, detectors, and environmental monitoring. Lecture, lab. Prerequisite: ECE 301.

462 Reactor Safety Analysis. (3) N
Power reactor safety and licensing methodologies. Reactor transient and accident analysis. Time dependent solution to neutron diffusion equation. Use of industry codes to assess fission product buildup, emergency core cooling behavior, reactivity, off-site releases, and dose calculations. Prerequisite: EEE 460.

463 Electrical Power Plant. (3) F
Nuclear, fossil, and solar energy sources. Analysis and design of steam supply systems, electrical generating systems, and auxiliary systems. Power plant efficiency, operation, and costs and analyses. Prerequisites: ECE 301, 340.

464 Nuclear Engineering Experiments. (3) N
Theory and applied concepts in reactor design, instrumentation, electronics, and shielding. Experimental measurements of nuclear parameters using subcritical reactors and fusion neutron generator. Fast and thermal activation analysis. Mossbauer spectrometry. Lecture, lab. Pre- or corequisite: EEE 460.

465 Reactor Theory and Design. (3) N
Reactor physics, core thermal-hydraulics, reactor kinetics and transient behavior, nuclear fuel steady-state performance, core heat removal, core thermal design of PWR, BWR, and LMFR systems. Prerequisite: EEE 460.

470 Electric Power Devices. (3) F
Analysis of 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.

471 Power System Analysis. (3) S
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.

473 Electrical Machinery. (3) F
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.

480 Feedback Systems. (4) F, S
Analysis and design of linear feedback systems. Frequency response and root locus techniques, series compensation, and state variable feedback. Lecture, lab. Prerequisite: EEE 303.

482 Introduction to State Space Methods. (3) F
Discrete and continuous systems in state space form controllability, stability, and pole placement. Observability and observers. Pre- or corequisites: EEE 303, 480; MAT 342.

490 Senior Design Laboratory. (3) F, S
Project-oriented laboratory. Each student must complete one or more design projects during the semester. Lecture, lab. Prerequisites: ECE 334; EEE 303; senior status or instructor approval. *General studies: L2.*

506 Digital Spectral Analysis. (3) S
Principles and applications of digital spectral analysis, least squares, random sequences, parametric, and non-parametric methods for spectral estimation. Prerequisites: EEE 407, 554.

525 VLSI Design. (3) F, S
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.

526 VLSI Architectures. (3) F
Special-purpose architectures for signal processing. Design of array processor systems at the system level and processor level. High-level synthesis. Prerequisite: CSE 330 or EEE 407 or instructor approval.

530 Advanced Silicon Processing. (3) S
Thin films, CVD, oxidation, diffusion, ion-implantation for VLSI, metallization, silicides, advanced lithography, dry etching, rapid thermal processing. Pre- or corequisite: EEE 435.

531 Semiconductor Device Theory I. (3) F
Transport and recombination theory, pn and Schottky barrier diodes, bipolar and junction field-effect transistors, and MOS capacitors and transistors. Prerequisite: EEE 436 or equivalent.

532 Semiconductor Device Theory II. (3) S
Advanced MOSFETs, charge-coupled devices, solar cells, photodetectors, light-emitting diodes, microwave devices, and modulation-doped structures. Prerequisite: EEE 531.

533 MOS Integrated Circuit Engineering. (3) F
MOS device physics, integrated circuit fabrication, CMOS, analog and digital circuit design, simulation and layout, and yield and reliability models. Prerequisite: EEE 436 or equivalent.

534 Semiconductor Transport. (3) F
Carrier transport in semiconductors. Hall effect, high electric field, Boltzmann equation, correlation functions, and carrier-carrier interactions. Prerequisite: EEE 434 or equivalent.

535 Solar Cells. (3) N
Photovoltaic devices, including homojunctions and heterojunctions. Photogeneration of carriers, spectral response, electrical characteristics, and efficiency. Prerequisite: EEE 436 or equivalent.

536 Semiconductor Characterization. (3) S
Measurement techniques for semiconductor materials and devices. Electrical, optical, physical, and chemical characterization methods. Prerequisite: EEE 436 or equivalent.

537 Semiconductor Optoelectronics I. (3) N
Electronic states in semiconductors, quantum theory of radiation, absorption processes, radiative processes, nonradiative processes, photoluminescence, and photonic devices. Prerequisite: EEE 434.

538 Semiconductor Optoelectronics II. (3) N
Material and device physics of semiconductor lasers, light-emitting diodes, and photodetectors. Emerging material and device technology in III-V semiconductors. Prerequisite: EEE 537.

539 Introduction to Solid State Electronics. (3) S
Crystal lattices, reciprocal lattices, quantum statistics, lattice dynamics, equilibrium, and nonequilibrium processes in semiconductors. Prerequisite: EEE 434.

541 Electromagnetic Fields and Guided Waves. (3) F
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 341 or equivalent.

542 Selected Microwave Devices. (3) N
Use of ferrite, semiconductor, and piezoelectric materials in microwave systems. Prerequisites: ECE 352 and EEE 445 *or* equivalents.

543 Antenna Analysis and Design. (3) F
Impedances, broadband antennas, frequency independent antennas, miniaturization, aperture antennas, horns, reflectors, lens antennas, and continuous sources design techniques. Prerequisite: EEE 443 or equivalent.

544 High Resolution Radar. (3) F
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* equivalents.

545 Microwave Circuit Design. (3) N
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.

546 Advanced Fiber-Optics. (3) S
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.

547 Microwave Solid State Circuit Design I. (3) N
Application of semiconductor characteristics to practical design of microwave mixers, detectors, limiters, switches, attenuators, multipliers, phase shifters, and amplifiers. Prerequisite: EEE 545 or instructor approval.

548 Coherent Optics. (3) N
Diffraction, lenses, optical processing, holography, electro-optics, and lasers. Prerequisite: EEE 341.

549 Lasers. (3) N
Theory and design of gas, solid, and semiconductor lasers. Prerequisite: EEE 448 or instructor approval.

550 Transform Theory and Applications. (3) F
Introduction to 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.

551 Information and Coding Theory. (3) N
Fundamental theorems of information theory for sources and channels; convolutional and burst codes. Prerequisites: EEE 451, 554.

552 Coherent Communications. (3) N
Systems analysis and design of telecommunication systems using phase-locked loops. Prerequisite: EEE 554.

554 Random Signal Theory I. (3) F
Application of statistical techniques to the representation and analysis of electrical signals and to communications systems analysis. Prerequisite: EEE 303 and 350 *or* instructor approval.

555 Random Signal Theory II. (3) S
Processing of signals in the presence of noise. Random signals, correlation, frequency spectra, estimation, filtering, noise, prediction, and transients. Prerequisite: EEE 554.

556 Detection and Estimation Theory. (3) N
Combination of the classical techniques of statistical inference and the random process characterization of communication, radar, and other modern data processing systems. Prerequisites: EEE 455, 554.

558 Modulation Theory. (3) N
Noise performance of analog and digital modulation systems. Emphasis on modern digital techniques in terrestrial and satellite communications systems. Prerequisites: EEE 455, 554.

566 Nuclear Instrumentation. (3) N
Design and analysis of imaging systems for nuclear sciences applications and research. Laboratory experiments using computerized multichannel analyzer systems, whole body counting systems and computerized tomography. Lecture, lab. Prerequisite: EEE 465 or instructor approval.

567 Radiation Shielding and Transport. (3) F
Shielding for radiation therapy, diagnostic radiology, cyclotrons, and nuclear reactors. Monte Carlo and empirical computational methods, regulations, and design problems. Cross-listed as BME 567. Prerequisite: BME/EEE 465.

569 Radiochemistry and Advanced Nuclear Instrumentation. (3) N
Advanced concepts in environmental and power plant radiochemistry. Chemical separations for iodine, strontium, radium, and uranium. Advanced detection concepts in alpha, gamma spectrometry, and liquid scintillation. Lecture, lab. Prerequisite: BME/EEE 465.

571 Power System Transients. (3) N
Analysis of transient currents and voltages generated by disturbances in power networks. EMTP method. Travelling waves. Transients in transformers and generators. Protection against transients. Prerequisite: EEE 471.

572 Advanced Power Electronics. (3) N
Analysis of 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 471.

573 Power System Control. (3) N
Concepts of economic and secure operation of power systems; load frequency control, economic dispatch, unit commitment, state estimation, and contingency analysis. Prerequisites: EEE 470, 471.

574 Computer Solution of Power Systems. (3) N
Algorithms for digital computation for power flow, fault, and stability analysis. Sparse matrix and vector programming methods, optimization, and stochastic methods. Prerequisites: EEE 470, 471.

577 Power System Planning. (3) F
Power flow and transient stability analysis, load forecasting methods, and reliability concepts. Transmission planning, loss of load probability and production cost analysis, and optimal network and generation expansion. Prerequisites: EEE 470, 471.

579 Power Transmission and Distribution. (3) S
High voltage transmission line design, such as conductors, corona, and RI and TV noise DC transmission. Distribution system analysis, including load characteristics, feeder voltage drop, and capacitor applications. Prerequisite: EEE 471.

581 Filtering of Stochastic Processes. (3) N
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.

582 Linear System Theory. (3) S
Controllability, observability, and realization theory for multivariable continuous time systems. Stabilization and asymptotic state estimation. Disturbance decoupling, noninteracting control. Prerequisite: EEE 482.

585 Digital Control Systems. (3) N
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.

586 Nonlinear Control Systems. (3) N
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.

587 Optimal Control Systems. (3) N
Application of calculus of variations, Pontryagin's principle, and dynamic programming to control problems. Computational techniques for solving optimal control problems. Prerequisite: EEE 482.

631 Heterojunctions and Superlattices. (3) F
Principles of heterojunctions and quantum well structures, band line-ups, optical, and electrical properties. Introduction to heterojunction devices. Prerequisites: EEE 436, 531.

632 Heterojunction Devices. (3) S
Principles of semiconductor heterojunctions and quantum wells are applied to the analysis of advanced electronic and optical devices. Devices studied are modulation doped field effect transistors (MODFETs), pseudomorphic MODFETs, heterojunction bipolar transistors, quantum well and superlattice optical detectors, modulators, and lasers. Prerequisites: EEE 434 (or equivalent), 436, 531, 631.

641 Advanced Electromagnetic Field Theory. (3) S
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 equivalent.

643 Advanced Topics in Electromagnetic Radiation. (3) S
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.

645 Microwave Filter Design. (3) N
Analysis and design of microwave low-pass, high-pass, band-pass, and band-stop filters and microwave diplexers/multiplexers. Prerequisite: EEE 545 or instructor approval.

647 Microwave Solid State Circuit Design II. (3) F
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.

731 Small MOS Devices. (3) S
Subthreshold current, threshold voltage modulation, scaling, and other small-size limitations. Prerequisite: EEE 532.

732 Advanced Bipolar Devices and Circuits. (3) F
Critical examination of new bipolar device and circuit technologies. Performance trade-offs, scaling effects, and modeling techniques. Prerequisite: EEE 531.

770 Advanced Topics in Power Systems. (3) N
Power system problems of current interest, approached at an advanced technical level, for mature students. Prerequisites: EEE 577 and 579 *or* equivalents; instructor approval.

Omnibus Courses: See page 44 for omnibus courses that may be offered.