Del E. Webb School of Construction

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PURPOSE

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

DEGREES

Construction—B.S.

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

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

Construction—M.S.

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

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

SPECIAL PROGRAMS

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

ASU 3+2 Program. The school also participates in the ASU 3+2 program with Grand Canyon University and Southwestern University. See “ASU 3+2 Programs,” page 200, for details.

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

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

ADMISSION

For information regarding requirements for admission, transfer, retention, qualification, and reinstatement, see “Undergraduate Admission,” page 62; “Admission,” page 195; and “College Degree Requirements,” page 198. A preprofessional category is available for applicants deficient in regular admission requirements. Vocational and craft-oriented courses taught at the community colleges are not accepted for credit toward a bachelor’s degree in Construction.

BASIC REQUIREMENTS

Students complete the following basic requirements before registering for advanced courses: (1) all first-semester, first-year courses and the university First-Year Composition requirement (see “University Graduation Requirements,” page 83) must be completed by the time the student has accumulated 48 semester hours of program requirements, and (2) all second-semester, first-year courses must be completed by the time the student has completed 64 semester hours of program requirements. Transfer students are given a one-semester waiver.

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

DEGREE REQUIREMENTS

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

GRADUATION REQUIREMENTS

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

In addition to fulfilling school and major requirements, majors must satisfy the General Studies requirements as noted in the "General Studies" section, page 87 and all university graduation requirements noted in the "University Graduation Requirements" section, page 83. Note that all three General Studies awareness areas are required. Consult your advisor for an approved list of courses.

SCHOOL COURSE REQUIREMENTS

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

Humanities and Fine Arts/Social and Behavioral Sciences

CON 101	Construction and Culture: A Built Environment *HU, G, H*	3
ECN 111	Macroeconomic Principles *SB*	3
ECN 112	Microeconomic Principles *SB*	3
HU, SB, and awareness area courses as needed		6
Total		15

Literacy and Critical Inquiry

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

Natural Sciences

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

Numeracy

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

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

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

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

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

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

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

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

The course work for the first two years is the same for the general building, heavy, residential, and speciality construction concentrations.

First Semester

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

Second Semester

ECE 100	Introduction to Engineering Design *CS*	4
ECN 112	Microeconomic Principles *SB*	3
ENG 102	First-Year Composition	3
PHY 112	General Physics *SQ*[2]	3
PHY 114	General Physics Laboratory *SQ*[2]	1
HU elective with awareness areas as needed		3
Total		17

Third Semester

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

Fourth Semester

ACC 230	Uses of Accounting Information I or ACC 394 ST: Financial Analysis and Accounting for Small Businesses[3] (3)	3

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

COM 225	Public Speaking *L*	3
CON 252	Building Construction Methods, Materials, and Equipment	3
CON 323	Strength of Materials	3
Basic science elective with lab		4
Total		16

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

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

[3] ACC 394 ST: Financial Analysis and Accounting for Small Businesses is recommended.

Concentration in General Building Construction

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

Requirements

CON 472	Development Feasibility Reports *L*	3
CON 483	Advanced Building Estimating	3
PUP 432	Planning and Development Control Law or PUP 433 Zoning Ordinances, Subdivision Regulations, and Building Codes (3)	3
REA 380	Real Estate Fundamentals	3
Upper-division technical elective		3
Total		15

Concentration in Heavy Construction

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

Requirements

CON 344	Route Surveying	3
CON 486	Heavy Construction Estimating	3
Upper-division business electives		6
Upper-division technical elective		3
Total		15

Concentration in Residential Construction

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

Requirements

CON 377	Residential Construction Production Procedures	3
CON 477	Residential Construction Business Practices	3
CON 484	Internship	3
MKT 300	Principles of Marketing	3
PUP 432	Planning and Development Control Law or PUP 433 Zoning Ordinances, Subdivision Regulations, and Building Codes (3)	3
Total		15

Concentration in Specialty Construction

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

Requirements

CON 468	Mechanical and Electrical Estimating	3
CON 494	ST: Cleanroom Construction	3
CON 494	ST: Electrical and Mechanical Project Management	3
Upper-division business electives		6
Total		15

CONSTRUCTION (CON)

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

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

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

CON 251 Microcomputer Applications for Construction. (3) F, S
Applications of the microcomputer as a problem-solving tool for the constructor. Use of spreadsheets, information management, and multimedia software. Prerequisite: ECE 100.

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

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

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

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

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

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

CON 371 Construction Management and Safety. (3) F, S
Organization and management theory applied to the construction process. Leadership functions. Safety procedures and equipment. OSHA requirement for construction. Prerequisite: junior standing.

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

CON 383 Construction Estimating. (3) F, S
Drawings and specifications. Methods and techniques used in construction estimating procedures. Introduction to computer software used in industry. Lecture, project workshops. Prerequisites: CON 243 and 251 and 252 *or* instructor approval.

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

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

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

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

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

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

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

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

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

CON 484 Internship. (1–12) N

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

CON 494 Special Topics. (3) F, S
(a) Cleanroom Construction. (3) F
(b) Electrical and Mechanical Project Management. (3) S

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

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

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

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

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

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

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

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

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

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

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

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

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

School of Engineering

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PURPOSE

A large percentage of all engineering degree holders are found in leadership positions in a wide variety of industrial settings. Although an education in engineering is generally considered to be one of the best technical educations, it also provides an opportunity for the development of many additional attributes, including ethical and professional characteristics. In this era of rapid technological change, an engineering education serves 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 depend upon how effectively this resource is developed.

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

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

social consequences of engineering activity. The goals include the promotion of the general welfare of the engineering profession.

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

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

ADMISSION

For information regarding requirements for admission, transfer, retention, disqualification, and reinstatement, see “Undergraduate Admission,” page 62; “Admission,” page 195; and “College Degree Requirements,” page 198.

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

DEGREES

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

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

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

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

The courses identified for each of these parts are intended to meet requirements imposed by the university and by the professional accrediting agency, the Computer Science Accreditation Board (CSAB), for programs in computing science.

In addition to First-Year Composition, the university requires, under the heading of General Studies, courses in literacy and critical inquiry, humanities and fine arts, social and behavioral sciences, mathematical studies, and natural sciences (see “General Studies,” page 87). There are also requirements in historical awareness, global awareness, and cultural diversity in the United States. ABET and CSAB impose additional requirements, particularly in mathematics and the basic sciences and in the courses for the major.

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

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

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

Majors and areas of study are offered by the seven departments: Bioengineering; Chemical and Materials Engineering; Civil and Environmental Engineering; Computer Science and Engineering; Electrical Engineering; Industrial Engineering; and Mechanical and Aerospace Engineering. The major in Engineering Special Studies is administered by the Office of the Dean. Engineering Special Studies makes use of the general structure of the engineering curricula noted above and provides students with an opportunity for study in engineering concentrations not available in the traditional engineering curricula at ASU.

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

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

Typical Freshman Year

CHM	114	General Chemistry for Engineers *SQ*	4
ECE	100	Introduction to Engineering Design *CS*	4
ECN	111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
ENG	101	First-Year Composition	3
ENG	102	First-Year Composition	3

MAT 270 Calculus with Analytic Geometry I *MA*	4
MAT 271 Calculus with Analytic Geometry II *MA*	4
PHY 121 University Physics I: Mechanics *SQ**	3
PHY 122 University Physics Laboratory I *SQ**	1
HU, SB, or awareness area course	3
Total	32

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

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

DEGREE REQUIREMENTS

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

1. *Oral and written English.* Communication skills are an essential component of an engineering education. All engineering students must complete the university First-Year Composition requirement (see "University Graduation Requirements," page 83), and the literacy and critical inquiry component under "Five Core Areas," page 87, of the General Studies requirement, which involves two courses beyond First-Year Composition.
2. *Selected nonengineering topics.* This area ensures that the engineering student acquires a satisfactory level of basic knowledge in the humanities and fine arts, social and behavioral sciences, mathematical studies, and the natural sciences. Courses in these subjects give engineers an increased awareness of their social responsibilities, provide an understanding of related factors in the decision-making process, and also provide a foundation for the study of engineering. Required courses go toward fulfilling the General Studies requirement. Additional courses in mathematics and the basic sciences are selected to meet ABET requirements.

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

COURSE REQUIREMENTS

A summary of the degree requirements is as follows:

First-Year Composition	6
General Studies/school requirements	58
Engineering core	15–19
Major (including area of study or concentration)*	45–49
Total	128

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

The specific course requirements for the B.S. and B.S.E. degrees follow.

First-Year Composition

Choose among the course combinations below 6

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

—or—

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

—or—

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

Total 6

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

General Studies/School Requirements

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

ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
HU course(s)		6 or 10
SB course(s)		3 or 7
Total		12–20

Literacy and Critical Inquiry

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

Natural Sciences/Basic Sciences

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

Numeracy/Mathematics

ECE 100	Introduction to Engineering Design *CS*	4
MAT 270	Calculus with Analytic Geometry I *MA*	4
MAT 271	Calculus with Analytic Geometry II *MA*	4
MAT 272	Calculus with Analytic Geometry III *MA*	4
MAT 274	Elementary Differential Equations *MA*	3
Department mathematics elective		2
Total		21
General Studies/school requirements total		58

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

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

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

Engineering Core Requirement

A minimum of five of the following eight courses are required. Courses selected are subject to departmental approval. See department requirements.

ECE 210	Engineering Mechanics I: Statics	3
ECE 301	Electrical Networks I	4
ECE 312	Engineering Mechanics II: Dynamics	3
ECE 313	Introduction to Deformable Solids	3
ECE 334	Electronic Devices and Instrumentation	4
ECE 340	Thermodynamics[1] or MSE 430 Thermodynamics of Materials (3)	3
ECE 350	Structure and Properties of Materials[2] or ECE 351 Civil Engineering Materials (3) or ECE 352 Properties of Electronic Materials (4)	3
Choose one microcomputer/microprocessor course below		3 or 4

BME 470 Microcomputer Applications in Bioengineering (4)
CHE 461 Process Control *CS* (4)
CSE 225 Assembly Language Programming and Microprocessors (Motorola) (4) or EEE 225 Assembly Language Programming and Microprocessors (Motorola) (4)
CSE 226 Assembly Language Programming and Microprocessors (Intel) (4) or EEE 226 Assembly Language Programming and Microprocessors (Intel) (4)
IEE 463 Computer-Aided Manufacturing and Control *CS* (3)

[1] CHM 345 Physical Chemistry I (3) may be substituted for ECE 340.

[2] CHM 346 Physical Chemistry II (3) may be substituted for ECE 350.

GRADUATION REQUIREMENTS

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

PROFESSIONAL ACCREDITATION

The undergraduate programs in Aerospace Engineering, Bioengineering, Chemical Engineering, Civil Engineering, Computer Systems Engineering, Electrical Engineering, Industrial Engineering, Materials Science and Engineering, and Mechanical Engineering are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc., Baltimore, Maryland, 410/347-7700. The Bachelor of Science program in Computer Science is accredited by the Computer Science Accreditation Commission of the Computing Sciences Accreditation Board.

ANALYSIS AND SYSTEMS (ASE)

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.

ASE 194 Special Topics. (2) F
(a) MEP Academic Success

ASE 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.

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

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

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

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

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

ASE 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.

ENGINEERING CORE (ECE)

ECE 100 Introduction to Engineering Design. (4) F, S
Introduction to engineering design; teaming; the profession of engineering; computer models in engineering; communication skills; quality and customer satisfaction. Prerequisites: high school computing and physics and algebra courses *or* equivalents. *General Studies: CS.*

ECE 194 Special Topics. (2) F, S
(a) Introduction to Engineering Design I. (2) F
(b) Introduction to Engineering Design II. (2) S

ECE 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 100; MAT 271 (or 291); PHY 121, 122.

ECE 300 Intermediate Engineering Design. (3) F, S, SS
Engineering design process concentrating on increasing the student's ability to prepare well-written technical communication and to define problems and generate and evaluate ideas. Teaming skills enhanced. Prerequisites: ECE 100; ENG 102 (or 105 or 108); at least two other engineering core courses. *General Studies: L.*

ECE 301 Electrical Networks I. (4) F, S, SS
Introduction to electrical networks. Component models, transient, and steady-state analysis. Lecture, lab. Prerequisite: ECE 100. Pre- or corequisites: MAT 274; PHY 131, 132.

ECE 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.

ECE 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.

ECE 314 Engineering Mechanics. (4) F, S, SS
Force systems, resultants, moments and equilibrium. Kinematics and kinetics of particles, systems of particles and rigid bodies. Energy and momentum principles. Lecture, recitation. Prerequisites: ECE 100; MAT 274; PHY 121, 122.

ECE 334 Electronic Devices and Instrumentation. (4) F, S, SS
Application of electric network theory to semiconductor circuits. Diodes/transistors/amplifiers/opamps/digital logic gates, and electronic instruments. Lecture, lab. Prerequisite: ECE 301.

ECE 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. Prerequisites: CHM 114 (or 116); ECE 210; PHY 131. Pre- or corequisite: MAT 274.

ECE 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.

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

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

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

ECE 384 Numerical 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. Prerequisite: MAT 272 or 291.

ECE 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.

ECE 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.

ECE 394 Special Topics. (3–4) F, S
(a) Conservation Principles. (4) F, S
(b) Engineering Systems. (4) F, S
(c) Introduction to Manufacturing Engineering. (3) F, S
(d) Properties that Matter. (4) F, S

ECE 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. Prerequisites: ENG 102 (or 105 or 108); completion of General Studies L requirement (or ECE 300); senior standing in an engineering major. *General Studies: L.*

SOCIETY, VALUES, AND TECHNOLOGY (STE)

STE 194 Special Topics. (2) F
(a) Engineering for Undecided

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. Credit is allowed for only BME 201 or STE 201. Prerequisite: ENG 102 or 105 or 108. *General Studies: L.*

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

Department of Bioengineering

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PROFESSORS
GUILBEAU, TOWE

ASSOCIATE PROFESSORS
GARCIA, HE, KIPKE, MASSIA, PIZZICONI
SWEENEY, YAMAGUCHI

ASSISTANT PROFESSOR
PANITCH

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

Faculty within the department also participate in the Engineering Special Studies program in premedical engi-

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

neering which is described separately in the "Programs in Engineering Special Studies" section, page 253.

This department has been part of the Department of Chemical, Bio, and Materials Engineering; the administrative change is anticipated to become effective summer 2000.

BIOENGINEERING—B.S.E.

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

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

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

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Bioengineering. A minimum of 50 upper-division semester hours is required.

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 83.

COURSE REQUIREMENTS

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

First-Year Composition

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

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences
ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
HU, SB, and awareness area courses 13

Total 16

Literacy and Critical Inquiry
BME 413 Biomedical Instrumentation *L* 3
BME 423 Biomedical Instrumentation Laboratory *L* 1
ECE 300 Intermediate Engineering Design *L* 3

Total 7

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

Total 16

Numeracy/Mathematics
ECE 100 Introduction to Engineering Design *CS* 4
MAT 242 Elementary Linear Algebra 2
or ECE 384 Numerical Analysis for Engineers I (2)
or ECE 386 Partial Differential Equations for Engineers (2)
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 21
General Studies/school requirements total 60

Engineering Core

ECE 210 Engineering Mechanics I: Statics 3
ECE 301 Electrical Networks I 4
ECE 334 Electronic Devices and Instrumentation 4
ECE 340 Thermodynamics 3

ECE	350	Structure and Properties of Materials	3
Total			17

Major

BIO	181	General Biology *SQ*	4
BME	201	Introduction to Bioengineering *L*	3
BME	318	Biomaterials	3
BME	331	Biomedical Engineering Transport I: Fluids	3
BME	334	Bioengineering Heat and Mass Transfer	3
BME	416	Biomechanics	3
BME	417	Biomedical Engineering Capstone Design I	3
BME	435	Physiology for Engineers	4
BME	470	Microcomputer Applications in Bioengineering	4
BME	490	Biomedical Engineering Capstone Design II	1–5
ECE	380	Probability and Statistics for Engineering Problem Solving *CS*	3
Technical electives			9
Minimum total			45

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

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

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

Bioengineering Areas of Study

Students interested in a career in bioengineering may elect to emphasize either biochemical, bioelectrical, biomaterials engineering, biomechanical, bionuclear, biosystems, molecular and cellular bioengineering, or premedical engineering in their studies.

Biochemical Engineering. This area is designed to strengthen the student's knowledge of chemistry and transport phenomena and is particularly well suited for students interested in biotechnology. Technical electives must include CHM 331 and 332 and BCH 361.

Bioelectrical Engineering. This area is designed to strengthen the student's knowledge of electrical systems, electronics, and signal processing. Students considering a career in bioelectrical phenomena, biocontrol systems, medical instrumentation, noninvasive imaging, neural engineering, and electrophysiology should consider this area of study.

Technical electives must include the following:

BME	350	Signals and Systems for Bioengineers or EEE 303 Signals and Systems (3)	3
BME	419	Biocontrol Systems	3
EEE	302	Electrical Networks II	3
Total			9

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

Technical electives must include the following:

MSE	353	Introduction to Materials Processing and Synthesis	3
MSE	355	Introduction to Materials Science and Engineering	3
MSE	470	Polymers and Composites or MSE 471 Introduction to Ceramics (3)	3
Total			9

Biomechanical Engineering. This area is designed to strengthen the student's knowledge of mechanics and control theory. Students interested in careers related to biomechanical design, orthotic/prosthetic devices, rehabilitation engineering, and orthopedic implants should consider this area of study. It also provides the fundamentals for the study of neuromuscular control and the study of human motion. From the requirements given under "General Studies/School Requirements," page 207, either ECE 384 Numerical Analysis for Engineers I (2) or MAT 242 Elementary Linear Algebra (2) must be taken as the department mathematics elective.

Technical electives must include the following:

BME	350	Signals and Systems for Bioengineers or BME 419 Biocontrol Systems (3) or EEE 303 Signals and Systems (3)	3
ECE	312	Engineering Mechanics II: Dynamics	3
ECE	313	Introduction to Deformable Solids	3
Total			9

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

Technical electives must include the following:

PHY	361	Introductory Modern Physics	3
Department-approved electives			6
Total			9

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

Technical electives must include the following:

BME	350	Signals and Systems for Bioengineers or BME 419 Biocontrol Systems (3)	3
BME	411	Biomedical Engineering I or BME 412 Biomedical Engineering II (3)	3
BME	415	Biomedical Transport Processes	3
Total			9

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

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

Technical electives must include the following:

BCH 361	Principles of Biochemistry	3
BIO 353	Cell Biology	3
CHM 331	General Organic Chemistry	3
Total		9

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

Technical electives must include the following:

CHM 331	General Organic Chemistry	3
CHM 332	General Organic Chemistry	3
CHM 335	General Organic Chemistry Laboratory	1
CHM 336	General Organic Chemistry Laboratory	1
Total		8

To fulfill medical school admission requirements, BIO 182 General Biology is also required in addition to the degree requirements.

Bioengineering Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM 113	General Chemistry *SQ*	4
ECE 100	Introduction to Engineering Design *CS*	4
ENG 101	First-Year Composition	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
Total		15

Second Semester

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

Second Year

First Semester

BIO 181	General Biology *SQ*	4
BME 201	Introduction to Bioengineering *L*	3
ECE 210	Engineering Mechanics I: Statics	3
MAT 272	Calculus with Analytic Geometry III *MA*	4
PHY 131	University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY 132	University Physics Laboratory II *SQ*[2]	1
Total		18

Second Semester

ECE 301	Electrical Networks I	4
ECE 350	Structure and Properties of Materials	3
MAT 274	Elementary Differential Equations *MA*	3
HU, SB, and awareness area courses[3]		6
Total		16

Third Year

First Semester

BME 331	Biomedical Engineering Transport I: Fluids	3
BME 435	Physiology for Engineers	4
ECE 300	Intermediate Engineering Design *L*	3
ECE 340	Thermodynamics	3
ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
MAT 242	Elementary Linear Algebra or ECE 384 Numerical Analysis for Engineers I (2) or ECE 386 Partial Differential Equations for Engineers (2)	2
Total		18

Second Semester

BME 318	Biomaterials	3
BME 334	Bioengineering Heat and Mass Transfer	3
ECE 334	Electronic Devices and Instrumentation	4
ECE 380	Probability and Statistics for Engineering Problem Solving *CS*	3
HU, SB, and awareness area course(s)[3]		4
Total		17

Fourth Year

First Semester

BME 413	Biomedical Instrumentation *L*	3
BME 416	Biomechanics	3
BME 417	Biomedical Engineering Capstone Design I	3
BME 423	Biomedical Instrumentation Laboratory *L*	1
HU, SB, or awareness area course[3]		3
Technical electives		3
Total		16

Second Semester

BME 470	Microcomputer Applications in Bioengineering	4
BME 490	Biomedical Engineering Capstone Design II	3
Technical electives		6
Total		13
Total degree requirements		128

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

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

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

BIOENGINEERING (BME)

BME 201 Introduction to Bioengineering. (3) 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. Credit is allowed for only BME 201 or STE 201. Prerequisite: ENG 102 or 105 or 108. *General Studies: L.*

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

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

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

BME 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. Prerequisite: ECE 340. Prerequisite with a grade of "C" or higher: BME 331.

BME 350 Signals and Systems for Bioengineers. (3) S
Application of principles of calculus and ordinary differential equations to modeling and analysis of responses, signals, and signal transfers in biosystems. Prerequisites: ECE 301; MAT 272, 274.

BME 411 Biomedical Engineering I. (3) A
Review of diagnostic and prosthetic methods using engineering methodology. Introduction to transport, metabolic, and autoregulatory processes in the human body. Prerequisite with a grade of "C" or higher: BME 334.

BME 412 Biomedical Engineering II. (3) A
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. Prerequisite: instructor approval.

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

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

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

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

BME 419 Biocontrol Systems. (3) F
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.

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

BME 435 Physiology for Engineers. (4) F
Physiology of the nervous, muscular, cardiovascular, endocrine, renal, and respiratory systems. Emphasizes use of quantitative methods in understanding physiological systems. Lecture, lab. Prerequisites: BIO 181 and CHM 116 and PHY 131 *or* instructor approval.

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

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

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

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

BME 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.

BME 513 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.

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

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

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

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

BME 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. Prerequisites: ECE 301 and MAT 274 *or* instructor approval.

BME 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.

BME 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.

BME 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.

BME 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: BME 413, 435; ECE 334.

BME 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.

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

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

BME 533 Transport Processes I. (3) 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. Credit is allowed for only BME 533 or CHE 533.

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

BME 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. Credit is allowed for only BME 543 or CHE 543.

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

BME 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. Credit is allowed for only BME 544 or CHE 544. Prerequisite: BME/CHE 543.

BME 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 516 or instructor approval.

BME 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: instructor approval.

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

Department of Chemical and Materials Engineering

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REGENTS' PROFESSOR
MAYER

PROFESSORS
ADAMS, BERMAN, DEY, KRAUSE, MAHAJAN, RAUPP, SATER

ASSOCIATE PROFESSORS
ALFORD, BECKMAN, BURROWS, RIVERA, TORREST

ASSISTANT PROFESSORS
S. BEAUDOIN, CHAWLA, RAZATOS

LECTURER
D. BEAUDOIN

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

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

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

This department has been known as the Department of Chemical, Bio, and Materials Engineering; the creation of a separate Department of Bioengineering is anticipated to become effective summer 2000.

CHEMICAL ENGINEERING—B.S.E.

Chemical engineers are generally concerned with transfer within and between liquid, gas, and solid phases and the chemical changes that may also occur. 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 fluid dynamics, mass transfer, solution thermodynamics, reaction kinetics, and separation techniques to technological endeavors such as pollution control within manufacturing and the environment, integrated circuit design, solid-state surface treatments, and materials processing.

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

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

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Chemical Engineering. A minimum of 50 upper-division semester hours is required.

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

First-Year Composition

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

—or—

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

—or—

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

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
HU, SB, and awareness area courses[1] 13

Total 16

Literacy and Critical Inquiry

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

Total 6

Natural Sciences/Basic Sciences

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

Total 16

Numeracy/Mathematics

ECE 100 Introduction to Engineering Design *CS* 4
ECE 384 Numerical Analysis for Engineers I 2
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 21
General Studies/school requirements total 59

Engineering Core

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

Total 20

Major

CHE 311 Introduction to Chemical Processing 3
CHE 331 Transport Phenomena I: Fluids 3
CHE 332 Transport Phenomena II: Energy Transfer 3
CHE 333 Transport Phenomena III: Mass Transfer 3
CHE 432 Principles of Chemical Engineering Design 3
CHE 442 Chemical Reactor Design 3
CHE 451 Chemical Engineering Laboratory 2
CHE 462 Process Design 3
CHM 332 General Organic Chemistry 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
ECE 385 Numerical Analysis for Engineers II 2
Technical electives 12

Total 43

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

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

Consult with your department academic advisor to ensure that all requirements are met.

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

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

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

Chemical Engineering Areas of Study

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

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

Chemistry Electives

BCH 361 Principles of Biochemistry 3
BCH 461 General Biochemistry 3
BCH 462 General Biochemistry 3

Technical Electives

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

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

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

Chemistry Electives
BCH 361 Principles of Biochemistry....3
BCH 461 General Biochemistry....3
BCH 462 General Biochemistry....3

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

Environmental. ASU does not offer a B.S.E. degree in Environmental Engineering, but students with this interest are encouraged to pursue a B.S.E. degree in Chemical Engineering with this area of study. Students interested in the management of hazardous wastes and air and water pollution should select from the following:

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

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

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

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

Technical Electives
BME 318 Biomaterials....3
CHE 458 Semiconductor Material Processing....3
ECE 352 Properties of Electronic Materials....4
MSE 353 Introduction to Materials Processing and Synthesis....3
MSE 354 Experiments in Materials Synthesis and Processing I....2
MSE 431 Corrosion and Corrosion Control....3
MSE 453 Experiments in Materials Synthesis and Processing II....2
MSE 454 Advanced Materials Processing and Synthesis....3
MSE 470 Polymers and Composites....3

Premedical. Students planning to attend medical school should select courses from those listed under the biomedical area. In addition, BIO 181, 182, and CHM 336 must be taken to satisfy medical-school requirements but are not counted toward the Chemical Engineering bachelor's degree.

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

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

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

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

Technical Electives
CHE 458 Semiconductor Material Processing....3
CHE 494 Special Topics....1–4
ECE 352 Properties of Electronic Materials....4
EEE 435 Microelectronics....3
EEE 436 Fundamentals of Solid-State Devices....3
EEE 439 Semiconductor Facilities and Cleanroom Practices....3
MSE 353 Introduction to Materials Processing and Synthesis....3
MSE 354 Experiments in Materials Synthesis and Processing I....2
MSE 453 Experiments in Materials Synthesis and Processing II....2
MSE 454 Advanced Materials Processing and Synthesis....3
MSE 472 Integrated Circuit Materials Science....3

Chemical Engineering
Program of Study
Typical Four-Year Sequence

First Year

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

Total....15

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

Total....15

Second Year

First Semester
CHE 311 Introduction to Chemical Processing....3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS*....3
ECE 394 ST: Conservation Principles....4
ECN 111 Macroeconomic Principles *SB*....3
or ECN 112 Microeconomic Principles *SB* (3)
MAT 274 Elementary Differential Equations *MA*....3

Total....16

Second Semester
CHE 331 Transport Phenomena I: Fluids....3
ECE 384 Numerical Analysis for Engineers I....2
ECE 394 ST: Properties that Matter....4

MAT 272 Calculus with Analytic Geometry III *MA* 4
HU or SB elective 4

Total 17

Third Year

First Semester

CHE 332 Transport Phenomena II: Energy Transfer..........3
CHE 342 Applied Chemical Thermodynamics 4
CHM 331 General Organic Chemistry 3
CHM 335 General Organic Chemistry Laboratory..........1
ECE 300 Intermediate Engineering Design *L* 3
HU or SB elective 3

Total 17

Second Semester

CHE 333 Transport Phenomena III: Mass Transfer..........3
CHE 352 Transport Laboratories *L*..........3
CHE 432 Principles of Chemical Engineering Design..........3
CHM 332 General Organic Chemistry 3
ECE 385 Numerical Analysis for Engineers II..........2
ECE 394 ST: Engineering Systems..........4

Total 18

Fourth Year

First Semester

CHE 442 Chemical Reactor Design 3
CHE 451 Chemical Engineering Laboratory..........2
CHE 461 Process Control *CS* 4
HU, SB, or awareness area course 3
Technical elective..........3

Total 15

Second Semester

CHE 462 Process Design..........3
HU, SB, or awareness area course 3
Technical elective..........9

Total 15
Total degree requirements:..........128

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

MATERIALS SCIENCE AND ENGINEERING—B.S.E.

Innovations that create new and improved materials help drive the cutting edge of new technologies in many industries, including automotive, aerospace, materials production, semiconductors, electronics, and health professions. The space shuttle, lightweight cars, and today's fastest computers have all been developed using the latest materials technologies. Materials engineers play a critical role in innovations in such applications. In advancing today's technologies, they fulfill a wide range of job responsibilities. They may

1. select the best material for a given application or develop innovative materials and processing techniques for new applications;
2. analyze materials failures in order to redesign more robust engineering components; and
3. manage or participate with teams of engineers working on larger scale engineering projects.

In summary, materials engineers play an important role in advancing leading-edge technologies in a wide range of industries.

The mission of the materials science and engineering program is to educate students in the application of basic principles of science toward the design and utilization of materials in engineering components for the betterment of humanity. The overall goal of the program is to produce high-quality graduates with a broad-based education in materials engineering who can effectively compete for the best positions in graduate school and or industry.

The program's mission is achieved by having its graduates fulfill the following objectives. Graduates should

1. have an ability and technical competence to apply knowledge and laboratory skills in math, science, computers, statistics, and basic engineering to the principles of families of materials that include metals, ceramics, polymers, composites, and semiconductors;
2. have an integrated understanding of structure, properties, processing, and performance of materials from classroom and laboratory as developed from exposure to families of materials in bulk and thin film geometries;
3. possess an ability to apply and integrate knowledge of materials, in conjunction with economic, ethical, and societal considerations, to solve problems in materials selection, design, and manufacturing;
4. have an ability to communicate effectively as individuals and as team members with engineers from materials and other engineering disciplines; and
5. identify themselves as members of the materials engineering profession, demonstrate professional collegiality, and be aware of opportunities for lifelong learning and for interactions in local professional communities.

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Materials Science and Engineering. A minimum of 50 upper-division semester hours is required.

Graduation Requirements. In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 83.

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

First-Year Composition

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

—or—

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

—or—

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

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
HU, SB, and awareness area courses 13

Total 16

Literacy and Critical Inquiry

ECE 300 Intermediate Engineering Design *L* 3
ECE 400 Engineering Communications *L* 3

Total 6

Natural Sciences/Basic Sciences

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

Total 16

Numeracy/Mathematics

ECE 100 Introduction to Engineering Design *CS* 4
MAT 242 Elementary Linear Algebra 2
or ECE 384 Numerical Analysis for Engineers I (2)
or ECE 386 Partial Differential Equations for Engineers (2)
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 21
General Studies/school requirements total 59

Engineering Core

ECE 210 Engineering Mechanics I: Statics 3
ECE 301 Electrical Networks I 4
ECE 313 Introduction to Deformable Solids 3
ECE 350 Structure and Properties of Materials 3
MSE 430 Thermodynamics of Materials 3

Total 16

Major

ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
MSE 353 Introduction to Materials Processing and Synthesis 3
MSE 354 Experiments in Materials Synthesis and Processing I 2
MSE 355 Introduction to Materials Science and Engineering 3
MSE 420 Physical Metallurgy 3
MSE 421 Physical Metallurgy Laboratory 1
MSE 440 Mechanical Properties of Solids 3
MSE 450 X-ray and Electron Diffraction 3
MSE 470 Polymers and Composites 3
MSE 471 Introduction to Ceramics 3
MSE 482 Materials Engineering Design 3
MSE 490 Capstone Design Project 3
Select two of the following four courses[3] 6
CHM 325 Analytical Chemistry (3)
CHM 331 General Organic Chemistry (3)
CHM 341 Elementary Physical Chemistry (3)
PHY 361 Introductory Modern Physics (3)
Technical electives[4] 8

Total 47

1 Both PHY 121 and 122 must be taken to secure SQ credit.
2 Both PHY 131 and 132 must be taken to secure SQ credit.
3 To take CHM 341 Elementary Physical Chemistry, CHM 331 Organic Chemistry must be taken as the prerequisite.
4 Three of the eight hours must be a non-MSE upper-division engineering elective course.

Materials Science and Engineering Areas of Study

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

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

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

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

CHM 331 General Organic Chemistry 3
CHM 332 General Organic Chemistry 3
CHM 471 Solid-State Chemistry 3
EEE 435 Microelectronics 3
EEE 436 Fundamentals of Solid-State Devices 3
EEE 439 Semiconductor Facilities and Cleanroom Practices 3
MSE 453 Experiments in Materials Synthesis and Processing II 2
MSE 454 Advanced Materials Processing and Synthesis 3
MSE 472 Integrated Circuit Materials Science 3

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

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

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

CHE 458 Semiconductor Material Processing 3
EEE 435 Microelectronics 3
EEE 436 Fundamentals of Solid-State Devices 3
EEE 439 Semiconductor Facilities and Cleanroom Practices 3
MSE 453 Experiments in Materials Synthesis and Processing II 2
MSE 454 Advanced Materials Processing and Synthesis 3
MSE 471 Introduction to Ceramics 3

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

CHE 458 Semiconductor Material Processing	3
MAE 422 Mechanics of Materials	4
MAE 441 Principles of Design	3
MAE 442 Mechanical Systems Design	3
MSE 431 Corrosion and Corrosion Control	3
MSE 441 Analysis of Material Failures	3
MSE 453 Experiments in Materials Synthesis and Processing II	2
MSE 454 Advanced Materials Processing and Synthesis	3
MSE 472 Integrated Circuit Materials Science	3

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

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

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

MAE 351 Manufacturing Processes	3
MSE 431 Corrosion and Corrosion Control	3
MSE 441 Analysis of Material Failures	3
MSE 472 Integrated Circuit Materials Science	3

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

CHM 331 General Organic Chemistry	3
CHM 332 General Organic Chemistry	3
CHM 471 Solid-State Chemistry	3
MSE 441 Analysis of Material Failures	3
MSE 472 Integrated Circuit Materials Science	3

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

First Year

First Semester

CHM 113 General Chemistry *SQ*	4
ECE 100 Introduction to Engineering Design *CS*	4
ENG 101 First-Year Composition	3
MAT 270 Calculus with Analytic Geometry I *MA*	4
Total	15

Second Semester

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

Second Year

First Semester

ECE 210 Engineering Mechanics I: Statics	3
ECN 111 Macroeconomic Principles *SB*	3
MAT 242 Elementary Linear Algebra or ECE 384 Numerical Analysis for Engineers I (2) or ECE 386 Partial Differential Equations for Engineers (2)	2
MAT 272 Calculus with Analytic Geometry III *MA*	4
PHY 131 University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY 132 University Physics Laboratory II *SQ*[2]	1
Total	16

Second Semester

ECE 301 Electrical Networks I	4
ECE 313 Introduction to Deformable Solids	3
ECE 350 Structure and Properties of Materials	3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS*	3
MAT 274 Elementary Differential Equations *MA*	3
Total	16

Third Year

First Semester

ECE 300 Intermediate Engineering Design *L*	3
MSE 353 Introduction to Materials Processing and Synthesis	3
MSE 355 Introduction to Materials Science and Engineering	3
Advanced science course[3]	3
HU, SB, and awareness area course(s)[4]	4
Total	16

Second Semester

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

Fourth Year

First Semester

MSE 440 Mechanical Properties of Solids	3
MSE 470 Polymers and Composites	3
MSE 471 Introduction to Ceramics	3
MSE 482 Materials Engineering Design	3
Technical elective	4
Total	16

Second Semester

ECE 400 Engineering Communications *L*	3
MSE 490 Capstone Design Project	3
Advanced science course[3]	3
HU, SB, or awareness area course[4]	3

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

Technical electives	4
Total	16
Degree requirements total	128

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

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

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

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

CHEMICAL ENGINEERING (CHE)

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

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

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

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

CHE 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 311; ECE 394 ST: Conservation Principles, ECE 394 ST: Properties that Matter. Pre- or corequisite: MAT 272.

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

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

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

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

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

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

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

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

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

CHE 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.

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

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

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

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

CHE 494 Special Topics. (1–4) F, S
(a) Advanced Process Control. (3)
(b) Biotechnology Techniques. (3)

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

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

CHE 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.

CHE 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.

CHE 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.

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

CHE 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.

CHE 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.

CHE 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. Credit is allowed for only BME 533 or CHE 533.

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

CHE 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.

CHE 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. Credit is allowed for only BME 543 or CHE 543.

CHE 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. Credit is allowed for only BME 544 or CHE 544. Prerequisite: BME/CHE 543.

CHE 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.

Faculty and programs geared toward producing professionals keep engineering students up-to-date with cutting-edge technology.

Tim Trumble photo

CHE 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.

CHE 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.

CHE 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.

CHE 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.

CHE 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.

CHE 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.

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

MATERIALS SCIENCE AND ENGINEERING (MSE)

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. Prerequisites: CHM 116 and PHY 131 *or* equivalents.

MSE 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. Prerequisite: MSE 353 or equivalent.

MSE 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.

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

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

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

MSE 431 Corrosion and Corrosion Control. (3) 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.

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

MSE 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.

MSE 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.

MSE 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.

MSE 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. Prerequisites: MSE 353 and 354 *or* equivalents.

MSE 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. Prerequisites: MSE 353 and 354 *or* equivalents.

MSE 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. Credit is allowed for only MAE 455 or MSE 470. Prerequisite: ECE 350.

MSE 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.

MSE 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.

MSE 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.

MSE 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.

MSE 496 Professional Seminar. (1–3) F, S
Professional and ethical aspects with a discussion of responsibilities. Lectures, field trips. Prerequisite: instructor approval.

MSE 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.

MSE 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.

MSE 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.

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

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

MSE 515 Thermodynamics of Materials. (3) 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.

MSE 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.

MSE 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.

MSE 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.

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

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

MSE 521 Defects in Crystalline Solids. (3) 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.

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

MSE 540 Fracture, Fatigue, and Creep. (3) 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.

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

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

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

MSE 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. Credit is allowed for only MSE 558 or SEM 558. Prerequisite: instructor approval.

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

MSE 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.

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

MSE 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.

MSE 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.

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

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

MSE 598 Special Topics. (3) A
(a) Growth and Processing of Semiconductor Devices

Department of Civil and Environmental Engineering

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PROFESSORS
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ASSOCIATE PROFESSORS
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ASSISTANT PROFESSORS
MUCCINO, OWUSU-ANTWI, WESTERHOFF, ZHU

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

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

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

The Department of Civil and Environmental 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.

Civil Engineering Areas of Study

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

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

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

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

Transportation/Materials Engineering. This area of study includes (1) transportation planning, design, and operation and (2) pavements and materials. Transportation planning, design, and operation covers urban transport planning, geometric design of facilities, traffic operations, evaluation of highway capacity and safety, and intelligent vehicle/highway systems. Pavements and materials focus on pavement analysis and design; pavement maintenance and rehabilitation; pavement evaluation and management; characterization of highway materials and durability of highway structures.

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

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

UNDERGRADUATE OPPORTUNITIES IN CIVIL AND ENVIRONMENTAL ENGINEERING

Students majoring in Civil Engineering have three choices:

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

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

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

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

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

CIVIL ENGINEERING—B.S.E.

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

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

Civil Engineering

First-Year Composition	6
General Studies/school requirements	54
Engineering core	19–20
Major	48–49
Total	128

Civil Engineering with Construction Engineering Concentration

First-Year Composition	6
General Studies/school requirements	54
Engineering core	20
Major	48
Total	128

Civil Engineering with Environmental Engineering Concentration

First-Year Composition	6
General Studies/school requirements	54
Engineering core	19
Major	49
Total	128

Graduation Requirements

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 83.

Course Requirements. See "Degree Requirements," page 207, and "Course Requirements," page 207, for General Studies, school, and engineering core requirements.

DEGREE REQUIREMENTS WITHOUT CONCENTRATION

Civil Engineering Core

Twenty-seven hours are required. Each sequence of the MAT courses and the ECE courses (excluding ECE 300, 351, and 380) must be completed with an average grade of "C" or higher before any 400-level CEE courses are taken. Also, each sequence of the CEE courses, and the senior design and technical elective courses must be completed with an average grade of "C" or higher. All are part of the CEE graduation requirement.

CEE	296	Civil Engineering Systems	3
CEE	315	Computer Methods for Civil Engineers	1
CEE	321	Structural Analysis and Design	4
CEE	341	Fluid Mechanics for Civil Engineers	4
CEE	351	Geotechnical Engineering	4
CEE	361	Introduction to Environmental Engineering	4
CEE	372	Transportation Engineering	4
ECE	380	Probability and Statistics for Engineering Problem Solving *CS*	3
Total			27

Civil Engineering Design Electives

Six semester hours from the following list are required.

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

Civil Engineering Technical Electives

Fifteen to 16 semester 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 seven hours may be selected from outside civil engineering, with an advisor's approval. One of the following construction courses may be taken as a technical elective: CON 341, 383, 495, and 496. Students must select technical electives from at least three different CEE areas of study.

Environmental Engineering. This area includes water treatment, industrial and domestic waste treatment and disposal, public health engineering, and industrial hygiene.

CEE	362	Unit Operations in Environmental Engineering	3
CEE	466	Sanitary Systems Design	3
CHM	231	Elementary Organic Chemistry *SQ*	3
MIC	220	Biology of Microorganisms or MIC 205 Microbiology *SG* (3) and MIC 206 Microbiology Laboratory *SG* (1)	3

Geotechnical/Geoenvironmental Engineering. This area includes assessment of engineering properties and design utilizing soils and rocks as engineering materials.

CEE	452	Foundations	3

Structures/Materials Engineering. This area includes analysis and design of structures for buildings, bridges, space frames, and structural mechanics.

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

Transportation/Materials Engineering. This area includes analysis and design of transportation facilities, transportation planning and economics, and transportation in the urban environment.

CEE 412 Pavement Analysis and Design 3
CEE 471 Intelligent Transportation Systems 3
CEE 475 Highway Geometric Design 3

Water Resources Engineering. This area includes planning and design of facilities for collection, storage and distribution of water, water systems management, and estimating availability of water resources.

CEE 440 Engineering Hydrology 3
CEE 441 Water Resources Engineering 3

Civil Engineering Program of Study
A Four-Year Sequence

First Year

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

Total 15

Second Semester
CEE 296 Civil Engineering Systems 3
ENG 102 First-Year Composition 3
MAT 271 Calculus with Analytic Geometry II *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[1] 3
PHY 122 University Physics Laboratory I *SQ*[1] 1

Total 14

Second Year

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

Total 17

Second Semester
CEE 315 Computer Methods for Civil Engineers 1
ECE 312 Engineering Mechanics II: Dynamics 3
ECE 313 Introduction to Deformable Solids 3
ECE 340 Thermodynamics 3
or ECE 301 Electrical Networks I (4)
ECE 384 Numerical Analysis for Engineers I 2
ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
Basic science elective 3

Total 18–19

Third Year

First Semester
CEE 321 Structural Analysis and Design 4
CEE 341 Fluid Mechanics for Civil Engineers 4
ECE 300 Intermediate Engineering Design *L* 3
ECE 351 Civil Engineering Materials 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3

Total 17

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

Total 15

Fourth Year

First Semester
Design elective 3
HU/SB and awareness area course(s)[3] 4
Technical electives 9

Total 16

Second Semester
CEE 486 Integrated Civil Engineering Design *L* 3
Design elective 3
HU/SB or awareness area course[3] 3
Technical electives 6–7

Total 15–16
Graduation requirement total 128

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

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

DEGREE REQUIREMENTS WITH ENVIRONMENTAL ENGINEERING CONCENTRATION

Environmental Engineering Core

See “Course Requirements,” page 207, for General Studies, school, and engineering core requirements.

Thirty semester hours are required. Each sequence of the MAT courses and the ECE courses (excluding ECE 300, 351, and 380) must be completed with an average grade of “C” or higher before any CEE 400-level courses are taken. Also, each sequence of the environmental engineering core courses, and the senior design and technical courses must be completed with an average grade of “C” or higher. This is a CEE graduation requirement.

CEE 296 Civil Engineering Systems 3
CEE 315 Computer Methods for Civil Engineers 1

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

CEE 321 Structural Analysis and Design 4
CEE 341 Fluid Mechanics for Civil Engineers 4
CEE 351 Geotechnical Engineering 4
CEE 361 Introduction to Environmental Engineering 4
CEE 372 Transportation Engineering 4
CHM 341 Elementary Physical Chemistry 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3

Total 30

Environmental Design Courses
CEE 441 Water Resources Engineering 3
CEE 466 Sanitary Systems Design 3

Total 6

Environmental Technical Courses
BIO 320 Fundamentals of Ecology 3
or BCH 361 Principles of Biochemistry (3)
or CHM 302 Environmental Chemistry (3)
or PUP 442 Environmental Planning (3)
or PUP 475 Environmental Impact Assessment (3)
CEE 362 Unit Operations in Environmental Engineering 3
CEE 440 Engineering Hydrology 3
MIC 205 Microbiology *SG* 3
MIC 206 Microbiology Laboratory *SG* 1

Total 13

Environmental Engineering Concentration
Program of Study
A Four-Year Sequence

First Year

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

Total 15

Second Semester
CEE 296 Civil Engineering Systems 3
ENG 102 First-Year Composition 3
MAT 271 Calculus with Analytic Geometry II *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[1] 3
PHY 122 University Physics Laboratory I *SQ*[1] 1

Total 14

Second Year

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

Total 17

Second Semester
CEE 315 Computer Methods for Civil Engineers 1
CHM 231 Elementary Organic Chemistry *SQ* 3
ECE 312 Engineering Mechanics II: Dynamics 3
ECE 313 Introduction to Deformable Solids 3
ECE 340 Thermodynamics 3
ECE 384 Numerical Analysis for Engineers I 2
ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)

Total 18

Third Year

First Semester
CEE 321 Structural Analysis and Design 4
CEE 341 Fluid Mechanics for Civil Engineers 4
ECE 300 Intermediate Engineering Design *L* 3
ECE 351 Civil Engineering Materials 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3

Total 17

Second Semester
CEE 351 Geotechnical Engineering 4
CEE 361 Introduction to Environmental Engineering 4
CEE 372 Transportation Engineering 4
CHM 341 Elementary Physical Chemistry 3
HU/SB or awareness area course[3] 3

Total 18

Fourth Year

First Semester
CEE 362 Unit Operations in Environmental Engineering 3
CEE 440 Engineering Hydrology 3
CEE 466 Sanitary Systems Design 3
MIC 205 Microbiology *SG* 3
MIC 206 Microbiology Laboratory *SG* 1
HU/SB and awareness area course(s)[3] 4

Total 17

Second Semester
BIO 320 Fundamentals of Ecology 3
or BCH 361 Principles of Biochemistry (3)
or CHM 302 Environmental Chemistry (3)
or PUP 442 Environmental Planning (3)
or PUP 475 Environmental Impact Assessment (3)
CEE 441 Water Resources Engineering 3
CEE 486 Integrated Civil Engineering Design *L* 3
HU/SB or awareness area course[3] 3

Total 12
Graduation requirement total 128

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

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

DEGREE REQUIREMENTS WITH CONSTRUCTION ENGINEERING CONCENTRATION

Construction Engineering Core

See “Degree Requirements,” page 197, for General Studies, school, and engineering core requirements.

Twenty-seven semester hours are required. Each sequence of the MAT courses and the ECE courses (excluding ECE 300, 351, and 380) must be completed with an average grade of “C” or higher before any CEE 400-level courses are taken. Also, each sequence of the construction engineering core courses and the senior design and technical courses must be completed with an average grade of “C” or higher. This is a CEE graduation requirement.

CEE 296 Civil Engineering Systems 3
CEE 315 Computer Methods for Civil Engineers 1

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

Total....27

Construction Engineering Design Courses
CEE 322 Steel Structures....3
CEE 452 Foundations....3

Total....6

Construction Engineering Technical Courses
CEE 323 Concrete Structures....3
CEE 481 Civil Engineering Project Management....3
CEE 483 Highway Materials, Construction, and Quality....3
CON 341 Surveying....3
CON 496 Construction Contract Administration *L*....3

Total....15

Construction Engineering Concentration Program of Study A Four-Year Sequence

First Year

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

Total....15

Second Semester
CEE 296 Civil Engineering Systems....3
ENG 102 First-Year Composition....3
MAT 271 Calculus with Analytic Geometry II *MA*....4
PHY 121 University Physics I: Mechanics *SQ*[1]....3
PHY 122 University Physics Laboratory I *SQ*[1]....1

Total....14

Second Year

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

Total....17

Second Semester
CEE 315 Computer Methods for Civil Engineers....1
ECE 301 Electrical Networks I....4
ECE 312 Engineering Mechanics II: Dynamics....3
ECE 313 Introduction to Deformable Solids....3
ECE 384 Numerical Analysis for Engineers I....2
ECN 111 Macroeconomic Principles *SB*....3
or ECN 112 Microeconomic Principles *SB* (3)
Basic science elective....3

Total....19

Third Year

First Semester
CEE 321 Structural Analysis and Design....4
CEE 341 Fluid Mechanics for Civil Engineers....4
ECE 300 Intermediate Engineering Design *L*....3
ECE 351 Civil Engineering Materials....3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS*....3

Total....17

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

Total....15

Fourth Year

First Semester
CEE 322 Steel Structures....3
CEE 452 Foundations....3
CEE 481 Civil Engineering Project Management....3
CON 341 Surveying....3
HU/SB and awareness area course(s)[3]....4

Total....16

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

Total....15
Graduation requirement total....128

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

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

CIVIL AND ENVIRONMENTAL ENGINEERING (CEE)

CEE 296 Civil Engineering Systems. (3) F, S
Introduction to civil engineering. Problem solving, economics, description of civil engineering systems, design concepts, ethics, and professional responsibilities. Lecture, field trips. Pre- or corequisite: ECE 100.

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

CEE 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.

CEE 315 Computer Methods for Civil Engineers. (1) F, S
Development of computer programs in a high-level language to solve civil engineering problems. Lecture, lab. Pre- or corequisite: ECE 384.

CEE 321 Structural Analysis and Design. (4) F, S
Statically determinate and indeterminate structures (trusses, beams, and frames) by classical and matrix methods. Introduction to structural design. Lecture, recitation. Prerequisites: ECE 312, 313. Pre- or corequisites: ECE 380, 384.

CEE 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. Prerequisite: CEE 321.

CEE 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. Prerequisite: CEE 321.

CEE 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.

CEE 341 Fluid Mechanics for Civil Engineers. (4) F, S
Fundamental principles and methods of fluid mechanics forming the analytical basis for water resources engineering. Conduit and open channel flow. 3 hours lecture, 1 hour lab. Prerequisites: ECE 312, 313. Pre- or corequisites: ECE 380, 384.

CEE 351 Geotechnical Engineering. (4) F, S
Index properties and engineering characteristics of soils. Compaction, permeability and seepage, compressibility and settlement, and shear strength. Lecture, lab. Prerequisites: ECE 312, 313. Pre- or corequisites: ECE 380, 384.

CEE 361 Introduction to Environmental Engineering. (4) F, S
Concepts of air and water pollution; environmental regulation, risk assessment, chemistry, water quality modeling, water and wastewater treatment systems designs. Lecture, lab. Prerequisites: ECE 312, 313. Pre- or corequisites: ECE 380, 384.

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

CEE 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: ECE 312, 313. Pre- or corequisites: ECE 380, 384.

CEE 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.

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

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

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

CEE 441 Water Resources Engineering. (3) 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.

CEE 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.

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

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

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

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

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

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

CEE 486 Integrated Civil Engineering Design. (3) F, S
Students are required to complete a civil engineering design in a simulated practicing engineering environment. Lecture, team learning. Limited to undergraduates in their final semester. Prerequisites: CEE 321, 341, 351, 361, 372. *General Studies: L*.

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

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

CEE 515 Properties of Concrete. (3) 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.

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

CEE 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.

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

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

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

CEE 533 Structural Optimization. (3) N
Linear and nonlinear programming. Problem formulation. Constrained and unconstrained optimization. Sensitivity analysis. Approximate techniques. FEM-based optimal design of mechanical and aerospace structures. Cross-listed as MAE 521. Credit is allowed for only CEE 533 or MAE 521. Prerequisite: instructor approval.

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

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

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

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

CEE 543 Water Resources Systems. (3) F
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: instructor approval.

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

CEE 547 Principles of River Engineering. (3) 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.

CEE 548 Sedimentation Engineering. (3) N
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.

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

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

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

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

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

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

CEE 557 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. Prerequisites: graduate standing; instructor approval.

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

CEE 560 Soil and Groundwater Remediation. (3) F
Techniques for remediation of contaminated soils and groundwaters are presented with basic engineering principles. Prerequisite: instructor approval.

CEE 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.

CEE 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.

CEE 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.

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

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

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

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

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

CEE 577 Urban Transportation Planning. (3) N
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.

CEE 580 Practicum. (1–12) N

CEE 590 Reading and Conference. (1–12) N

CEE 592 Research. (1–12) N

CEE 599 Thesis. (1–12) N

CEE 792 Research. (1–15) N

CEE 799 Dissertation. (1–15) N

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.*

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

Department of Computer Science and Engineering

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PROFESSORS
ASHCROFT, COLLOFELLO, FARIN, GOLSHANI, LEWIS, NIELSON, TSAI, J. URBAN, YAU

ASSOCIATE PROFESSORS
BARAL, BHATTCHARYA, DASGUPTA, DIETRICH, FALTZ, GHOSH, HUEY, KAMBHAMPATI, LINDQUIST, LIU, MILLER, O'GRADY, PANCHANATHAN, PHEANIS, SEN, S. URBAN

ASSISTANT PROFESSORS
BAZZI, CANDAN, CHALASANI, G. GANNOD, RICHA, WAGNER

LECTURERS
DeLIBERO, B. GANNOD, R. HOUSTON, NAVABI, THURMAN, WHITEHOUSE

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

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

DEGREE REQUIREMENTS

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

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 83.

DEGREES

Computer Science—B.S.

The faculty in the Department of Computer Science and Engineering offer a B.S. degree that prepares the student for a career in computer science. A student pursuing a B.S. degree must complete the First-Year Composition requirement, the General Studies requirement, department degree requirements, the computer science core courses, a senior-level breadth requirement in the major, technical electives, and unrestricted electives. For more information, contact the department office, refer to the department Web site, or e-mail questions to cse.ugrad.desk@asu.edu.

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

First-Year Composition

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

Total 6

General Studies/Department Requirements

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

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

Total 6

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

Total 12

Numeracy/Mathematics
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
MAT 243 Discrete Mathematical Structures 3
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 342 Linear Algebra 3

Total 21
General Studies/department requirement total 57

Computer Science Core

CSE 120 Digital Design Fundamentals 3
CSE 200 Concepts of Computer Science 3
CSE 210 Object-Oriented Design and Data Structures *CS* 3
CSE 225 Assembly Language Programming and Microprocessors (Motorola) 4
or CSE 226 Assembly Language Programming and Microprocessors (Intel) (4)
CSE 240 Introduction to Programming Languages 3
CSE 310 Data Structures and Algorithms 3
CSE 330 Computer Organization and Architecture 3

CSE 340 Principles of Programming Languages 3
CSE 355 Introduction to Theoretical Computer Science 3
CSE 360 Introduction to Software Engineering 3
CSE 430 Operating Systems 3

Total computer science core 34

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

Total 31
Degree requirements total 128

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

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

[3] This elective may be satisfied by any physics courses requiring PHY 131 as a prerequisite or any laboratory science for majors in the discipline and satisfying the SQ General Studies requirement (except PHS 110). See an advisor for approved listing.

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

Computer Science
Program of Study
Typical Four-Year Sequence

First Year

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

Total 16

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

Total 17

Second Year

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

Total 17

Second Semester
CSE 225 Assembly Language Programming and Microprocessors (Motorola) 4
or CSE 226 Assembly Language Programing and Microprocessors (Intel) (4)
CSE 310 Data Structures and Algorithms 3
PHY 131 University Physics II: Electricity and Magnetism *SQ*[3] 3
PHY 132 University Physics Laboratory II *SQ*[3] 1
HU/SB or awareness area course[1] 3
L elective 3

Total 17

Third Year

First Semester
CSE 330 Computer Organization and Architecture 3
CSE 340 Principles of Programming Languages 3
MAT 342 Linear Algebra 3
HU/SB or awareness area course[1] 3
Laboratory science for engineering majors *SQ*[4] 4

Total 16

Second Semester
CSE 355 Introduction to Theoretical Computer Science 3
CSE 360 Introduction to Software Engineering 3
CSE 430 Operating Systems 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
HU/SB or awareness area course[1] 3

Total 15

Fourth Year

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

Total 15

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

Total 15

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

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

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

[4] This elective may be satisfied by any physics courses requiring PHY 131 as a prerequisite or any laboratory science for majors in the discipline and satisfying the SQ General Studies requirement (except PHS 110). See an advisor for approved listing.

Computer Systems Engineering—B.S.E.

The Department of Computer Science and Engineering offers a B.S.E. degree that prepares the student for a career in computer systems engineering. This degree program provides training in both engineering and computer science. The following list specifies departmental requirements for the B.S.E. degree in Computer Systems Engineering.

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

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

—or—

ENG 107	English for Foreign Students (3)	
ENG 108	English for Foreign Students (3)	
Total		6

General Studies/Department Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111	Macroeconomic Principles *SB*	3
	or ECN 112 Microeconomic Principles *SB* (3)	
HU and SB electives		13
Total		16

Literacy and Critical Inquiry

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

Natural Sciences/Basic Sciences

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

Numeracy/Mathematics

MAT 243	Discrete Mathematical Structures	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
MAT 271	Calculus with Analytic Geometry II *MA*	4
MAT 272	Calculus with Analytic Geometry III *MA*	4
MAT 274	Elementary Differential Equations *MA*	3
MAT 342	Linear Algebra	3
Total		21
General Studies/department requirement total		64

Engineering Core

CSE 200	Concepts of Computer Science *CS*	3
CSE 225	Assembly Language Programming and Microprocessors (Motorola)	4
ECE 100	Introduction to Engineering Design *CS*	4
ECE 210	Engineering Mechanics I: Statics	3
ECE 301	Electrical Networks I	4
ECE 334	Electronic Devices and Instrumentation	4
Total		22

Computer Science Core

CSE 120	Digital Design Fundamentals	3
CSE 210	Object-Oriented Design and Data Structures *CS*	3
CSE 240	Introduction to Programming Languages	3
CSE 310	Data Structures and Algorithms	3
CSE 330	Computer Organization and Architecture	3
CSE 340	Principles of Programming Languages	3
CSE 355	Introduction to Theoretical Computer Science	3
CSE 360	Introduction to Software Engineering	3
CSE 421	Microprocessor System Design I	4
CSE 422	Microprocessor System Design II	4
CSE 430	Operating Systems	3
ECE 380	Probability and Statistics for Engineering Problem Solving *CS*	3
Technical elective(s)[3]		4
Total		42

Degree requirement total		128

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

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

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

Computer Systems Engineering Program of Study Typical Four-Year Sequence

First Year

First Semester

CSE 200	Concepts of Computer Science *CS*	3
ECE 100	Introduction to Engineering Design *CS*	4
	or CSE 120 Digital Design Fundamentals (3)	
ECN 111	Macroeconomic Principles *SB*	3
ENG 101	First-Year Composition	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
Total		17

Second Semester

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

Second Year

First Semester

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

Second Semester

CSE 240	Introduction to Programming Languages	3
CSE 330	Computer Organization and Architecture	3
ECE 210	Engineering Mechanics I: Statics	3
MAT 274	Elementary Differential Equations *MA*	3
PHY 131	University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY 132	University Physics Laboratory II *SQ*[2]	1
Total		16

Third Year

First Semester

CSE 310	Data Structures and Algorithms	3
CSE 421	Microprocessor System Design I	4
ECE 300	Intermediate Engineering Design *L*	3
MAT 342	Linear Algebra	3
HU/SB or awareness area course[3]		3
Total		16

Second Semester

CSE 340	Principles of Programming Languages	3
CSE 360	Introduction to Software Engineering	3
ECE 380	Probability and Statistics for Engineering Problem Solving *CS*	3
PHY 361	Introductory Modern Physics	3

HU/SB and awareness area course(s)[3]		4
Total		16

Fourth Year

First Semester

CSE 355	Introduction to Theoretical Computer Science	3
CSE 422	Microprocessor System Design II	4
CSE 430	Operating Systems	3
ECE 301	Electrical Networks I	4
HU/SB or awareness area course[3]		3
Total		17

Second Semester

CSE 423	Microcomputer System Hardware *L*	3
ECE 334	Electronic Devices and Instrumentation	4
HU/SB or awareness area course[3]		3
Technical electives		4
Total		14

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

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

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

COMPUTER SCIENCE AND ENGINEERING (CSE)

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

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

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

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

CSE 181 Applied Problem Solving with Visual BASIC. (3) F, S, SS
Introduction of systematic definition of problems, solution formulation, and method validation. Computer solution using Visual BASIC required for projects. Lecture, lab. Prerequisites: MAT 117; nonmajor. *General Studies: CS.*

CSE 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. Prerequisites: MAT 170; nonmajor. *General Studies: CS.*

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

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

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

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

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

CSE 240 Introduction to Programming Languages. (3) F, S, SS
Introduction to the procedural (C++), applicative (LISP), and declarative (Prolog) languages. Lecture, lab. Prerequisite: CSE 210.

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

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

CSE 340 Principles of Programming Languages. (3) F, S, SS
Introduction to language design and implementation. Parallel, machine-dependent and declarative features; type theory; specification, recognition, translation, run-time management. Prerequisites: CSE 240, 310; CSE/EEE 225 (or 226).

CSE 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.

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

CSE 408 Multimedia Information Systems. (3) 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 310.

CSE 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.

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

CSE 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. Prerequisite: CSE/EEE 225.

CSE 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.

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

CSE 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. *General Studies: L.*

CSE 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.

CSE 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.

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

CSE 438 Systems Programming. (3) 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. *General Studies: L.*

CSE 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.

CSE 445 Distributed Computing with Java and CORBA. (3) F, S
Technologies for developing software components. Client-server computing with sockets and distributed objects. Dynamic interface discovery and invocation. Lecture, projects. Prerequisite: CSE 310 or instructor approval.

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

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

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

CSE 459 Logic for Computing Scientists. (3) 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.

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

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

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

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

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

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

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

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

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

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

CSE 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.

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

CSE 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.

CSE 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.

CSE 517 Hardware Design Languages. (3) A
Introduction to hardware design languages. Modeling concepts for specification, simulation, and synthesis. Prerequisite: CSE 423 or EEE 425 or instructor approval.

CSE 518 Synthesis with Hardware Design Languages. (3) N
Modeling VLSI design in hardware design languages for synthesis. Transformation of language-based designs to physical layout. Application of synthesis tools. Prerequisite: CSE 517.

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

CSE 521 Microprocessor Applications. (4) A
Microprocessor technology and its application to the design of practical digital systems. Hardware, assembly language programming, and interfacing of microprocessor-based systems. Lecture, lab. Prerequisite: CSE 421.

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

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

CSE 530 Operating System Internals. (3) A
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.

CSE 531 Distributed and Multiprocessor Operating Systems. (3) A
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.

CSE 532 Advanced Operating System Internals. (3) N
Memory, processor, process and communication management, and concurrency control in the Windows NT multiprocessor and distributed operating system kernels and servers. Prerequisites: CSE 530; 531 (or 536).

CSE 534 Advanced Computer Networks. (3) F, S
Advanced network protocols and infrastructure, applications of high-performance networks to distributed systems, high-performance computing and multimedia domains, special features of networks. Prerequisite: CSE 434.

CSE 536 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.

CSE 537 ATM Network Design. (3) S
Principles of ATM networks, switch architecture, traffic management, call and connection control, routing, internetworking with ATM networks, signaling, and OAM. Prerequisite: CSE 434.

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

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

CSE 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.

CSE 555 Theory of Computation. (3) F, S
Rigorous treatment of regular languages, context-free languages, Turing machines and decidability, reducibility, and other advanced topics in computability theory. Prerequisite: CSE 355 or instructor approval.

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

CSE 562 Software Process Automation. (3) A
Representing the software process; creating a measured and structured working environment; using, constructing, and adapting component-based tools. Prerequisite: CSE 360.

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

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

CSE 565 Software Verification, Validation, and Testing. (3) A
Test planning, requirements-based and code-based testing techniques, tools, reliability models, and statistical testing. Prerequisite: CSE 460.

CSE 566 Software Project, Process, and Quality Management. (3) A
Project management, risk management, configuration management, quality management, and simulated project management experiences. Prerequisite: CSE 360.

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

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

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

CSE 574 Planning and Learning Methods in AI. (3) A
Reasoning about time and action, plan synthesis and execution, improving planning performance, applications to manufacturing intelligent agents. Prerequisite: CSE 471 or equivalent.

CSE 575 Decision-Making Strategies in AI. (3) S
Automatic knowledge acquisition, automatic analysis/synthesis of strategies, distributed planning/problem solving, causal modeling, predictive human-machine environments. Prerequisite: CSE 471 or 571 or equivalent.

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

CSE 577 Advanced Computer-Aided Geometric Design I. (3) 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.

CSE 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.

CSE 579 NURBs: Nonuniform Rational B-Splines. (3) A
Projective geometry, NURBs-based modeling, basic theory of conics and rational Bezier curves, rational B-splines, surfaces, rational surfaces, stereographic maps, quadrics, IGES data specification. Prerequisites: CSE 470, 477.

CSE 593 Applied Project. (1–12) N

Department of Electrical Engineering

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REGENTS' PROFESSORS
BALANIS, FERRY

PROFESSORS
BACKUS, CROUCH, EL-GHAZALY, GOODNICK, GORUR, HEYDT, HIGGINS, HOPPENSTEADT, HUI, KARADY, KOZICKI, PALAIS, PAN, ROEDEL, SCHRODER, SPANIAS, THORNTON

ASSOCIATE PROFESSORS
ABERLE, ALLEE, BIRD, CHAKRABARTI, COCHRAN, EL-SHARAWY, GREENEICH, GRONDIN, HOLBERT, LAI, MORRELL, RODRIGUEZ, SHEN, SI, SKROMME, TSAKALIS, TYLAVSKY, ZHANG

ASSISTANT PROFESSORS
CAPONE, DUMAN, KARAM, PAPANDREOU-SUPPAPPOLA, VASILESKA-KAFEDZISKA, YAZDI

The professional activities of electrical engineers directly affect the everyday lives of most of the world's population.

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

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 in Electrical Engineering will be involved in a variety of electrical and electronic problems in the course of their careers. To ensure the necessary breadth of knowledge, the Electrical Engineering curriculum includes basic (core) engineering courses and courses in networks and electronic circuits, electromagnetic fields and waves, microprocessors, communication and control systems, solid-state electronics, electrical power systems, and other specialty courses.

ELECTRICAL ENGINEERING—B.S.E.

The goal of the Electrical Engineering undergraduate program is to prepare the graduates for entry-level positions as electrical engineers for the broad range of opportunities available in industrial, commercial, and governmental organizations, and to prepare the graduates for continued learning experiences either in a formal graduate program or in continuing education applications.

The curriculum in Electrical Engineering builds upon the base provided by the engineering core. Beyond the engineering core, the curriculum includes a number of required electrical engineering and technical elective courses. Approved technical elective courses serve to provide students with an opportunity either to broaden their background in electrical engineering or to study, in greater depth, technical subjects in which they have special interests. Successful completion of the curriculum leaves the student prepared to embark on a career in electrical engineering or to pursue advanced education in graduate school.

The engineering design experience is structured around three backbone courses employing engineering teams: ECE 100 Introduction to Engineering Design (freshman year), ECE 300 Intermediate Engineering Design (junior year), and EEE 490 Senior Design Laboratory. The integrated experience is strengthened with required courses, EEE 120 Digital Design Fundamentals, EEE 225/226 Assembly Language Programming and Microprocessors, EEE 303 Signals and Systems, and EEE 360 Energy Conversion and Transport. Students focus on design pertaining to specific electrical engineering areas in their senior technical electives before the culminating, capstone design experience in EEE 490.

DEGREE REQUIREMENTS

A minimum of 128 semester hours is necessary for the B.S.E. degree in Electrical Engineering. A minimum of 50 upper-division semester hours is required.

GRADUATION REQUIREMENTS

A student must earn a grade of "C" or higher in the mathematics and physics courses listed in the program of study. The student must also have an overall GPA of at least 2.00 for the following group of courses: CSE 100; ECE 300, 301, 334, 352; all courses with an EEE prefix; and all other courses used as technical electives.

In addition to fulfilling school and major requirements, students must satisfy all university graduation requirements. See "University Graduation Requirements," page 83.

COURSE REQUIREMENTS

The specific course requirements for the B.S.E. degree in Electrical Engineering follow.

First-Year Composition[1]

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

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111 Macroeconomic Principles *SB* 3
or ECN 112 Microeconomic Principles *SB* (3)
HU courses 6–10
SB courses 3–7

Minimum total 16

Literacy and Critical Inquiry

ECE 300 Intermediate Engineering Design *L* 3
EEE 490 Senior Design Laboratory *L* 3

Total 6

Natural Sciences/Basic Sciences

CHM 114 General Chemistry for Engineers *SQ* 4
or CHM 116 General Chemistry *SQ* (4)
PHY 121 University Physics I: Mechanics *SQ*[2] 3
PHY 122 University Physics Laboratory I *SQ*[2] 1
PHY 131 University Physics II: Electricity and Magnetism *SQ*[3] 3
PHY 132 University Physics Laboratory II *SQ*[3] 1
PHY 241 University Physics III 3

Total 15

Numeracy and Mathematics

ECE 100 Introduction to Engineering Design *CS* 4
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3
MAT 342 Linear Algebra 3
MAT 362 Advanced Mathematics for Engineers and Scientists I 3

Total 25

General Studies/school requirements total....................................62

Engineering Core

ECE	301	Electrical Networks I	4
ECE	314	Engineering Mechanics	4
ECE	334	Electronic Devices and Instrumentation	4
ECE	352	Properties of Electronic Materials	4
EEE	225	Assembly Language Programming and Microprocessors (Motorola)	4
		or EEE 226 Assembly Language Programming and Microprocessors (Intel) (4)	
Total			20

[1] A minimum grade of “C” is required.

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

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

Electrical Engineering Major

The following courses are required to fulfill the Electrical Engineering major:

CSE	100	Principles of Programming with C++ *CS*	3
EEE	120	Digital Design Fundamentals	3
EEE	302	Electrical Networks II	3
EEE	303	Signals and Systems	3
EEE	340	Electromagnetic Engineering I	4
EEE	350	Random Signal Analysis	3
EEE	360	Energy Conversion and Transport	4
Total			23

The program in Electrical Engineering requires a total of 17 hours of technical electives. With department approval, a maximum of two technical electives may be taken outside electrical engineering. Qualified students may choose from approved courses in business, engineering, mathematics, and the sciences at or above the 300-level, including graduate courses. Students must have a GPA of not less than 3.00 and approval of the dean to enroll in EEE graduate-level courses. To ensure breadth of knowledge, students *must* select courses from at least three of the following six areas. In addition, to ensure depth, two courses must be taken in one area.

Communications and Signal Processing

EEE	407	Digital Signal Processing	4
EEE	455	Communication Systems	4
EEE	459	Communication Networks	3

Control

EEE	480	Feedback Systems	4
EEE	482	Introduction to State Space Methods	3

Electromagnetics

EEE	440	Electromagnetic Engineering II	4
EEE	443	Antennas	3
EEE	445	Microwaves	4
EEE	448	Fiber Optics	4

Electronic Circuits

EEE	405	Filter Design	3
EEE	425	Digital Systems and Circuits	4
EEE	433	Analog Integrated Circuits	3

Power Systems

EEE	460	Nuclear Concepts for the 21st Century	3
EEE	463	Electrical Power Plant	3
EEE	470	Electric Power Devices	3
EEE	471	Power System Analysis	3
EEE	473	Electrical Machinery	3

Solid-State Electronics

EEE	434	Quantum Mechanics for Engineers	3
EEE	435	Microelectronics	3
EEE	436	Fundamentals of Solid-State Devices	3
EEE	437	Optoelectronics	3
EEE	439	Semiconductor Facilities and Cleanroom Practices	3

With department approval Computer Science and Engineering courses at or above the 300 level may be substituted for one of the above areas.

Electrical Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM	114	General Chemistry for Engineers *SQ*	4
		or CHM 116 General Chemistry *SQ* (4)	
ECE	100	Introduction to Engineering Design[1] *CS*	4
		or EEE 120 Digital Design Fundamentals (3)	
ENG	101	First-Year Composition	3
MAT	270	Calculus with Analytic Geometry I *MA*	4
Total			14 or 15

Second Semester

EEE	120	Digital Design Fundamentals[1]	3
		or ECE 100 Introduction to Engineering Design *CS* (4)	
ENG	102	First-Year Composition	3
MAT	271	Calculus with Analytic Geometry II *MA*	4
PHY	121	University Physics I: Mechanics *SQ*[2]	3
PHY	122	University Physics Laboratory I *SQ*[2]	1
Total			15 or 14

Second Year

First Semester

CSE	100	Principles of Programming with C++ *CS*	3
ECN	111	Macroeconomic Principles *SB*	3
		or ECN 112 Microeconomic Principles *SB* (3)	
MAT	272	Calculus with Analytic Geometry III *MA*	4
MAT	274	Elementary Differential Equations *MA*	3
PHY	131	University Physics II: Electricity and Magnetism *SQ*[3]	3
PHY	132	University Physics Laboratory II *SQ*[3]	1
Total			17

Second Semester

ECE	301	Electrical Networks I	4
EEE	225	Assembly Language Programming and Microprocessors (Motorola)	4
		or EEE 226 Assembly Language Programming and Microprocessors (Intel) (4)	
MAT	362	Advanced Mathematics for Engineers and Scientists I	3
PHY	241	University Physics III	3
HU/SB or awareness area course[4]			3
Total			17

Third Year

First Semester

ECE	300	Intermediate Engineering Design *L*	3
EEE	302	Electrical Networks II	3

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

EEE 340	Electromagnetic Engineering I	4
MAT 342	Linear Algebra	3
HU/SB and awareness area course(s)[4]		4
Total		17

Second Semester

ECE 334	Electronic Devices and Instrumentation	4
ECE 352	Properties of Electronic Materials	4
EEE 303	Signals and Systems	3
EEE 360	Energy Conversion and Transport	4
Total		15

Fourth Year

First Semester

ECE 314	Engineering Mechanics	4
EEE 350	Random Signal Analysis	3
HU/SB or awareness area course[4]		3
Technical electives		7
Total		17

Second Semester

EEE 490	Senior Design Laboratory *L*	3
HU/SB or awareness area course[4]		3
Technical electives		10
Total		16

1 Both ECE 100 and EEE 120 are required.

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

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

4 Engineering students may not use aerospace studies (AES) or military science (MIS) courses to satisfy HU or SB requirements.

ELECTRICAL ENGINEERING (EEE)

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

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

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

EEE 294 Special Topics. (1–4) N

EEE 302 Electrical Networks II. (3) F, S, SS
Analysis of linear and nonlinear networks. Analytical and numerical methods. Prerequisite: ECE 301. Pre- or corequisite: MAT 362.

EEE 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.

EEE 340 Electromagnetic Engineering I. (4) 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, 132.

EEE 350 Random Signal Analysis. (3) F, S
Probabilistic and statistical analysis as applied to electrical signals and systems. Pre- or corequisite: EEE 303 or MAE 317.

EEE 360 Energy Conversion and Transport. (4) F, S
Three-phase circuits. Energy supply systems. Magnetic circuit analysis, synchronous generators, transformers, induction and DC machines. Transmission Line Modeling and Design. Lecture, lab. Prerequisite: EEE 302.

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

EEE 407 Digital Signal Processing. (4) 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.

EEE 425 Digital Systems and Circuits. (4) F, S
Digital logic gate analysis and design. Propagation delay times, fan out, power dissipation, noise margins. Design of MOS and bipolar logic families, including NMOS, CMOS, standard and advanced TTL, ECL, and BiCMOS. Inverter, combinational and sequential logic circuit design, MOS memories, VLSI circuits. Computer simulations using PSPICE. Lecture, lab. Prerequisite: ECE 334.

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

EEE 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. Prerequisites: ECE 352; EEE 340.

EEE 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.

EEE 436 Fundamentals of Solid-State Devices. (3) F, S
Semiconductor fundamentals, pn junctions, metal-semiconductor contacts, metal-oxide-semiconductor capacitors and field-effect transistors, bipolar junction transistors. Prerequisite: ECE 352.

EEE 437 Optoelectronics. (3) 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. Prerequisite: EEE 436.

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

EEE 440 Electromagnetic Engineering II. (4) F, S
Second half of an introductory course in electromagnetic theory and its application in electrical engineering. Analytical and numerical solution of boundary value problems. Advanced transmission lines; waveguides; antennas; radiation and scattering. Lecture, lab. Prerequisite: EEE 340 or equivalent.

EEE 443 Antennas. (3) S
Fundamental parameters; engineering principles and radiation integrals; linear wire antennas; loops and arrays; numerical computations; measurements. Prerequisite: EEE 340 or equivalent.

EEE 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 340 or equivalent.

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

EEE 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 350.

EEE 459 Communication Networks. (3) S
Fundamentals of communication networks. Study of Seven-Layer OSI Model. Focus on functionality and performance of protocols used in communication networks. Prerequisite: EEE 350.

EEE 460 Nuclear Concepts for the 21st Century. (3) N
Radiation interactions, damage, dose, and instrumentation. Cosmic rays, satellite effects; soft errors; transmutation doping. Fission reactors, nuclear power. TMI, Chernobyl. Radioactive waste. Prerequisite: PHY 241 or 361.

EEE 463 Electrical Power Plant. (3) F
Nuclear, fossil, and solar energy sources. Analysis and design of steam supply systems, electrical generating systems, and auxiliary systems. Power plant efficiency and operation. Prerequisites: ECE 301, 340 (or PHY 241).

EEE 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.

EEE 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.

EEE 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.

EEE 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.

EEE 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 corequisite: EEE 480.

EEE 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 300, 334; EEE 303; senior status. *General Studies: L.*

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

EEE 507 Multidimensional Signal Processing. (3) F
Processing and representation of multidimensional signals. Design of systems for processing multidimensional data. Introduction to image and array processing issues. Prerequisite: EEE 407 or instructor approval.

EEE 508 Digital Image Processing and Compression. (3) S
Fundamentals of digital image perception, representation, processing, and compression. Emphasis on image coding techniques. Signals include still pictures and motion video. Prerequisites: EEE 350 and 407 *or* equivalents.

EEE 511 Artificial Neural Computation Systems. (3) F
Networks for computation, learning function representations from data, learning algorithms and analysis, function approximation and information representation by networks, applications in control systems and signal analysis. Prerequisite: instructor approval.

EEE 523 Advanced Analog Integrated Circuits. (3) F
Analysis and design of analog integrated circuits: analog circuit blocks, reference circuits, operational-amplifier circuits, feedback, and nonlinear circuits. Prerequisite: EEE 433 or equivalent.

EEE 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.

EEE 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.

EEE 527 Analog to Digital Converters. (3) F
A detailed introduction to the design of Nyquist rate, CMOS analog to digital converters. Prerequisite: EEE 523.

EEE 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.

EEE 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.

EEE 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.

EEE 533 Semiconductor Process/Device Simulation. (3) F
Process simulation concepts, oxidation, ion implantation, diffusion, device simulation concepts, pn junctions, MOS devices, bipolar transistors. Prerequisite: EEE 436 or equivalent.

EEE 534 Semiconductor Transport. (3) S
Carrier transport in semiconductors. Hall effect, high electric field, Boltzmann equation, correlation functions, and carrier-carrier interactions. Prerequisites: EEE 434, 436 (or 531).

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

EEE 537 Semiconductor Optoelectronics I. (3) F
Electronic states in semiconductors, quantum theory of radiation, absorption processes, radiative processes, nonradiative processes, photoluminescence, and photonic devices. Prerequisites: EEE 434, 436 (or 531).

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

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

EEE 541 Electromagnetic Fields and Guided Waves. (3) N
Polarization and magnetization; dielectric, conducting, anisotropic, and semiconducting media; duality, uniqueness, and image theory; plane wave functions, waveguides, resonators, and surface guided waves. Prerequisite: EEE 440 or equivalent.

EEE 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.

EEE 544 High Resolution Radar. (3) N
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.

EEE 545 Microwave Circuit Design. (3) S
Analysis and design of microwave attenuators, in-phase and quadrature-phase power dividers, magic tee's, directional couplers, phase shifters, DC blocks, and equalizers. Prerequisite: EEE 445 or instructor approval.

EEE 546 Advanced Fiber-Optics. (3) N
Theory of propagation in fibers, couplers and connectors, distribution networks, modulation, noise and detection, system design, and fiber sensors. Prerequisite: EEE 448 or instructor approval.

EEE 547 Microwave Solid-State Circuit Design I. (3) S
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.

EEE 548 Coherent Optics. (3) N
Diffraction, lenses, optical processing, holography, electro-optics, and lasers. Prerequisite: EEE 440 or equivalent.

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

EEE 550 Transform Theory and Applications. (3) N
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.

EEE 551 Information and Coding Theory. (3) N
Fundamental theorems of information theory for sources and channels; convolutional and burst codes. Prerequisites: EEE 553, 554.

EEE 552 Digital Communications I. (3) S
Fundamentals of digital communications: complex signal theory; modulation; optimal coherent and incoherent receivers; coded modulation and the Viterbi algorithm. Prerequisites: EEE 455, 554.

EEE 553 Error-Correcting Codes. (3) S
Application of modern algebra to the design of random error-detecting and error-correcting block codes. Prerequisite: EEE 455.

EEE 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 350 or instructor approval.

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

EEE 556 Detection and Estimation Theory. (3) S
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.

EEE 558 Digital Communications II. (3) F
Continuation of EEE 552. Advanced topics in digital communications: synchronization; multipath and fading; equalization; miscellaneous topics. Prerequisite: EEE 552.

EEE 571 Power System Transients. (3) N
Simple switching transients. Transient analysis by deduction. Damping of transients. Capacitor and reactor switching. Transient recovery voltage. Travelling waves on transmission lines. Lightning. Protection of equipment against transient overvoltages. Introduction to computer analysis of transients. Prerequisite: EEE 471.

EEE 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 470.

EEE 573 Electric Power Quality. (3) S
Sinusoidal waveshape maintenance; study of momentary events, power system harmonics, instrumentation, filters, power conditioners, and other power quality enhancement methods. Prerequisite: EEE 360 or equivalent.

EEE 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, numerical integration techniques, stochastic methods, solution of the least squares problem. Prerequisite: EEE 471.

EEE 577 Power Engineering Operations and Planning. (3) F
Economic dispatch, unit commitment, dynamic programming, power system planning and operation, control, generation modeling, AGC, and power production. Prerequisite: EEE 471 or graduate standing.

EEE 579 Power Transmission and Distribution. (3) S
High-voltage transmission line electric design; conductors, corona, RI and TV noise, insulators, clearances. DC characteristic, feeders voltage drop, and capacitors. Prerequisite: EEE 470.

EEE 581 Filtering of Stochastic Processes. (3) 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.

EEE 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.

EEE 584 Internship. (1–12) N

EEE 585 Digital Control Systems. (3) F
Analysis and design of digital and sampled data control systems, including sampling theory, z-transforms, the state transition method, stability, design, and synthesis. Prerequisites: EEE 482, 550.

EEE 586 Nonlinear Control Systems. (3) 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.

EEE 587 Optimal Control. (3) F
Optimal control of systems. Calculus of variations, dynamic programming, linear quadratic regulator, numerical methods, and Pontryagin's principle. Cross-listed as MAE 507. Credit is allowed for only EEE 587 or MAE 507. Prerequisite: EEE 482 or MAE 506.

EEE 588 Design of Multivariable Control Systems. (3) S
Practical tools for designing robust MIMO controllers. State feedback and estimation, model-based compensators, MIMO design methodologies, CAD, real-world applications. Prerequisite: EEE 480 or equivalent.

EEE 606 Adaptive Signal Processing. (3) F
Principles/applications of adaptive signal processing, adaptive linear combiner, Wiener least-squares solution, gradient search, performance surfaces, LMS/RLS algorithms, block time/frequency domain LMS. Prerequisites: EEE 506, 554.

EEE 607 Speech Coding for Multimedia Communications. (3) S
Speech and audio coding algorithms for applications in wireless communications and multimedia computing. Prerequisite: EEE 407. Pre- or corequisite: EEE 506.

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

EEE 632 Heterojunction Devices. (3) N
Applications of heterostructures, quantum wells, and superlattice to modulation-doped FETs, heterostructure bipolar transistors, lasers, detectors, and modulators. Prerequisites: EEE 434 and 631 (or 537).

EEE 641 Advanced Electromagnetic Field Theory. (3) N
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.

EEE 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.

EEE 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.

EEE 686 Adaptive Control. (3) N
Main topics covered: adaptive identification, convergence, parametric models, performance and robustness properties of adaptive controllers, persistence of excitation, and stability. Prerequisites: EEE 582 and 586 *or* instructor approval.

EEE 731 Advanced MOS Devices. (3) S
Threshold voltage, subthreshold current, scaling, small geometry effects, hot electrons, and alternative structures. Prerequisite: EEE 531.

EEE 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.

Department of Industrial Engineering

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PROFESSORS
DOOLEY, HENDERSON, HOGG, HUBELE, KEATS, MONTGOMERY, WOLFE

ASSOCIATE PROFESSORS
ANDERSON-ROWLAND, COCHRAN, MACKULAK, MOOR, ROBERTS, ROLLIER, RUNGER, SHUNK, VILLALOBOS, YE

ASSISTANT PROFESSORS
CARLYLE, FOWLER, MOU, SENTURK

The industrial engineer (IE) provides leadership for American organizations in reestablishing competitiveness in the global marketplace through system integration and productivity improvement. No challenge can be greater than improving productivity, which is the application of knowledge and skills to provide improved goods and services to enhance the quality of life, both on and off the job. This improvement must be achieved without waste of physical and human resources while maintaining the environmental balance. Industrial engineers are the “productivity people” who provide the necessary leadership and skills to integrate technology. This gives IEs a wide range of interests and responsibilities.

As in other engineering fields, industrial engineering is concerned with solving problems through the application of scientific and practical knowledge. What sets industrial engineering apart from other engineering disciplines is its broader scope. An IE relates to the total picture of productivity. An IE looks at the “big picture” of what makes society perform best—the right combination of human resources, natural resources, synthetic structures, and equipment. An IE bridges the gap between management and operations, dealing with and motivating people as well as determining what tools should be used and how they should be used.

An IE deals with people as well as things. In fact, industrial engineering is often called the “people-oriented profession.” It is a primary function of the IE to integrate people and technology-oriented systems. Therefore, IEs are active in the fields of ergonomics and human factors.

To be competitive in this global economy, it is essential to emphasize and continually improve the quality of goods and services. Industrial engineering is the only engineering discipline offering course work in designing and implementing quality assurance systems.

The IE’s skills are applicable to every kind of organization. IEs learn how to approach, think about, and solve productivity and integration problems regardless of their settings. IEs work in manufacturing facilities, banks, hospitals, government, transportation, construction, and social services. Within this wide variety of organizations, IEs get involved in projects such as designing and implementing quality control systems, independent work groups, the work flow in a medical laboratory, real-time production control systems, computer-based management information systems, and manufacturing operating systems, to name a few. A unique feature of most industrial engineering assignments is that they involve interdisciplinary teams. For example, the IE might be the leader of a team consisting of electrical and mechanical engineers, accountants, computer scientists, and planners. This IE program gives the student the skills necessary to direct these teams. These skills include team building, brainstorming, group dynamics, and interpersonal relationships.

IEs have a sound background in technology integration, management theory and application, engineering economics and cost analysis. They are well equipped to deal with problems never seen before, making them prime candidates for promotion through the management career path, especially in high-tech organizations. In fact, more than half of all practicing IEs are in management positions. This area of expertise has placed the IE in the leadership role in the establishment of a new field of activity called “management of technology.”

Industrial engineers are well trained in the development and use of analytical tools, and their most distinctive skill is in the area of model building. IEs must quickly learn and understand the problems of their clients. In this context, good people skills and good analytic skills are essential. This industrial engineering program offers both.

INDUSTRIAL ENGINEERING—B.S.E.

The curriculum in Industrial Engineering builds upon mathematics, computer programming, and the engineering core. Beyond this foundation, the curriculum includes a number of required IE core courses, IE electives, and study area electives, enabling students to focus on a specific career objective.

By successfully completing this curriculum, the student is prepared to embark on a career in industrial engineering or to pursue advanced education in graduate school.

The career-focused study-areas are as follows:

1. Industrial and management systems: For a broad traditional IE career in the design and analysis of manufacturing and service systems.
2. Information and telecommunication systems: For a career in the application of integrated computer and telecommunication systems to manufacturing and service systems analysis and design.
3. Global industrial engineering leadership: For a career in global manufacturing and service organizations.
4. High-tech manufacturing: For a career in the design and analysis of integrated manufacturing systems.
5. Preprofessional and service systems: For a career in law, medicine or public service or careers in the design and analysis of health care, agribusiness,

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banking/financial, and government/public-administration systems.

Degree Requirements

A minimum of 128 semester hours is necessary for the B.S.E. degree in Industrial Engineering, including a minimum of 50 upper-division semester hours.

Graduation Requirements

To graduate, a student must satisfy all university, college, and department requirements. See "University Graduation Requirements," page 83, and "College Degree Requirements," page 198.

Course Requirements

Students take 60 semester hours of university English proficiency and general studies course work, 20 hours of engineering core, 30 hours of industrial engineering courses, six hours of industrial engineering electives, and 12 hours of career-focused study area electives. Each study area has an associated list of recommended general studies, IE electives, and study area courses. The course work for the undergraduate degree can be classified into the following categories:

First-Year Composition

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

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 112 Microeconomic Principles *SB* 3
HU courses 6–10
SB courses 3–7

Minimum total 16

Literacy and Critical Inquiry

ECE 300 Intermediate Engineering Design *L* 3
Approved IE L course 3

Total 6

Natural Sciences/Basic Sciences

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

Total 15

Numeracy/Mathematics

MAT 242 Elementary Linear Algebra 2
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 17
General Studies/school requirements total 54

Engineering Core

ECE 100 Introduction to Engineering Design *CS* 4
ECE 210 Engineering Mechanics I: Statics 3
ECE 301 Electrical Networks I 4
ECE 312 Engineering Mechanics II: Dynamics 3
ECE 350 Structure and Properties of Materials 3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3

Total 20

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

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

Industrial Engineering Major

The following courses are required:

ASE 485 Engineering Statistics *CS* 3
CSE 100 Principles of Programming with C++ *CS* 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
IEE 300 Economic Analysis for Engineers 3
IEE 368 Facilities Analysis and Design 3
IEE 374 Quality Control *CS* 3
IEE 461 Production Control 3
IEE 475 Simulating Stochastic Systems *CS* 3
IEE 476 Operations Research Techniques/Applications *CS* 4
IEE 494 ST: Industrial Engineering Applications Seminar 2

Total 30

Industrial Engineering Electives Area

Students select six semester hours of industrial engineering electives. For course information, see the list of recommended courses in the department advising office.

Career-Focused Study Area Electives

Students select a minimum of 12 semester hours from the following recommended electives in one of the five career-focused study areas:

Global Industrial Engineering Leadership

ECN 306 Survey of International Economics *SB, G* 3
IBS 300 Principles of International Business *G* 3
IBS 400 Cultural Factors in International Business *C, G* 3
Any approved international business elective 3

High-Tech Manufacturing

ECE 352 Properties of Electronic Materials 4
EEE 435 Microelectronics 3
EEE 436 Fundamentals of Solid-State Devices 3
MSE 335 Introduction to Materials Science and Engineering 3
MSE 441 Analysis of Materials Failure 3
MSE 470 Polymers and Composites 3

Industrial and Management Systems

IEE 305 Information Systems Engineering *CS* 3
IEE 360 Manufacturing Processes 3
IEE 361 Manufacturing Processes Lab 1
IEE 431 Engineering Administration 3
Any approved engineering or business elective 3

Information and Telecommunication Systems

CSE 200 Concepts of Computer Science *CS* 3
CSE 210 Object-Oriented Design and Data Structure 3
CSE 240 Introduction to Programming Languages 3
IEE 305 Information Systems Engineering *CS* 3

Preprofessional and Service Systems

Agribusiness Systems

AGB 340 Food Processing 3
AGB 341 Food Analysis 3
AGB 351 Management Science *CS* 3
AGB 364 Agribusiness Technologies I 3

AGB 414 Agribusiness Analysis *L* 3
AGB 440 Food Safety 3
AGB 442 Food and Industrial Microbiology 3

Banking and Financial Systems
FIN 300 Fundamentals of Finance 3
FIN 331 Financial Markets and Institutions 3
FIN 361 Managerial Financing 3
FIN 431 Management of Financial Institutions 3

Government and Public Administration Systems
POS 310 American National Government *SB* 3
POS 316 State and Local Government *SB* 3
POS 320 Public Administration *SB* 3
POS 333 Interest Groups *SB* 3

Health Care Systems
HSA 473 Comparative Health Systems 3
HSA 498 PS: Health Care Finance 3
HSA 498 PS: Health Economics 3
HSA 498 PS: Health Service Administration and Policy 3
HSA 498 PS: Policy Issues in Health Care 3

Prelaw Systems
AGB 456 World Agricultural Resources *G* 3
AJS 360 Substantive Criminal Law (ASU West) 3
COM 422 Advanced Argumentation 3
GLB 300 Gateway to Global Business (ASU West) 3
LES 306 Business Law 3
POL 470 Law and Political Order (ASU West) 3

Premedicine Systems
BIO 181 General Biology *SQ* 4
BIO 182 General Biology *SG* 4
BIO 351 Developmental Anatomy 3
CHM 331 General Organic Chemistry 3
CHM 332 General Organic Chemistry 3
CHM 335 General Organic Chemistry Lab 1
CHM 336 General Organic Chemistry Lab 1

Industrial Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester
CHM 114 General Chemistry for Engineers *SQ* 4
or CHM 116 General Chemistry *SQ*[1]
ECE 100 Introduction to Engineering Design *CS* 4
or HU/SB elective (4)[2]
ENG 101 First-Year Composition 3
MAT 270 Calculus with Analytic Geometry I *MA* 4

Total 15

Second Semester
ECN 112 Microeconomic Principles *SB* 3
ENG 102 First-Year Composition 3
MAT 271 Calculus with Analytic Geometry II *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[3] 3
PHY 122 University Physics Laboratory I *SQ*[3] 1
HU/SB elective[2] 3
or ECE 100 Introduction to Engineering Design *CS* (4)

Total 17

Second Year

First Semester
CSE 100 Principles of Programming with C++ *CS* 3
IEE 300 Economic Analysis for Engineers 3
MAT 242 Elementary Linear Algebra 2
MAT 272 Calculus with Analytic Geometry III *MA* 4
PHY 131 University Physics II: Electricity and Magnetism *SQ*[4] 3
PHY 132 University Physics Laboratory II *SQ*[4] 1

Total 16

Second Semester
ECE 210 Engineering Mechanics I: Statics 3
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3
IEE 494 ST: Industrial Engineering Applications Seminar 2
MAT 274 Elementary Differential Equations *MA* 3
Basic science elective[5] 3

Total 17

Third Year

First Semester
ASE 485 Engineering Statistics *CS* 3
IEE 368 Facilities Analysis and Design 3
IEE 374 Quality Control *CS* 3
HU/SB elective[2] 4
Industrial Engineering elective 3

Total 16

Second Semester
ECE 300 Intermediate Engineering Design *L* 3
ECE 312 Engineering Mechanics II: Dynamics 3
ECE 350 Structure and Properties of Materials 3
IEE 476 Operations Research Techniques/Applications *CS* 4
Study area elective 3

Total 16

Fourth Year

First Semester
ECE 301 Electrical Networks I 4
IEE 461 Production Control 3
IEE 475 Simulating Stochastic Systems *CS* 3
HU/SB elective[2] 3
Industrial Engineering elective 3

Total 16

Second Semester
HU/SB elective[2] 3
Senior Capstone *L* 3
Study area electives 9

Total 15

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1 Students who have taken no high school chemistry should take CHM 113 and 116.
2 Engineering students may not use aerospace studies (AES) or military science (MIS) courses to satisfy HU or SB requirements.
3 Both PHY 121 and 122 must be taken to secure SQ credit.
4 Both PHY 131 and 132 must be taken to secure SQ credit.
5 Must be an earth science or life science course; if physics or chemistry, the course must be of a more advanced level than CHM 114 or 116 or PHY 131.

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

INDUSTRIAL ENGINEERING (IEE)

IEE 300 Economic Analysis for Engineers. (3) F, S
Economic evaluation of alternatives for engineering decisions, emphasizing the time value of money. Prerequisites: ECE 100; MAT 270.

IEE 305 Information Systems Engineering. (3) F
Emphasis on systems analysis, design and implementation of information systems using fourth generation languages and alternative data base structures. Prerequisite: CSE 100. *General Studies: CS.*

IEE 360 Manufacturing Processes. (3) F, S
Production technique and equipment. Casting and molding, forming, machining, joining and assembly, computer-integrated manufacturing, rapid prototyping, and electronics manufacturing. Cross-listed as MAE 351. Credit is allowed for only IEE 360 or MAE 351. Prerequisite: ECE 350.

IEE 361 Manufacturing Processes Lab. (1) F, S
Series of labs designed to illustrate concepts presented in IEE 360 on production technique and equipment. Corequisite: IEE 360 (or MAE 351).

IEE 368 Facilities Analysis and Design. (3) F
Planning analysis and design of methods of the tangible physical assets of the firm. Emphasis on facilities location, materials handling, automation, computer integration, and utilization of financial resources. Applications in diverse fields. Lecture, lab. Prerequisite: IEE 300.

IEE 369 Work Analysis and Design. (3) S
Planning analysis and design of methods of accomplishing work. Emphasis on human factors, work planning, methods analysis and design, and work measurement. Applications in diverse fields. Lecture, lab.

IEE 374 Quality Control. (3) F
Control charting and other statistical process control techniques. Organization and managerial aspects of quality assurance, plus acceptance sampling plans. Prerequisite: ECE 380. *General Studies: CS.*

IEE 431 Engineering Administration. (3) F
Introducing quantitative and qualitative approaches to management functions, engineering administration, organizational analysis, decision making, and communication. Prerequisite: senior standing.

IEE 437 Human Factors Engineering. (3) F
Study of the human psychological and physiological factors that underlie the design of equipment and the interaction between people and machines.

IEE 461 Production Control. (3) F
Techniques for the planning, control, and evaluation of production systems. Project management, forecasting, inventory control, scheduling, enterprise requirements planning. Prerequisites: ASE 485; CSE 100; IEE 476.

IEE 463 Computer-Aided Manufacturing and Control. (3) S
Computer control in manufacturing, CIM, NC, logic controllers, group technology, process planning and robotics. Prerequisite: C programming capability. *General Studies: CS.*

IEE 475 Simulating Stochastic Systems. (3) F, S
Analysis of stochastic systems using basic queuing networks and discrete event simulation. Basic network modeling, shared resources, routing, assembly logic. Not open to students with credit in IEE 545. Prerequisites: ASE 485; CSE 100; IEE 476. *General Studies: CS.*

IEE 476 Operations Research Techniques/Applications. (4) F, S
Industrial systems applications with operations research techniques. Resource allocation, product mix, production, shipping, task assignment, market share, machine repair, customer service. Not open to students with credit in IEE 546. Prerequisites: ASE 485; CSE 100. *General Studies: CS.*

IEE 490 Project in Design and Development. (3) F, S
Individual or team capstone project in creative design and synthesis. Prerequisite: senior standing.

IEE 494 Special Topics. (2) N
(a) Industrial Engineering Applications Seminar

IEE 505 Applications Engineering. (3) F
Develop working knowledge of application systems development tools needed for computer integrated enterprise. Includes techniques for application generation in fourth and fifth generation software environments. Topics include client server network systems, decision support systems, and transaction systems in distributed environment.

IEE 511 Analysis of Decision Processes. (3) S
Methods of making decisions in complex environments and statistical decision theory; effects of risk, uncertainty, and strategy on engineering and managerial decisions. Prerequisite: ECE 380.

IEE 520 Ergonomics Design. (3) S
Human physiological and psychological factors in the design of work environments and in the employment of people in man-machine systems. Open-shop lab assignments in addition to class work. Prerequisite: IEE 437 or 547.

IEE 530 Enterprise Modeling. (3) S
Focus on social, economic, and technical models of the enterprise with emphasis on the management of technological resources. Included are organization, econometric, financial, and large-scale mathematical models.

IEE 531 Topics in Engineering Administration. (3) S 2002
Consideration given to philosophical, psychological, political, and social implications of administrative decisions. Prerequisite: IEE 532 or instructor approval.

IEE 532 Management of Technology. (3) F
Topics include designing a technical strategy; technological forecasting; interfacing marketing engineering and manufacturing; designing and managing innovation systems; creativity; application of basic management principles to technology management. Prerequisite: IEE 431 or 541 or instructor approval.

IEE 533 Scheduling and Network Analysis Models. (3) S
Application of scheduling and sequencing algorithms, deterministic and stochastic network analysis, and flow algorithms. Prerequisites: ECE 380; IEE 476 (or 546).

IEE 541 Engineering Administration. (3) F
Introducing quantitative and qualitative approaches to management functions, engineering administration, organizational analysis, decision making, and communication. IEE 431 students ineligible.

IEE 543 Computer-Aided Manufacturing and Control. (3) S
Computer control in manufacturing, CIM, NC, logic controllers, group technology, process planning and robotics. IEE 463 students ineligible. Prerequisite: C programming capability.

IEE 545 Simulating Stochastic Systems. (3) F, S
Analysis of stochastic systems using basic queuing networks and discrete event simulation. Basic network modeling, shared resources, routing, assembly logic. Not open to students with credit in IEE 475. Prerequisites: ASE 485; CSE 100 (or equivalent); IEE 476 (or 546).

IEE 546 Operations Research Techniques/Applications. (4) F, S
Students model and analyze industrial systems applications with operations research techniques. Resource allocation, product mix, production, shipping, task assignment, market share, machine repair, customer service. Not open to students with credit in IEE 476. Prerequisites: ASE 485; CSE 100.

IEE 547 Human Factors Engineering. (3) F
Study of people at work; designing for human performance effectiveness and productivity. Considerations of human physiological and psychological factors. Open only to students without previous credit for IEE 437.

IEE 552 Strategic Technological Planning. (3) S
Study of concept of strategy, strategy formulation process, and strategic planning methodologies with emphasis on engineering design and manufacturing strategy, complemented with case studies. An analytical executive planning decision support system is presented and used throughout course. Pre- or corequisite: IEE 545 or 566 or 567 or 574 or 575.

IEE 560 Object-Oriented Information Systems. (3) S
Application of object-oriented technology concepts to manufacturing and enterprise systems. Topics include Java, object management systems, and application design. Prerequisites: CSE 100; IEE 305 or 505; *or* equivalents.

IEE 561 Production Systems. (3) F, S
Understanding how factories operate, how performance is measured, and how operational changes impact performance metrics. Operational philosophies, increasing production efficiency through quantitative methods. Prerequisites: ASE 485 (or equivalent); IEE 475, 476.

IEE 562 Computer-Aided Manufacturing (CAM) Tools. (3) F
Current topics in automation, distributed control, control code generation, control logic validation, CAM integration, CAD/CAM data structures, planning for control systems. Topics vary by semester. Prerequisite: IEE 463 or 543 or equivalent.

IEE 563 Systems Analysis for Distributed Systems. (3) S
Analysis and design of distributed groupware applications for manufacturing and enterprise systems. Prerequisite: ECE 380.

IEE 564 Planning for Computer-Integrated Manufacturing. (3) F
Theory and use of IDEF methodology in planning for flexible manufacturing, robotics, and real-time control. Simulation concepts applied to computer-integrated manufacturing planning. Prerequisite: IEE 463 or 543.

IEE 565 Computer-Integrated Manufacturing Research. (3) S
Determination and evaluation of research areas in computer-integrated manufacturing, including real-time software, manufacturing information systems, flexible and integrated manufacturing systems, robotics, and computer graphics. Prerequisite: IEE 564.

IEE 566 Simulation in Manufacturing. (3) S
Use of simulation in computer-integrated manufacturing with an emphasis on modeling material handling systems. Programming, declarative, and intelligence-based simulation environments. Prerequisite: IEE 545.

IEE 567 Simulation System Analysis. (3) F
Simulation modeling of processes involving discrete and continuous system components. Topics include random number generators, output analysis, variance reduction, and statistical issues related to simulation. Prerequisite: IEE 545.

IEE 569 Advanced Statistical Methods. (3) F 2000
Application of statistical inference procedures, based on ranks, to engineering problems. Efficient alternatives to classical statistical inference constrained by normality assumptions. Prerequisite: ASE 485 or 500.

IEE 570 Advanced Quality Control. (3) S
Economic-based acceptance sampling, multiattribute acceptance sampling, narrow limit gauging in inspector error and attributes acceptance sampling, principles of quality management, and selected topics from current literature. Prerequisite: ASE 485 or 500 or equivalent.

IEE 571 Quality Management. (3) F
Total quality concepts, quality strategies, quality and competitive position, quality costs, vendor relations, the quality manual, and quality in the services. Prerequisite: IEE 431 or 541.

IEE 572 Design of Engineering Experiments. (3) F, S
Analysis of variance and experimental design. Topics include general design methodology, incomplete blocks, confounding, fractional replication, and response surface methodology. Prerequisite: ASE 485 or 500.

IEE 573 Reliability Engineering. (3) S
Nature of reliability, time to failure densities, series/parallel/standby systems, complex system reliability, Bayesian reliability, and sequential reliability tests. Prerequisite: ECE 380.

IEE 574 Applied Deterministic Operations Research Models. (3) F, S
Advanced techniques in operations research are developed for the solution of complex industrial systems problems. Goal programming, integer programming, heuristic methods, dynamic and nonlinear programming. Prerequisites: IEE 476 (or 546); MAT 242.

IEE 575 Applied Stochastic Operations Research Models. (3) S
Students formulate and solve industrial systems problems with stochastic components using analytical techniques. Convolution, continuous-time Markov chains, queues with batching, priorities, balking, open/closed queuing networks. Prerequisites: ASE 485; IEE 476 (or 546).

IEE 577 Decision and Expert Systems Methodologies. (3) F
Application of artificial intelligence methodologies in decision support systems. Topics include neural networks, fuzzy logic systems, and expert systems. Prerequisite: CSE 100 or equivalent.

IEE 578 Regression Analysis. (3) F
A course in regression model building oriented toward engineers/physical scientists. Topics include linear regression, diagnostics biased and robust fitting, nonlinear regression. Prerequisite: ASE 485 or 500.

IEE 579 Time Series Analysis and Forecasting. (3) F 2001
Forecasting time series by the Box-Jenkins and exponential smoothing techniques; existing digital computer programs are utilized to augment the theory. Prerequisites: ASE 485 (or 500); IEE 461.

IEE 582 Response Surfaces and Process Optimization. (3) S
An introduction to response surface method and its applications. Topics include steepest ascent, canonical analysis, designs, and optimality criteria. Prerequisite: IEE 572.

IEE 591 Seminar. (1–12) N
(a) Effects of Economics/New Products Market
(b) Manufacturing Strategy
(c) New Product Strategy
(d) Strategic Product Development

IEE 672 Advanced Topics in Experimental Design. (3) S 2002
Engineering applications of factorial and fractional factorial designs with randomization restrictions, analysis techniques in parameter comparison, missing data, unbalanced designs. Prerequisite: IEE 572 or instructor approval.

IEE 677 Regression and Linear Models. (3) S 2001
General linear models, applications, theory, including least squares, maximum likelihood estimation, properties of estimators, likelihood ratio tests and computational procedures. Prerequisite: IEE 578 or instructor approval.

IEE 679 Time Series Analysis and Control. (3) F 2000
Identification, estimation, diagnostic checking techniques for ARIMA models, transfer functions, multiple time series models for feedback and feedforward control schemes. Prerequisite: IEE 579 or instructor approval.

IEE 681 Reliability, Availability, and Serviceability. (3) F 2000
Organizing hardware and software, integrity and fault-tolerant design, maintenance design and strategy, Markov models, fault-free analysis, and military standards. Prerequisite: ECE 380.

Department of Mechanical and Aerospace Engineering

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PROFESSORS
BOYER, CHATTOPADHYAY, DAVIDSON, EVANS, FERNANDO, JANKOWSKI, KRAJCINOVIC, LAANANEN, LIU, PECK, REED, ROY, SARIC, SHAH, SIERADZKI, TSENG, WIE, YAO

ASSOCIATE PROFESSORS
CHEN, KOURIS, KUO, LEE, MIGNOLET, PHELAN, RANKIN, SQUIRES, WELLS

ASSISTANT PROFESSORS
CHAPSKY, FUSSELL, McNEILL, PERALTA, SUGAR

The Department of Mechanical and Aerospace Engineering is the administrative home for two undergraduate majors: Aerospace Engineering and Mechanical Engineering.

Both majors build on the broad exposure to the engineering, chemical, and physical sciences and the mathematics embodied in the General Studies and engineering core courses required of all engineering students.

The Aerospace Engineering major provides students an education in technological areas critical to the design and development of aerospace vehicles and systems. Aerospace

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

Engineering graduates are typically employed at government laboratories (e.g., NASA) and in a wide range of aerospace and mechanical industries. The Mechanical Engineering major is perhaps one of the most broadly applicable programs in engineering, providing education for a wide variety of employment opportunities.

The two majors, discussed in more detail below, can serve as entry points to immediate professional employment or to graduate study. The emphasis in all fields is on the development of fundamental knowledge that will have long-lasting utility in our rapidly changing technical society.

DEGREE REQUIREMENTS

All degree programs in the department require that students attain a minimum GPA of 2.00 in the engineering core and in the major and take a minimum of 50 upper-division semester hours in order to be eligible for graduation. Also, the department may require additional or remedial course work for those students who have demonstrated a trend toward academic difficulties.

GRADUATION REQUIREMENTS

In addition to fulfilling school and major requirements, majors must satisfy all university graduation requirements. See "University Graduation Requirements," page 83.

COURSE REQUIREMENTS

General Studies

See "Course Requirements," page 207, for General Studies, school, and engineering core course requirements.

Engineering Core

Students in the Department of Mechanical and Aerospace Engineering are required to take the following from among the choices listed on page 208 as part of the engineering core requirements:

ECE	100	Introduction to Engineering Design *CS*	4
ECE	210	Engineering Mechanics I: Statics	3
ECE	300	Intermediate Engineering Design *L*	3
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	350	Structure and Properties of Materials	3
Total			26

AEROSPACE ENGINEERING—B.S.E.

The goal of the Aerospace Engineering program is to provide students with an education in technological areas critical to the design and development of aerospace vehicles and systems. The program emphasizes aeronautical engineering with topics in required courses covering aerodynamics, aerospace materials, aerospace structures, propulsion, flight mechanics, aircraft performance, and stability and control. Astronautic topics such as orbital mechanics, attitude dynamics, spacecraft control, and rocket propulsion are also covered in required courses.

Design is integrated throughout the curriculum beginning with ECE 100 Introduction to Engineering Design and followed later by ECE 300 Intermediate Engineering Design, both of which focus on basic design theory as well as professional practice. These required courses are followed by topic-specific design content in aerospace engineering courses in the junior and senior years. The senior capstone design course integrates design and analysis topics from the earlier courses and completes the required design sequence. This sequence includes a minimum of 20 semester hours of required design. In addition, many of the aerospace technical electives have design content.

Laboratory experience is provided in the areas of aerodynamics, aerospace structures, and vibrations. Laboratory facilities include four major wind tunnels, an integrated mechanical-testing laboratory, a controls laboratory, and a vibrations laboratory.

Aerospace Engineering Major

Aerospace Engineering students are required to take the following two courses in addition to those required for the major:

MAT	242	Elementary Linear Algebra	2
PHY	361	Introductory Modern Physics	3

The Aerospace Engineering major consists of the following courses:

ECE	384	Numerical Analysis for Engineers I	2
ECE	386	Partial Differential Equations for Engineers	2
EEE	350	Random Signal Analysis	3
MAE	317	Dynamic Systems and Control	3
MAE	361	Aerodynamics I	3
MAE	413	Aircraft Performance, Stability, and Control	3
MAE	415	Vibration Analysis	4
MAE	425	Aerospace Structures	4
MAE	444	Fundamentals of Aerospace Design	3
MAE	460	Gas Dynamics	3
MAE	462	Space Vehicle Dynamics and Control	3
MAE	463	Propulsion	3
MAE	464	Aerospace Laboratory	3
MAE	468	Aerospace Systems Design *L*	3
Area of emphasis (technical electives)			6
Total			48

Aerospace Engineering Areas of Study

To further the design experience, all Aerospace Engineering students must choose at least one technical elective from the following list of courses:

MAE	426	Design of Aerospace Structures	3
MAE	461	Aerodynamics II	3
MAE	465	Rocket Propulsion	3
MAE	466	Rotary Wing Aerodynamics and Performance	3
MAE	467	Aircraft Performance	3
MAE	469	Projects in Astronautics and Aeronautics	3

The remaining technical elective(s) may be selected from among any of the courses listed in the following course tables or from courses listed under the Mechanical Engineering areas of study. The courses are grouped so that the student may select an elective package of closely related courses. A student may, with prior approval of the advisor and department, select a general area and a corresponding set of courses not listed that would support a career objective not covered by the categories shown below. *Note:* MAE 371 may *not* be substituted for MAE 361, and MAE 422 may *not* be substituted for MAE 425.

Aerodynamics. Select from these courses:

MAE	372	Fluid Mechanics	3
MAE	435	Turbomachinery	3

MAE 461 Aerodynamics II....3
MAE 463 Propulsion....3
MAE 466 Rotary Wing Aerodynamics and Performance....3
MAE 471 Computational Fluid Dynamics....3
MAE 490 Projects in Design and Development *L*....3
MAT 421 Applied Computational Methods *CS*....3

Aerospace Materials. Select from these courses:

MAE 455 Polymers and Composites....3
MSE 355 Introduction to Materials Science and Engineering....3
MSE 420 Physical Metallurgy....3
MSE 440 Mechanical Properties of Solids....3
MSE 441 Analysis of Material Failures....3
MSE 450 X-ray and Electron Diffraction....3
MSE 471 Introduction to Ceramics....3

Aerospace Structures. Select from these courses:

MAE 404 Finite Elements in Engineering....3
MAE 426 Design of Aerospace Structures....3
MAE 455 Polymers and Composites....3
MAE 490 Projects in Design and Development *L*....3

Computer Methods. Select from these courses:

ASE 485 Engineering Statistics *CS*....3
CSE 310 Data Structures and Algorithms....3
CSE 422 Microprocessor System Design II....4
CSE 428 Computer-Aided Processes....3
IEE 463 Computer-Aided Manufacturing and Control *CS*....3
IEE 475 Simulating Stochastic Systems *CS*....3
MAE 404 Finite Elements in Engineering....3
MAE 406 CAD/CAM Applications in MAE....4
MAE 471 Computational Fluid Dynamics....3
MAE 541 CAD Tools for Engineers....3
MAT 421 Applied Computational Methods *CS*....3
MAT 423 Numerical Analysis I *CS*....3
MAT 425 Numerical Analysis II *CS*....3

Design. Select from these courses:

MAE 341 Mechanism Analysis and Design....3
MAE 404 Finite Elements in Engineering....3
MAE 406 CAD/CAM Applications in MAE....4
MAE 426 Design of Aerospace Structures....3
MAE 435 Turbomachinery....3
MAE 442 Mechanical Systems Design....3
MAE 446 Thermal Systems Design....3
MAE 455 Polymers and Composites....3
MAE 466 Rotary Wing Aerodynamics and Performance....3
MAE 467 Aircraft Performance....3
MAE 490 Projects in Design and Development *L*....3
MSE 440 Mechanical Properties of Solids....3
MSE 441 Analysis of Material Failures....3

Mechanical. Any courses listed under the Mechanical Engineering concentrations except MAE 371 and 422 may be selected.

Propulsion. Select from these courses:

MAE 382 Thermodynamics....3
MAE 388 Heat Transfer....3
MAE 434 Internal Combustion Engines....3
MAE 435 Turbomachinery....3
MAE 436 Combustion....3
MAE 461 Aerodynamics II....3
MAE 465 Rocket Propulsion....3
MAE 466 Rotary Wing Aerodynamics and Performance....3
MAE 471 Computational Fluid Dynamics....3
MAE 490 Projects in Design and Development *L*....3

System Dynamics and Control. Select from these courses:

CSE 428 Computer-Aided Processes....3
EEE 480 Feedback Systems....4
EEE 482 Introduction to State Space Methods....3
MAE 417 Control System Design....3
MAE 447 Robotics and Its Influence on Design....3
MAE 469 Projects in Astronautics or Aeronautics....3
MAE 490 Projects in Design and Development *L*....3

TYPICAL FOUR-YEAR SEQUENCE

The first two years are usually devoted to the General Studies and engineering core requirements. Thus, the degree programs in the department share essentially the same course schedule for that period of time. A typical schedule is given below.

Aerospace Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM 114 General Chemistry for Engineers *SQ*....4
or CHM 116 General Chemistry *SQ* (4)
ECE 100 Introduction to Engineering Design *CS*....4
or HU/SB elective[1]
ENG 101 First-Year Composition....3
MAT 270 Calculus with Analytic Geometry I *MA*....4

Total....15

Second Semester

ENG 102 First-Year Composition....3
MAT 242 Elementary Linear Algebra....2
MAT 271 Calculus with Analytic Geometry II *MA*....4
PHY 121 University Physics I: Mechanics *SQ*[2]....3
PHY 122 University Physics Laboratory I *SQ*[2]....1
HU/SB and awareness area course[1]....3
or ECE 100 Introduction to Engineering Design *CS* (4)

Total....16

Second Year

First Semester

ECE 210 Engineering Mechanics I: Statics....3
ECE 350 Structure and Properties of Materials....3
MAT 272 Calculus with Analytic Geometry III *MA*....4
MAT 274 Elementary Differential Equations *MA*....3
PHY 131 University Physics II: Electricity and Magnetism *SQ*[3]....3
PHY 132 University Physics Laboratory II *SQ*[3]....1

Total....17

Second Semester

ECE 301 Electrical Networks I....4
ECE 312 Engineering Mechanics II: Dynamics....3
ECE 313 Introduction to Deformable Solids....3
ECE 340 Thermodynamics....3
ECE 384 Numerical Analysis for Engineers I....2
ECE 386 Partial Differential Equations for Engineers....2

Total....17

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

Third Year

First Semester

ECE 300	Intermediate Engineering Design *L*	3
MAE 317	Dynamic Systems and Control	3
MAE 361	Aerodynamics I	3
MAE 425	Aerospace Structures	4
HU, SB, or awareness area course[1]		3
Total		16

Second Semester

EEE 350	Random Signal Analysis	3
MAE 413	Aircraft Performance, Stability, and Control	3
MAE 444	Fundamentals of Aerospace Design	3
MAE 460	Gas Dynamics	3
HU, SB, or awareness area course[1]		3
Total		15

Fourth Year

First Semester

MAE 415	Vibration Analysis	4
MAE 462	Space Vehicle Dynamics and Control	3
MAE 463	Propulsion	3
PHY 361	Introductory Modern Physics	3
Required design technical elective		3
Total		16

Second Semester

MAE 464	Aerospace Laboratory	3
MAE 468	Aerospace Systems Design *L*	3
Technical electives		3
HU, SB, and awareness area courses[1]		7
Total		16

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

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

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

MECHANICAL ENGINEERING—B.S.E.

Mechanical engineering is a creative discipline that draws upon a number of basic sciences to design the devices, machines, processes, and systems that involve mechanical work and its conversion from and into other forms. It includes: the conversion of thermal, chemical, and nuclear energy into mechanical energy through various engines and power plants; the transport of energy via devices like heat exchangers, pipelines, gears, and linkages; the use of energy to perform a variety of tasks for the benefit of society, such as in transportation vehicles of all types, manufacturing tools and equipment, and household appliances. Furthermore, since all hardware products must be constructed of solid materials and because most products contain parts that transmit forces, mechanical engineering is involved in the structural integrity and materials selection for almost every product on the market.

Mechanical engineers are employed in virtually every kind of industry. They are involved with seeking new knowledge through research, with doing creative design and development, and with the production, control, management, and sales of the devices and systems needed by society. Therefore, a major strength of a mechanical engineering education is the flexibility it provides in future employment opportunities for its graduates.

The undergraduate curriculum includes the study of the principles governing the use of energy; the principles of design, instruments and control devices; and the application of these studies to the creative solution of practical, modern problems.

Design is integrated throughout the curriculum, beginning with ECE 100 Introduction to Engineering Design and followed later by ECE 300 Intermediate Engineering Design, both of which focus on basic design theory as well as professional practice. These required courses are followed by topic specific design content in mechanical engineering courses in the junior and senior years. The senior capstone design course combines the design topics from the earlier courses and completes the required design sequence. In addition, many of the mechanical technical electives have design content.

Laboratory experience is provided in the areas of thermofluid systems, mechanics of materials, and controls. Laboratory facilities include a thermal systems laboratory, an integrated mechanical-testing laboratory, a controls laboratory, and a manufacturing laboratory.

Mechanical Engineering Major

Mechanical Engineering students are required to select the following supplemental courses:

ECE 384	Numerical Analysis for Engineers I	2
ECE 386	Partial Differential Equations for Engineers	2
EEE 350	Random Signal Analysis	3
MAT 242	Elementary Linear Algebra	2
PHY 361	Introductory Modern Physics	3

The Mechanical Engineering major requires the following departmental courses:

MAE 317	Dynamic Systems and Control	3
MAE 318	Dynamic Systems and Control Laboratory	1
MAE 371	Fluid Mechanics	3
MAE 388	Heat Transfer	3
MAE 422	Mechanics of Materials	4
MAE 441	Principles of Design	3
MAE 443	Engineering Design	3
MAE 490	Projects in Design and Development *L*	3
MAE 491	Experimental Mechanical Engineering	3
Area of emphasis (technical electives)		15
Total		41

Mechanical Engineering Areas of Study

Technical electives may be selected from among any of the following courses or from courses listed under the Aerospace Engineering areas of study. The courses are grouped to assist a student in identifying areas of specialization. Students preferring a broader technical background may choose courses from different areas. Generally, no more than two technical elective courses from outside the department are allowed. Credit for courses not on the list requires prior approval of the advisor and department. Mechanical Engineering students may not use MAE 361 or 425 to fulfill degree requirements.

Aerospace. Any courses listed under the Aerospace Engineering areas of study except MAE 361 and 425 may be selected.

Biomechanical. Select from these courses:

BME 411	Biomedical Engineering I	3
BME 412	Biomedical Engineering II	3

BME 416 Biomechanics 3
BME 419 Biocontrol Systems 3
EEE 302 Electrical Networks II 3
EEE 434 Quantum Mechanics for Engineers 3

Computer Methods. Select from these courses:

ASE 485 Engineering Statistics *CS* 3
CSE 310 Data Structures and Algorithms 3
CSE 422 Microprocessor System Design II 4
CSE 428 Computer-Aided Processes 3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3
IEE 475 Simulating Stochastic Systems *CS* 3
MAE 404 Finite Elements in Engineering 3
MAE 406 CAD/CAM Applications in MAE 4
MAE 471 Computational Fluid Dynamics 3
MAE 541 CAD Tools for Engineers 3
MAT 421 Applied Computational Methods *CS* 3
MAT 423 Numerical Analysis I *CS* 3
MAT 425 Numerical Analysis II *CS* 3

Control and Dynamic Systems. Select from these courses:

CSE 428 Computer-Aided Processes 3
EEE 360 Energy Conversion and Transport 4
IEE 463 Computer-Aided Manufacturing and Control *CS* 3
MAE 413 Aircraft Performance, Stability, and Control 3
MAE 417 Control System Design 3
MAE 462 Space Vehicle Dynamics and Control 3
MAE 467 Aircraft Performance 3

Design. Select from these courses:

MAE 341 Mechanism Analysis and Design 3
MAE 351 Manufacturing Processes 3
MAE 404 Finite Elements in Engineering 3
MAE 406 CAD/CAM Applications in MAE 4
MAE 413 Aircraft Performance, Stability, and Control 3
MAE 417 Control System Design 3
MAE 434 Internal Combustion Engines 3
MAE 435 Turbomachinery 3
MAE 442 Mechanical Systems Design 3
MAE 446 Thermal Systems Design 3
MAE 447 Robotics and Its Influence on Design 3
MAE 462 Space Vehicle Dynamics and Control 3
MAE 467 Aircraft Performance 3

Energy Systems. Select from these courses:

EEE 360 Energy Conversion and Transport 4
MAE 372 Fluid Mechanics 3
MAE 382 Thermodynamics 3
MAE 434 Internal Combustion Engines 3
MAE 435 Turbomachinery 3
MAE 436 Combustion 3
MAE 446 Thermal Systems Design 3

Engineering Mechanics. Select from these courses:

MAE 341 Mechanism Analysis and Design 3
MAE 402 Introduction to Continuum Mechanics 3
MAE 404 Finite Elements in Engineering 3
MAE 413 Aircraft Performance, Stability, and Control 3
MAE 415 Vibration Analysis 4
MAE 426 Design of Aerospace Structures 3
MAE 442 Mechanical Systems Design 3
MAE 460 Gas Dynamics 3
MAE 461 Aerodynamics II 3
MAE 471 Computational Fluid Dynamics 3
MAT 421 Applied Computational Methods *CS* 3
MAT 423 Numerical Analysis I *CS* 3
MSE 440 Mechanical Properties of Solids 3

Manufacturing. Select from these courses:

CSE 428 Computer-Aided Processes 3
IEE 300 Economic Analysis for Engineers 3
IEE 374 Quality Control *CS* 3
IEE 461 Production Control 3
IEE 463 Computer-Aided Manufacturing and Control *CS* 3
MAE 341 Mechanism Analysis and Design 3
MAE 351 Manufacturing Processes 3
MAE 404 Finite Elements in Engineering 3
MAE 442 Mechanical Systems Design 3
MAE 447 Robotics and Its Influence on Design 3
MAE 455 Polymers and Composites 3
MSE 355 Introduction to Materials Science and Engineering 3
MSE 420 Physical Metallurgy 3
MSE 431 Corrosion and Corrosion Control 3
MSE 440 Mechanical Properties of Solids 3

Stress Analysis, Failure Prevention, and Materials. Select from these courses:

MAE 341 Mechanism Analysis and Design 3
MAE 404 Finite Elements in Engineering 3
MAE 426 Design of Aerospace Structures 3
MAE 447 Robotics and Its Influence on Design 3
MAE 455 Polymers and Composites 3
MSE 355 Introduction to Materials Science and Engineering 3
MSE 420 Physical Metallurgy 3
MSE 431 Corrosion and Corrosion Control 3
MSE 440 Mechanical Properties of Solids 3
MSE 450 X-ray and Electron Diffraction 3

Thermosciences. Select from these courses:

MAE 372 Fluid Mechanics 3
MAE 382 Thermodynamics 3
MAE 433 Air Conditioning and Refrigeration 3
MAE 434 Internal Combustion Engines 3
MAE 435 Turbomachinery 3
MAE 436 Combustion 3
MAE 446 Thermal Systems Design 3
MAE 460 Gas Dynamics 3
MAE 463 Propulsion 3
MAE 471 Computational Fluid Dynamics 3

Mechanical Engineering
Program of Study
Typical Four-Year Sequence

First Year

First Semester

CHM 114 General Chemistry for Engineers *SQ* 4
or CHM 116 General Chemistry *SQ* (4)
ECE 100 Introduction to Engineering Design *CS* 4
or HU or SB elective[1]
ENG 101 First-Year Composition 3
MAT 270 Calculus with Analytic Geometry I *MA* 4

Total 15

Second Semester

ENG 102 First-Year Composition 3
MAT 242 Elementary Linear Algebra 2
MAT 271 Calculus with Analytic Geometry II *MA* 4
PHY 121 University Physics I: Mechanics *SQ*[2] 3

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see “General Studies,” page 87. For graduation requirements, see “University Graduation Requirements,” page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see “Classification of Courses,” page 60.

PHY 122	University Physics Laboratory I *SQ*[2]	1
HU, SB, and awareness area course[1]		3
	or ECE 100 Introduction to Engineering Design *CS* (4)	
Total		16

Second Year

First Semester

ECE 210	Engineering Mechanics I: Statics	3
ECE 350	Structure and Properties of Materials	3
MAT 272	Calculus with Analytic Geometry III *MA*	4
MAT 274	Elementary Differential Equations *MA*	3
PHY 131	University Physics II: Electricity and Magnetism *SQ*[3]	3
PHY 132	University Physics Laboratory II *SQ*[3]	1
Total		17

Second Semester

ECE 301	Electrical Networks I	4
ECE 312	Engineering Mechanics II: Dynamics	3
ECE 313	Introduction to Deformable Solids	3
ECE 340	Thermodynamics	3
ECE 386	Partial Differential Equations for Engineers	2
Total		15

Third Year

First Semester

ECE 300	Intermediate Engineering Design *L*	3
MAE 317	Dynamic Systems and Control	3
MAE 318	Dynamic Systems and Control Laboratory	1
MAE 371	Fluid Mechanics	3
MAE 422	Mechanics of Materials	4
HU, SB, or awareness area course[1]		3
Total		17

Second Semester

ECE 384	Numerical Analysis for Engineers I	2
EEE 350	Random Signal Analysis	3
MAE 388	Heat Transfer	3
MAE 441	Principles of Design	3
HU, SB, or awareness area course[1]		3
Technical elective		3
Total		17

Fourth Year

First Semester

MAE 491	Experimental Mechanical Engineering	3
PHY 361	Introductory Modern Physics	3
HU, SB, and awareness area course(s)[1]		4
Technical electives		6
Total		16

Second Semester

MAE 443	Engineering Design	3
MAE 490	Projects in Design and Development *L*	3
HU, SB, and awareness area course[1]		3
Technical electives		6
Total		15

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

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

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

MECHANICAL AND AEROSPACE ENGINEERING (MAE)

MAE 317 Dynamic Systems and Control. (3) F, S
Modeling and representations of dynamic physical systems, including transfer functions, block diagrams, and state equations. Transient response. Principles of feedback control and linear system analysis, including root locus and frequency response. Prerequisite: ECE 312. Pre- or corequisite: ECE 386. Corequisite for Mechanical Engineering majors only: MAE 318.

MAE 318 Dynamic Systems and Control Lab. (1) F, S
Series of labs designed to illustrate concepts presented in MAE 317. Lab. Corequisite for Mechanical Engineering majors only: MAE 317.

MAE 341 Mechanism Analysis and Design. (3) A
Positions, velocities, and accelerations of machine parts; cams, gears, flexible connectors, and rolling contact; introduction to synthesis. Prerequisite: ECE 312.

MAE 351 Manufacturing Processes. (3) F, S
Production technique and equipment. Casting and molding, forming, machining, joining and assembly, computer-integrated manufacturing, rapid prototyping, and electronics manufacturing. Cross-listed as IEE 360. Credit is allowed for only IEE 360 or MAE 351. Prerequisite: ECE 350.

MAE 361 Aerodynamics I. (3) A
Fluid statics, conservation principles, stream function, velocity potential, vorticity, inviscid flow, Kutta-Joukowski, thin-airfoil theory, and panel methods. Prerequisites: ECE 312, 340.

MAE 371 Fluid Mechanics. (3) F, S
Introductory concepts of fluid motions; fluid statics; control volume forms of basic principles; viscous internal flows. Prerequisites: ECE 312, 340.

MAE 372 Fluid Mechanics. (3) A
Application of basic principles of fluid mechanics to problems in viscous and compressible flow. Prerequisites: ECE 384, 386; MAE 361 (or 371).

MAE 382 Thermodynamics. (3) A
Applied thermodynamics; gas mixtures, psychrometrics, property relationships, power and refrigeration cycles, and reactive systems. Prerequisite: ECE 340.

MAE 388 Heat Transfer. (3) F, S
Steady and unsteady heat conduction, including numerical solutions; thermal boundary layer concepts and applications to free and forced convection. Thermal radiation concepts. Prerequisite: MAE 361 or 371.

MAE 402 Introduction to Continuum Mechanics. (3) A
Application of the principles of continuum mechanics to such fields as flow-in porous media, biomechanics, electromagnetic continua, and magneto-fluid mechanics. Prerequisites: ECE 313; MAE 361 (or 371); MAT 242 (or 342).

MAE 404 Finite Elements in Engineering. (3) A
Introduction to ideas and methodology of finite element analysis. Applications to solid mechanics, heat transfer, fluid mechanics, and vibrations. Prerequisites: ECE 313; MAT 242 (or 342).

MAE 406 CAD/CAM Applications in MAE. (4) A
Solution of engineering problems with the aid of state-of-the-art software tools in solid modeling, engineering analysis, and manufacturing; selection of modeling parameters; reliability tests on software. 3 hours lecture, 3 hours lab. Prerequisites: MAE 441; instructor approval.

MAE 413 Aircraft Performance, Stability, and Control. (3) S
Aircraft performance, cruise, climbing and turning flights, energy maneuverability, 6 DOF equations for aircraft, aerodynamic stability derivatives, flight stability/control. Prerequisites: MAE 317, 361.

MAE 415 Vibration Analysis. (4) F, S
Free and forced response of single and multiple degree of freedom systems, continuous systems; applications in mechanical and aerospace systems numerical methods. Lecture, lab. Prerequisites: ECE 312; MAE 422 (or 425); MAT 242 (or 342).

MAE 417 Control System Design. (3) A
Tools and methods of control system design and compensation, including simulation, response optimization, frequency domain techniques, state variable feedback, and sensitivity analysis. Introduction to nonlinear and discrete time systems. Prerequisite: MAE 317.

MAE 422 Mechanics of Materials. (4) F, S
Failure theories, energy methods, finite element methods, plates, torsion of noncircular members, unsymmetrical bending, shear center, and beam column. Lecture, lab. Prerequisites: ECE 313; MAT 242 (or 342). Pre- or corequisite: ECE 386.

MAE 425 Aerospace Structures. (4) A
Stability, energy methods, finite element methods, torsion, unsymmetrical bending and torsion of multicelled structures, design of aerospace structures. Lecture, lab. Prerequisites: ECE 313; MAT 242 (or 342).

MAE 426 Design of Aerospace Structures. (3) A
Flight vehicle loads, design of semi-monocoque structures, local buckling and crippling, fatigue, aerospace materials, composites, joints, and finite element applications. Prerequisites: MAE 361, 425.

MAE 433 Air Conditioning and Refrigeration. (3) A
Air conditioning processes; environmental control; heating and cooling loads; psychrometry; refrigeration cycles. Prerequisite: MAE 388 or MET 432 or instructor approval.

MAE 434 Internal Combustion Engines. (3) A
Performance characteristics, combustion, carburetion and fuel-injection, and the cooling and control of internal combustion engines. Computer modeling. Lab. Prerequisite: MAE 388.

MAE 435 Turbomachinery. (3) A
Design and performance of turbomachines, including steam, gas and hydraulic turbines, centrifugal pumps, compressors, fans, and blowers. Pre- or corequisite: MAE 361 or 371.

MAE 436 Combustion. (3) A
Thermochemical and reaction rate processes; combustion of gaseous and condensed-phase fuels. Applications to propulsion and heating systems. Pollutant formation. Prerequisite: MAE 388.

MAE 441 Principles of Design. (3) F, S
Conceptual and embodiment design of mechanical elements; form synthesis; material selection, failure modes, manufacturability tolerances, common mechanisms, and machine elements. Lecture, lab (project). Prerequisites: ECE 300, 350. Pre- or corequisite: MAE 422 or 425.

MAE 442 Mechanical Systems Design. (3) A
Application of design principles and techniques to the synthesis, modeling, and optimization of mechanical, electromechanical, and hydraulic systems. Prerequisites: MAE 422 (or 425), 441.

MAE 443 Engineering Design. (3) F, S
Group projects to design engineering components and systems. Problem definition ideation, modeling, and analysis; decision making and documentation activities emphasized. 6 hours lab. Prerequisite: MAE 441.

MAE 444 Fundamentals of Aerospace Design. (3) S
Design theory and design tools applied to aerospace engineering. Engineering drawings, solid modeling, RFP's, Federal Aviation Regulations and military specifications, aircraft sizing, rapid prototyping. Lab, projects. Prerequisites: ECE 300; MAE 361, 425. Pre- or corequisite: MAE 413.

MAE 446 Thermal Systems Design. (3) A
Application of engineering principles and techniques to the modeling and analysis of thermal systems and components. Optimization techniques are presented and their use demonstrated. Prerequisite: ECE 300; MAE 388.

MAE 447 Robotics and Its Influence on Design. (3) A
Robot applications, configurations, singular positions, and work space; modes of control; vision; programming exercises; design of parts for assembly. Prerequisite: MAE 317.

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

MAE 460 Gas Dynamics. (3) A
Compressible flow at subsonic and supersonic speeds; duct flow; normal and oblique shocks, perturbation theory, and wind tunnel design. Prerequisites: ECE 386; MAE 361 (or 371).

MAE 461 Aerodynamics II. (3) A
Transonic/hypersonic flows, wing theory, Navier-Stokes, laminar/turbulent shear flows, pressure drop in tubes, separation, drag, viscous/inviscid interaction, and wing design. Prerequisite: MAE 460.

MAE 462 Space Vehicle Dynamics and Control. (3) F
Attitude dynamics and control, launch vehicles, orbital mechanics, orbital transfer/rendezvous, space mission design, space structures, spacecraft control systems design. Prerequisite: MAE 317.

MAE 463 Propulsion. (3) A
Fundamentals of gas-turbine engines and design of components. Principles and design of rocket propulsion and alternative devices. Lecture, design projects. Prerequisite: ECE 386. Pre- or corequisite: MAE 361 (or 371).

MAE 464 Aerospace Laboratory. (3) F, S
Aerodynamic flow parameters; flow over airfoils and bodies of revolution; flow visualization; computer-aided data acquisition and processing; boundary layer theory. 1 hour lecture, 4 hours lab. Prerequisites: ECE 386; MAE 361, 460.

MAE 465 Rocket Propulsion. (3) A
Rocket flight performance; nozzle design; combustion of liquid and solid propellants; component design; advanced propulsion systems; interplanetary missions; testing. Prerequisite: MAE 361 or 371.

MAE 466 Rotary Wing Aerodynamics and Performance. (3) A
Introduction to helicopter and propeller analysis techniques. Momentum, blade-element, and vortex methods. Hover and forward flight. Ground effect, autorotation, and compressibility effects. Prerequisites: ECE 386 and MAE 361 *or* instructor approval.

MAE 467 Aircraft Performance. (3) A
Integration of aerodynamic and propulsive forces into aircraft performance design. Estimation of drag parameters for design. Engine, airfoil selection. Conceptual design methodology. Lecture, design projects. Prerequisite: MAE 361 or 371. Pre- or corequisite: MAE 441.

MAE 468 Aerospace Systems Design. (3) F, S
Group projects related to aerospace vehicle design, working from mission definition and continuing through preliminary design. Prerequisites: MAE 361, 413, 463. *General Studies: L.*

MAE 469 Projects in Astronautics or Aeronautics. (3) F, S
Various multidisciplinary team projects available each semester. Projects include design of high-speed rotocraft autonomous vehicles, liquid-fueled rockets, microaerial vehicles, satellites. Prerequisite: instructor approval.

MAE 471 Computational Fluid Dynamics. (3) A
Numerical solutions for selected problems in fluid mechanics. Prerequisites: ECE 384; MAE 361 (or 371).

MAE 490 Projects in Design and Development. (3) F, S
Capstone projects in fundamental or applied aspects of engineering. Prerequisites: MAE 441, 491. *General Studies: L.*

MAE 491 Experimental Mechanical Engineering. (3) F, S
Experimental and analytical studies of phenomena and performance of fluid flow, heat transfer, thermodynamics, refrigeration, and mechanical power systems. 6 hours lab. Prerequisites: EEE 350; MAE 388.

MAE 498 Pro-Seminar. (1–3) N
Special topics for advanced students. Application of the engineering disciplines to design and analysis of modern technical devices and systems. Prerequisite: instructor approval.

MAE 504 Laser Diagnostics. (3) S
Fundamentals of optics and the interaction of light with matter. Laser sources, laser spectroscopy, velocimetry, particle sizing, and surface characterization.

MAE 505 Perturbation Methods. (3) N
Nonlinear oscillations, strained coordinates, renormalization, multiple scales, boundary layers, matched asymptotic expansions, turning point problems, and WKBJ method. Cross-listed as MAT 505. Credit is allowed for only MAE 505 or MAT 505.

MAE 506 Advanced System Modeling, Dynamics, and Control. (3) S
Lumped-parameter modeling of physical systems with examples. State variable representations and dynamic response. Introduction to modern control. Prerequisite: ASE 582 or MAT 442.

MAE 507 Optimal Control. (3) F
Optimal control of systems. Calculus of variations, dynamic programming, linear quadratic regulator, numerical methods, and Pontryagin's principle. Cross-listed as EEE 587. Credit is allowed for only EEE 587 or MAE 507. Prerequisite: EEE 482 or MAE 506.

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.

MAE 509 Robust Multivariable Control. (3) S
Characterization of uncertainty in feedback systems, robustness analysis, synthesis techniques, multivariable Nyquist criteria, computer-aided analysis and design. Prerequisites: MAE 417, 506.

MAE 510 Dynamics and Vibrations. (3) F
Lagrange's and Hamilton's equations, rigid body dynamics, gyroscopic motion, and small oscillation theory.

MAE 511 Acoustics. (3) F
Principles underlying the generation, transmission, and reception of acoustic waves. Applications to noise control, architectural acoustics, random vibrations, and acoustic fatigue.

MAE 512 Random Vibrations. (3) S
Review of probability theory, random processes, stationarity, power spectrum, white noise process, random response of single and multiple DOF systems, and Markov processes simulation. Prerequisite: MAE 510 or instructor approval.

MAE 515 Structural Dynamics. (3) S
Free vibration and forced response of discrete and continuous systems, exact and approximate methods of solution, finite element modeling, and computational techniques. Prerequisite: MAE 510 or instructor approval.

MAE 518 Dynamics of Rotor-Bearing Systems. (3) S
Natural whirl frequency, critical speed, and response analysis of rigid and flexible rotor systems. Bearing influence and representation. Stability analysis. Methods of balancing.

MAE 520 Solid Mechanics. (3) F
Introduction to tensors: kinematics, kinetics, and constitutive assumptions leading to elastic, plastic, and viscoelastic behavior. Applications.

MAE 521 Structural Optimization. (3) N
Linear and nonlinear programming. Problem formulation. Constrained and unconstrained optimization. Sensitivity analysis. Approximate techniques. FEM-based optimal design of mechanical and aerospace structures. Cross-listed as CEE 533. Credit is allowed for only CEE 533 or MAE 521. Prerequisite: instructor approval.

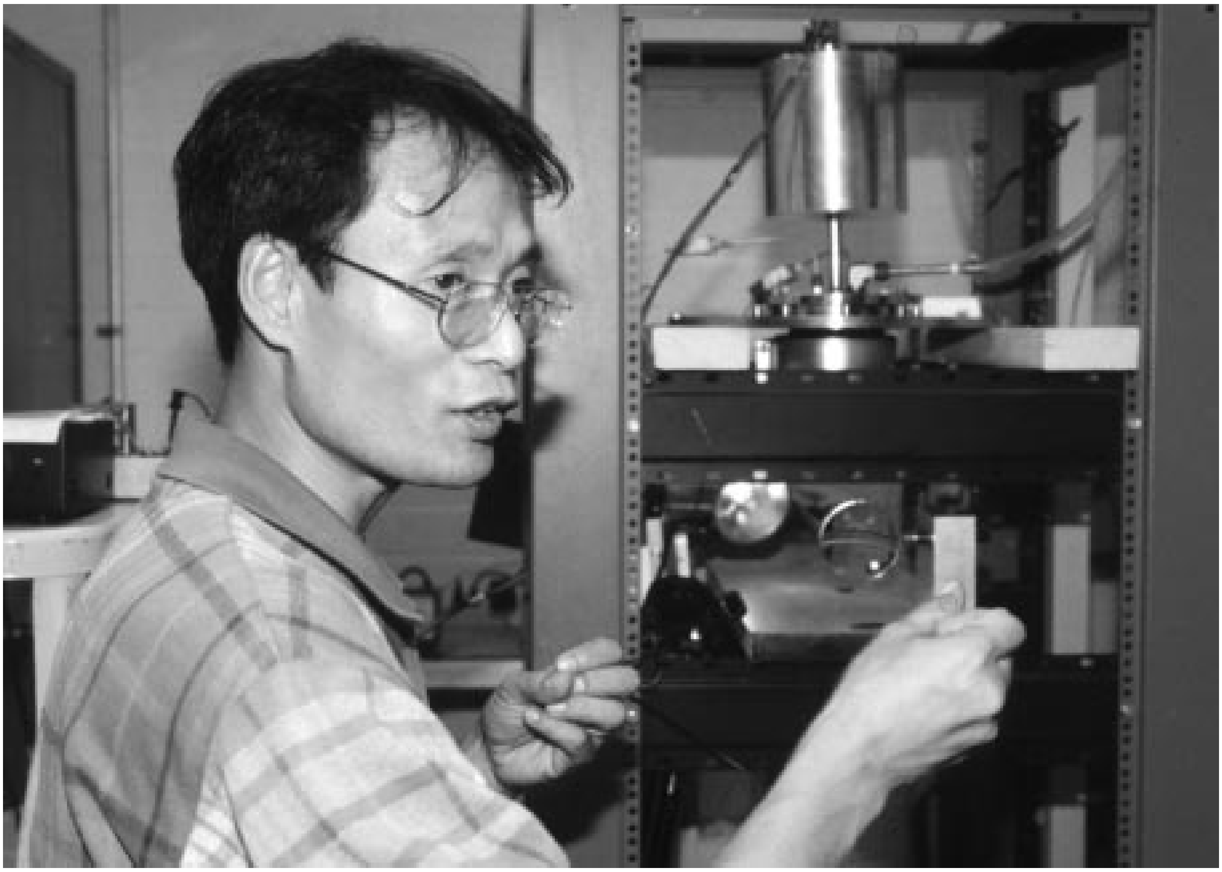
MAE 523 Theory of Plates and Shells. (3) F
Linear and nonlinear theories of plates. Membrane and bending theories of shells. Shells of revolution. Prerequisite: MAE 520.

MAE 524 Theory of Elasticity. (3) S
Formulation and solution of 2- and 3-dimensional boundary value problems. Prerequisite: MAE 520.

MAE 527 Finite Element Methods in Engineering Science. (3) F
Discretization, interpolation, elemental matrices, assembly, and computer implementation. Application to solid and fluid mechanics, heat transfer, and time dependent problems. Prerequisite: ASE 582.

MAE 536 Combustion. (3) N
Thermodynamics; chemical kinetics of combustion. Explosion and ignition theories. Reactive gas dynamics. Structure, propagation, and stability of flames. Experimental methods. Prerequisite: MAE 436 or instructor approval.

MAE 540 Advances in Engineering Design Theory. (3) F
Survey of research in engineering design process, artifact and design, knowledge, formal and informal logic, heuristic and numerical searches, theory of structure and complexity. Prerequisite: graduate standing.



The College of Engineering and Applied Sciences is known for the quality and variety of its programs. Tim Trumble photo

MAE 541 CAD Tools for Engineers. (3) F
Elements of computer techniques required to develop CAD software. Data structures, including lists, trees, and graphs. Computer graphics, including 2- and 3-dimensional algorithms and user interface techniques.

MAE 542 Geometric Modeling in CAD/CAM. (3) S
Geometric and solid modeling, curve and surface design, CAD database architectures, and integration of solid modeling into engineering processes. Prerequisite: MAE 541 or instructor approval.

MAE 544 Mechanical Design and Failure Prevention. (3) F
Modes of mechanical failure; application of principles of elasticity and plasticity in multiaxial state of stress to design synthesis; failure theories; fatigue; creep; impact. Prerequisite: MAE 443.

MAE 546 CAD/CAM Applications in MAE. (4) F
Solution of engineering problems with the aid of state-of-the-art software tools in solid modeling, engineering analysis; and manufacturing; selection of modeling parameters; reliability tests on software. Open only to students without previous credit for MAE 406. 3 hours lecture, 3 hours lab. Prerequisite: instructor approval.

MAE 547 Mechanical Design and Control of Robots. (3) N
Homogeneous transformations, 3-dimensional kinematics, geometry of motion, forward and inverse kinematics, workspace and motion trajectories, dynamics, control, and static forces.

MAE 548 Mechanism Synthesis and Analysis. (3) S
Algebraic and graphical methods for exact and approximate synthesis of cam, gear, and linkage mechanisms; design optimization; methods of planar motion analysis; characteristics of plane motion; spatial kinematics.

MAE 557 Mechanics of Composite Materials. (3) S
Analysis of composite materials and applications. Micromechanical and macromechanical behavior. Classical lamination theory developed with investigation of bending-extension coupling.

MAE 560 Propulsion Systems. (3) N
Design of air-breathing gas turbine engines for aircraft propulsion; mission analysis; cycle analysis; engine sizing; component design.

MAE 561 Computational Fluid Dynamics. (3) S
Finite-difference and finite-volume techniques for solving the subsonic, transonic, and supersonic flow equations. The method of characteristics. Numerical grid-generation techniques. Prerequisite: MAE 571 or instructor approval.

MAE 563 Unsteady Aerodynamics. (3) S
Unsteady incompressible and compressible flow. Wings and bodies in oscillatory and transient motions. Kernel function approach and panel methods. Aeroelastic applications. Prerequisite: MAE 460 or 461.

MAE 564 Advanced Aerodynamics. (3) F
Perturbation method. Linearized subsonic and supersonic flows. Thin wing/slender body theories. Lifting surface theory. Panel method computation. Prerequisite: MAE 460 or 461.

MAE 566 Rotary-Wing Aerodynamics. (3) F
Introduction to helicopter and propeller analysis techniques. Momentum, blade-element, and vortex methods. Hover and forward flight. Ground effect, autorotation, and compressibility effects. Prerequisite: MAE 361.

MAE 571 Fluid Mechanics. (3) F
Basic kinematic, dynamic, and thermodynamic equations of the fluid continuum and their application to basic fluid models.

MAE 572 Inviscid Fluid Flow. (3) S
Mechanics of fluids for flows in which the effects of viscosity may be ignored. Potential flow theory, waves, and inviscid compressible flows. Prerequisite: MAE 571.

MAE 573 Viscous Fluid Flow. (3) F
Mechanics of fluids for flows in which the effects of viscosity are significant. Exact and approximate solutions of the Navier-Stokes system, laminar flow at low and high Reynolds number. Prerequisite: MAE 571.

MAE 575 Turbulent Shear Flows. (3) F
Homogeneous, isotropic, and wall turbulence. Experimental results. Introduction to turbulent-flow calculations. Prerequisite: MAE 571.

MAE 577 Turbulent Flow Modeling. (3) S
Reynolds equations and their closure. Modeling of simple and complex turbulent flows, calculations of internal and external flows, and application to engineering problems. Prerequisite: MAE 571.

MAE 581 Thermodynamics. (3) F
Basic concepts and laws of classical equilibrium thermodynamics; applications to engineering systems. Introduction to statistical thermodynamics.

MAE 582 Statistical Thermodynamics. (3) A
Kinetic and quantum theory. Statistical mechanics; ensemble theory. Structure and thermodynamics of noninteracting and interacting particles. Boltzmann integro-differential equation. Prerequisite: graduate standing.

MAE 585 Conduction Heat Transfer. (3) F
Basic equations and concepts of conduction heat transfer. Mathematical formulation and solution (analytical and numerical) of steady and unsteady, one- and multidimensional heat conduction and phase change problems. Prerequisites: ECE 386; MAE 388.

MAE 586 Convection Heat Transfer. (3) S
Basic concepts and governing equations. Analysis of laminar and turbulent heat transfer for internal and external flows. Natural and mixed convection. Prerequisite: MAE 388.

MAE 587 Radiation Heat Transfer. (3) F
Advanced concepts and solution methodologies for radiation heat transfer, including exchange of thermal radiation between surfaces, radiation in absorbing, emitting, and scattering media and radiation combined with conduction and convection. Prerequisite: MAE 388.

MAE 588 Two-Phase Flows and Boiling Heat Transfer. (3) S
Pool and flow boiling heat transfer, condensation heat transfer, various models of vapor-liquid mixture flows, gas-solid mixture flows, and experimental measurement techniques.

MAE 589 Heat Transfer. (3) F
Basic concepts; physical and mathematical models for heat transfer. Applications to conductive, convective, radiative, and combined mode heat transfer. Prerequisite: MAE 388.

MAE 594 Graduate Research Conference. (1) F, S
Topics in contemporary research. Required every semester of all departmental graduate students registered for 9 or more semester hours. Not for degree credit.

MAE 598 Special Topics. (1–3) F, S
Special topics courses, including the following, which are regularly offered, are open to qualified students:
(a) Advanced Spacecraft Control
(b) Aeroelasticity
(c) Aerospace Vehicle Guidance and Control
(d) Boundary Layer Stability
(e) Hydrodynamic Stability
(f) Plasticity
(g) Polymers and Composites

Programs in Engineering Special Studies

Daniel F. Jankowski
Director

The major of Engineering Special Studies accommodates students whose educational objectives require more intensity of concentration on a particular subject or more curricular flexibility within an engineering discipline than the traditional departmental majors generally permit. The major is a School of Engineering program. Unlike the departmental major areas, however, there is not a separate faculty. The

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faculty teaching and advising in these programs are from the various departments within the School of Engineering.

For many students, engineering studies form the basis of preparation for professional engineering work where proficiency in the application of science and the physical and social technologies is brought to bear on problems of a large scope. The necessary breadth that these students seek often is not obtainable in traditional engineering fields. Rather, specially designed programs of course work that merge the required principles and approaches drawn from all fields of engineering and other pertinent disciplines are desired.

The B.S.E. degree in Engineering Special Studies is designed primarily for students intending to pursue engineering careers at a professional level in industry or graduate studies.

ENGINEERING SPECIAL STUDIES—B.S.E.

Premedical Engineering. In the past decade, the interrelation between engineering and medicine has become vigorous and exciting. Our rapidly expanding technology dictates that engineering will continue to become increasingly involved in all branches of medicine. As this develops, so will the need for physicians trained in the engineering sciences—medical men and women with a knowledge of computer technology, transport phenomena, biomechanics, bioelectric phenomena, operations research, and cybernetics. This concentration is of special interest to students desiring entry into a medical college and whose medical interests lie in research, aerospace and undersea medicine, artificial organs, prostheses, biomedical engineering, or biophysics. Since both engineering and medicine have as their goal the well-being of humans, this program is compatible with any field of medical endeavor.

Academic Requirements. The following courses are required in the premedical engineering concentration and have been selected to meet all university and school requirements.

Note: To fulfill medical school admission requirements, BIO 182 General Biology is also required in addition to the degree requirements and is best taken in summer session before the Medical College Admission Test (MCAT).

First-Year Composition

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

—or—

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

—or—

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

Total 6

General Studies/School Requirements

Humanities and Fine Arts/Social and Behavioral Sciences

ECN 111 Macroeconomic Principles *SB*[1] 3
or ECN 112 Microeconomic Principles *SB*[1] (3)

HU, SB, and awareness area courses[2] 13

Total 16

Literacy and Critical Inquiry

BME 413 Biomedical Instrumentation *L* 3
BME 423 Biomedical Instrumentation Laboratory *L* 1
ECE 300 Intermediate Engineering Design *L* 3

Total 7

Natural Sciences

PHY 121 University Physics I: Mechanics *SQ*[3] 3
PHY 122 University Physics Laboratory I *SQ*[3] 1
PHY 131 University Physics II: Electricity and Magnetism *SQ*[4] 3
PHY 132 University Physics Laboratory II *SQ*[4] 1

Total 8

Numeracy/Mathematics

ECE 100 Introduction to Engineering Design *CS* 4
ECE 384 Numerical Analysis for Engineers I 2
or ECE 386 Partial Differential Equations for Engineers (2)
or MAT 242 Elementary Linear Algebra (2)
MAT 270 Calculus with Analytic Geometry I *MA* 4
MAT 271 Calculus with Analytic Geometry II *MA* 4
MAT 272 Calculus with Analytic Geometry III *MA* 4
MAT 274 Elementary Differential Equations *MA* 3

Total 21

General Studies/school requirements total 52

Engineering Core

ECE 210 Engineering Mechanics I: Statics 3
ECE 301 Electrical Networks I 4
ECE 334 Electronic Devices and Instrumentation 4
ECE 340 Thermodynamics 3
ECE 350 Structure and Properties of Materials 3

Total 17

Engineering Special Studies Program Major—
Premedical Engineering Concentration

BIO 181 General Biology *SQ* 4
BME 201 Introduction to Bioengineering *L* 3
BME 318 Biomaterials 3
BME 331 Biomedical Engineering Transport I: Fluids 3
BME 334 Bioengineering Heat and Mass Transfer 3
BME 416 Biomechanics 3
BME 417 Biomedical Engineering Capstone Design I 3
BME 435 Physiology for Engineers 4
BME 470 Microcomputer Applications in Bioengineering 4
BME 490 Biomedical Engineering Capstone Design II 3
CHM 113 General Chemistry *SQ* 4
CHM 116 General Chemistry *SQ* 4
CHM 331 General Organic Chemistry 3
CHM 332 General Organic Chemistry 3
CHM 335 General Organic Chemistry Laboratory 1
CHM 336 General Organic Chemistry Laboratory 1
ECE 380 Probability and Statistics for Engineering Problem Solving *CS* 3
Technical elective 1

Total 53

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1 ECN 111 or ECN 112 must be included to fulfill the HU and SB requirements.

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

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

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

Premedical Engineering Program of Study Typical Four-Year Sequence

First Year

First Semester

CHM 113	General Chemistry *SQ*	4
ECE 100	Introduction to Engineering Design *CS*	4
ENG 101	First-Year Composition	3
MAT 270	Calculus with Analytic Geometry I *MA*	4
Total		15

Second Semester

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

Second Year

First Semester

BIO 181	General Biology *SQ*	4
BME 201	Introduction to Bioengineering *L*	3
ECE 210	Engineering Mechanics I: Statics	3
MAT 272	Calculus with Analytic Geometry III *MA*	4
PHY 131	University Physics II: Electricity and Magnetism *SQ*[2]	3
PHY 132	University Physics Laboratory II *SQ*[2]	1
Total		18

Second Semester

CHM 331	General Organic Chemistry	3
CHM 335	General Organic Chemistry Laboratory	1
ECE 301	Electrical Networks I	4
ECE 350	Structure and Properties of Materials	3
ECN 111	Macroeconomic Principles *SB* or ECN 112 Microeconomic Principles *SB* (3)	3
MAT 274	Elementary Differential Equations *MA*	3
Total		17

Third Year

First Semester

BME 331	Biomedical Engineering Transport I: Fluids	3
BME 435	Physiology for Engineers	4
CHM 332	General Organic Chemistry	3
ECE 300	Intermediate Engineering Design *L*	3
ECE 340	Thermodynamics	3
Total		16

Second Semester

BME 318	Biomaterials	3
BME 334	Bioengineering Heat and Mass Transfer	3
CHM 336	General Organic Chemistry Laboratory	1
ECE 334	Electronic Devices and Instrumentation	4
MAT 242	Elementary Linear Algebra *MA* or ECE 384 Numerical Analysis for Engineers I (2) or ECE 386 Partial Differential Equations for Engineers (2)	2
HU, SB, and awareness area course(s)[3]		4
Total		17

Fourth Year

First Semester

BME 413	Biomedical Instrumentation *L*	3
BME 416	Biomechanics	3
BME 417	Biomedical Engineering Capstone Design I	3
BME 423	Biomedical Instrumentation Laboratory *L*	1
HU, SB, and awareness area courses[3]		6
Total		16

Second Semester

BME 470	Microcomputer Applications in Bioengineering	4
BME 490	Biomedical Engineering Capstone Design II	3
ECE 380	Probability and Statistics for Engineering Problem Solving *CS*	3
HU, SB, and awareness area course[3]		3
Technical elective		1
Total		14
Degree requirements total		128

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

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

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

NOTE: For the General Studies requirement, courses, and codes (such as L, SQ, C, and H), see "General Studies," page 87. For graduation requirements, see "University Graduation Requirements," page 83. For an explanation of additional omnibus courses offered but not listed in this catalog, see "Classification of Courses," page 60.