College of ENGINEERING

Janie M. Fouke, DEAN

The College of Engineering develops the abilities of its students so that they may continually progress with the advancing field of engineering and take part in the solution of technical as well as economic and social problems, which will arise during their lifetimes. Since engineering deals primarily with the adaptation of nature's forces, materials, and energies for the benefit of society, our engineering programs are planned to provide our engineering students with firm knowledge and understanding of the fundamental engineering sciences and of engineering methods for the application of this knowledge. Programs require a strong base in mathematics as a universal language and tool of the engineer. Since the engineer will always work with others, we urge our students to take advantage of extensive opportunities to learn from the other academic areas on this campus.

UNDERGRADUATE PROGRAMS

There is an opportunity for students to choose alternative paths of study leading to the Bachelor of Science degree:

1. Programs with a major in the Engineering Professional Fields.
2. Programs with a major in Engineering Sciences.
3. The Engineering Arts Program.

Programs With a Major in the Engineering Professional Fields

The Bachelor of Science degree may be earned in programs designed to prepare students for work in biosystems engineering, chemical engineering, civil engineering, computer engineering, electrical engineering, engineering mechanics, manufacturing engineering, materials science and engineering, and mechanical engineering.

Details of specific programs in these areas are given in sections that follow.

Programs With a Major in the Engineering Sciences

The Bachelor of Science degree may also be earned in Engineering Sciences with a major in computer science. Flexibility is provided in the selection of major and minor subject matter areas, and the program permits the individual student to select study areas not included in the programs of the professional engineering fields. Students are encouraged to combine the engineering science fields with supporting studies from other engineering areas or from business management, the social and behavioral sciences, or the physical sciences.

Detailed program requirements for majors in the engineering sciences are given in sections that follow.

The Engineering Arts Major

The Engineering Arts major is a cross–disciplinary major, which enables students to develop an awareness of technology and apply it to a broad range of non–technical disciplines. Opportunities are available for interaction between technological awareness and business, communication arts and sciences, and agriculture (packaging). The purpose and course content of the Engineering Arts major is significantly different from the majors in either the engineering professional fields or the engineering sciences. Detailed requirements for the Engineering Arts major are given in a section that follows.

Engineering for International Service

Students who plan international engineering careers may wish to earn a Bachelor of Arts degree in an appropriate major in the College of Arts and Letters or the College of Social Science, in addition to the Bachelor of Science degree with a major in the College of Engineering. Interested students should consult the statement on *Requirements for a Second Bachelor's Degree* in the *Undergraduate Education* section of this catalog and contact their academic advisers for further information.

Biomedical Engineering Option

The biomedical engineering option is oriented toward biomechanics and biomaterials. The option is designed for students who plan to pursue graduate study in biomedical areas or to seek employment in selected medical areas.

The option, which is administered by the College of Engineering, is available as an elective to students who are enrolled in bachelor's degree programs in the College of Engineering or in other colleges.

With the approval of the department and college that administer the student's degree program, courses that are used to satisfy the requirements for the option may also be used to satisfy the requirements for the bachelor's degree.

Requirements for the Biomedical Engineering Option

The student must complete:

				CREDITS
1.	The following course (4 credits):			
	PSL	250	Introductory Physiology	4
2.	One of the following courses (3 or 4 credits):			
	BS	110	Organisms and Populations	4
	BS	111	Cells and Molecules	3
3.	At least three of the following courses (9 credits):			
	BME	424	Biomaterials and Biocompatibility	3
	BME	441	Tissue Mechanics	3
	BME	442	Biodynamics	3
	BME	445	Biomechanical Design	3
	BME	491	Special Topics (MTC)	3 to 12
	MSM	490	Independent Study	1 to 6

Upon completion of the requirements for the biomedical engineering option, the student should contact the Associate Dean for Undergraduate Studies in the College of Engineering and request certification for the completion of the option. After the certification is approved by the Dean of the College of Engineering, the Office of the Registrar will enter on the student's academic record the name of the option and the date that it was completed. This certification will appear on the student's transcript.

Cooperative Engineering Education

Cooperative Engineering Education is a program of alternating full–time employment in industry and full–time study on campus. A typical schedule alternates semesters of employment and study. Five years are required to complete requirements for the degree.

Employment provides practical on–the–job experience by exposing students to types of work done by engineers. Salaries vary and are set by agreement between the student and the employer. Locations of jobs are nationwide. Students must be willing to live away from home and away from the campus.

Because employment cannot be guaranteed for all applicants, enrollments in the Cooperative Engineering Education program may be limited. Students are selected to participate in the program on the basis of demonstrated academic ability and a firm commitment to pursuing careers in the technical sector.

The Cooperative Engineering Education program requires a minimum of three semesters of full–time employment in a position in industry that has been approved by the College of Engineering. The student is required to be enrolled in EGR 393 Engineering Cooperative Education during each term of employment. Upon completion of the Cooperative Engineering Education program, the student should contact the College of Engineering and request certification for the completion of the program. After the certification is approved by the Dean of the College, the Office of the Registrar will enter on the student's academic record the name of the program and the date that it was completed. This certification of completion will appear on the student's transcript.

Students who are interested in the Cooperative Engineering Education program should contact the Office of Cooperative Education, 1410 Engineering Building, during their first semester on campus.

Honors Study

The College of Engineering encourages honors students to develop distinctive undergraduate programs in either the engineering sciences or in the fields offered by the several professional departments. A member of the faculty is selected to serve as adviser to Honors College students in each major field, and it is his or her responsibility to help the student plan a rigorous and balanced program which will also reflect the student's special interests and competencies. Independent study experience is strongly encouraged when relevant to the student's total program.

Accreditation

The following degree programs have been accredited by the Accreditation Board for Engineering and Technology, Inc. (ABET): Biosystems Engineering, Chemical Engineering, Civil Engineering, Computer Engineering, Electrical Engineering, Engineering Mechanics, Materials Science and Engineering, and Mechanical Engineering.

Registration as a Professional Engineer

In Michigan, the State Board of Registration for Professional Engineers provides an opportunity for students during the senior year to take the first half of a sixteen–hour, two–part examination as the first step toward registration, provided the degree is to be awarded within six months and the degree program is one that has been accredited by the ABET or determined as equivalent by the State Board. After a minimum of four years of experience, the applicant may take the second half of the examination.

On completion of registration, an engineer establishes professional standing on the basis of legal requirements and receives authority to practice the engineering profession before the public.

Freshmen

Students meeting the general University requirements shown in the *Undergraduate Education* section of this catalog are enrolled as Undergraduate University Division students but may declare a preengineering major preference in the College of Engineering. Such students are assigned faculty advisers from the College. In addition to the general University requirements for admission, students who elect a preengineering major preference should have completed three units of college preparatory mathematics (one and one–half units of algebra, one unit of plane geometry, and one–half unit of trigonometry). Additional work in mathematics and science is highly desirable and may make advanced placement in courses possible.

Students entering with less than the minimum mathematics prerequisites may take some of the necessary courses after en-

tering the University. However, such students will need additional time to complete the work for the degree.

Since the normal work of the freshman year and much of the sophomore year is the same for all programs in the College of Engineering, new students may defer the choice of a field of study in most cases until the end of the freshman year. However, special attention should be given to various **program requirements** as they appear below under the major fields. Thus the first year or so may be used in becoming acquainted with the opportunities offered by the various engineering areas best suited to a student's talents.

Admission as a Junior

Enrollments in the College of Engineering are limited. Minimal criteria for application to the College are:

1. Completion of at least 56 credits of the first two years of the Engineering program with a cumulative grade–point average of 2.00 or higher.
2. Completion of Mathematics 132, 133.
3. Completion of Chemistry 141 or 151.
4. Completion of Physics 183 or 183B.
5. Completion of Computer Science and Engineering 131 or 231.

Admission is based on the cumulative grade–point average of all courses taken and a grade–point average calculated on all courses in mathematics, the physical and biological sciences, and engineering. In addition, factors such as work experience, diversity, and residency may be considered.

For additional information about admissions criteria and procedures, students should contact the Office of the Associate Dean for Student Affairs, College of Engineering.

Admission to a Second Bachelor's Degree Program

Students seeking admission to a second bachelor's degree program must meet the same requirements as for admission to the College as a junior.

Graduation Requirements for All Majors

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of the catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Computer Science and Engineering Arts, 124 credits are required for the Bachelor of Science degree in Manufacturing Engineering, and 128 credits, including general elective credits, are required for the Bachelor of Science degree with majors in the other Engineering Professional Fields. A student electing advanced aerospace or military science studies may be required to earn part or all of the credits for that program in addition to the minimum credits required for graduation.

   Students who are enrolled in majors leading to the Bachelor of Science degree in the College of Engineering may complete an alternative track to Integrative Studies in Biological and Physical Sciences that consists of the following courses:
   a. One of the following courses: Biological Science 110, 111; Botany and Plant Pathology 105; Entomology 205; Microbiology 205, 301; Physiology 250; Zoology 141.
   b. Two of the following courses: Chemistry 141, Chemistry 151, Physics 183 or 183B, Physics 184.
   c. One of the following laboratory courses: Biological Science 110, 111L; Botany and Plant Pathology 106; Chemistry 161; Microbiology 206; Physics 191.

   Credits earned in the alternative track may also be counted toward College and major requirements for the Bachelor of Science degree.
2. The requirements of the College of Engineering for the Bachelor of Science degree that are listed below:
   a. Mathematics 132, 133, 234, and 235. Computer Science majors may substitute Mathematics 314 for Mathematics 235.
   b. Chemistry 141 or 151. Computer Science majors are not required to complete Chemistry 141 or 151.
   c. Physics 183 or 183B and 184.
   d. Computer Science and Engineering 131 or 231.

Students who are enrolled in bachelor's degree programs in the College of Engineering may elect a Specialization in Environmental Studies. For additional information, refer to the *Specialization in Environmental Studies* statement in the *College of Natural Science* section of this catalog.

ENGINEERING ARTS

It is the intent of the Engineering Arts major to provide educational opportunities for the undergraduate student who wishes to develop an awareness of technology and apply it to one of a broad range of nontechnical areas. The program is designed to develop an individual who is: (1) knowledgeable of the impact of technology on society; (2) capable of recognizing how analytical tools are used in the solution of problems; (3) aware of the theoretical constraints under which new developments must work; (4) able to aid in the application of these techniques to a wide range of problems; and (5) competent in a specific area of application.

This program is designed to develop a uniquely qualified individual capable of functioning in a variety of employment contexts which are directly dependent on the application area. A few of the cross–disciplinary areas include: technical sales, technical journalism, communications, telecommunications, packaging, industrial management, production management, public administration, urban applications, environmental issues, political analysis, law, and virtually any area in which it is desirable to combine technical awareness with nontechnical fields.

Requirements for the Bachelor of Science Degree in Engineering Arts

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Engineering Arts.

   The University's Tier II writing requirement for the Engineering Arts major is met by completing Electrical and Computer Engineering 345 and Engineering 410. Those courses are referenced in item 3. a. below.

   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.

   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

				CREDITS
a.	All of the following courses:			29
	CE	280	Introduction to Environmental Engineering	3
	CEM	161	Chemistry Laboratory I	1
	ECE	345	Electronic Instrumentation and Systems	3
	EGR	300	Technology, Society and Public Policy	2
	EGR	410	System Methodology	2
	ME	180	Engineering Communications	3
	ME	201	Thermodynamics	3
	ME	221	Statics	3
	ME	222	Mechanics of Deformable Solids	3
	MSE	250	Materials Science and Engineering	3
	STT	351	Probability and Statistics for Engineers	3
b.	Cognate:			22 to 33

Cognates in Business-Supply Chain Management, Packaging, Product Design, and Telecommunication are available to majors in Engineering Arts. Students should consult with their adviser prior to their selection of a cognate. Students must select *one* of the following cognates.

Business-Supply Chain Management 22

ACC	230	Survey of Accounting Concepts	3
EC	210	Economics Principles Using Calculus	3
FI	320	Introduction to Finance	3
GBL	323	Introduction to Business Law	3
MGT	325	Management Skills and Processes	3
MSC	303	Introduction to Supply Chain Management	3
MSC	305	Supply Chain Management	4

Packaging 30

All of the following courses:

CEM	143	Survey of Organic Chemistry	4
EC	210	Economics Principles Using Calculus	3
PKG	101	Principles of Packaging	3
PKG	221	Packaging with Glass and Metal	3
PKG	370	Packaging and the Environment	3
PKG	432	Packaging Processes	4
PKG	475	Packaging Economics	3
PKG	480	Packaging Laws and Regulations	3

One of the following courses:

PKG	322	Packaging with Paper and Paperboard	4
PKG	323	Packaging with Plastics	4

Product Design 33

ME	285	Computer Aided Design Tools	3
ME	385	Introduction to Product Design	3
ME	386	Computer Aided Product Design	3
ME	423	Intermediate Mechanics of Deformable Solids	3
ME	424	Computational Mechanics	3
ME	477	Manufacturing Processes (W)	3
ME	497	Biomechanical Design	3
MSE	499	Senior Research and Design Project (W)	6
STA	110	Drawing I	3
Technical elective			3

Telecommunication 31

ACC	230	Survey of Accounting Concepts	3
EC	201	Introduction to Microeconomics	3
TC	100	The Information Society	3
TC	200	History and Economics of Telecommunication	4
TC	201	Introduction to Telecommunication Technology	4
TC	310	Basic Telecommunication Policy	4
TC	361	Telecommunication System and Service Policies	3
TC	463	Digital Telecommunication Networks	3
TC	465	Telecommunication Network Management (W)	4

TEACHER CERTIFICATION OPTION

A computer science disciplinary minor in the College of Engineering is available for teacher certification.

Students who elect the computer science disciplinary minor must contact the Department of Computer Science and Engineering.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

GRADUATE STUDY

The College of Engineering offers programs leading to the Master of Science and Doctor of Philosophy degrees in the following fields:

chemical engineering
civil engineering
computer science
electrical engineering
engineering mechanics
environmental engineering
materials science and engineering
mechanical engineering

Programs leading to the Master of Science and Doctor of Philosophy degrees in biosystems engineering are offered through the College of Agriculture and Natural Resources.

Programs leading to the Master of Science and Doctor of Philosophy degrees in agricultural engineering are offered through the College of Agriculture and Natural Resources.

All programs are designed to provide a fundamental approach to basic engineering principles with emphasis on scientific methods, and to lead to careers in engineering research and development or teaching. Advanced work in the major field of specialization is combined with supporting courses in one or more other fields to develop individuals capable of creative work in engineering science and areas of application.

Students who are enrolled in Master of Science degree programs in the Department of Agricultural Engineering may elect a Specialization in Food Safety. For additional information, refer to the statement on the specialization in the *College of Veterinary Medicine* section of this catalog.

Master of Science

In addition to meeting the requirements of the University as described in the *Graduate Education* section of this catalog, students must meet the requirements specified below.

Admission

Regular Status. Admission to a master's degree program with regular status may be granted by the department, subject to the availability of resources and to the approval of the dean, upon consideration of the likelihood that the applicant will be able to pursue a master's program successfully without taking collateral courses. As evidence of eligibility for admission, the student may offer any of the following:

a. The possession of a bachelor's degree in an accredited program in engineering with a grade–point average not lower than 3.00 for the final two years of the undergraduate program, or with standing in the upper quarter of the graduating class in the student's major.
b. The possession of a bachelor's degree in engineering or a related field where the applicant has shown very high academic achievement, as certified by the department.
c. Evidence of ability and resolution to complete a master's program, as attested by the department upon review of the applicant's academic record, test scores, experience, reference statements, professional qualifications, proposed studies, and other relevant information.

Provisional Status. Admission to a master's degree program with provisional status may be granted by the department, subject to the approval of the dean:

a. To an applicant qualified for regular admission except that collateral courses are deemed necessary, or
b. To an applicant whose record is incomplete.

If collateral courses are required, the minimum acceptable grades and the semesters by which those courses must be completed will be specified on the admission form. The provisional status will be changed to regular status when the conditions specified on the admission form have been met, as certified by the department and approved by the dean.

Program Filing

The student's program of study must be approved before the student completes 6 credits of graduate work in order for the student to continue to enroll in the master's degree program.

For any independent study or selected topics course that is included in the student's approved program of study, the subject material and the instructor must be specified.

Modification of Program

With reference to the student's approved program of study, none of the following types of changes will be approved:

1. Adding or deleting a course for which a grade has already been assigned under any of the three grading systems (numerical, Pass–No Grade, or Credit–No Credit).
2. Adding or deleting a course for which grading was postponed by the use of the DF–Deferred marker.
3. Adding or deleting a course which the student dropped after the middle of the semester and for which "W" or "N" or "0.0" was designated.
4. Adding or deleting a course during the final semester of enrollment in the master's degree program.

Requirements for the Master of Science Degree

The student must:

1. Complete a minimum of 30 credits in 400–, 800–, and 900–level courses under either Plan A (with thesis) or Plan B (without thesis). Courses below the 400 level may not be counted toward the requirements for the degree.
   a. **Requirements for Plan A**: The student must:
      (1) Complete a minimum of 20 credits in courses at the 800–900 level.
      (2) Complete at least 4, but not more than 8, credits in Master's Thesis Research (course number 899 in the department of the student's major).
      (3) Provide to the major professor and to the department a hard–bound copy of the thesis made from the original unbound manuscript submitted to the Office of The Graduate School. Arrangements for delivery of the copies shall be made when the original manuscript is submitted to the Office of The Graduate School.
   b. **Requirements for Plan B**: The student must:
      (1) Complete a minimum of 18 credits in courses at the 800–900 level.
2. Pass the final certifying examination administered by the student's department. It is the student's responsibility to obtain detailed information about this examination from the department.

Academic Standards

1. **Grades**. The student must earn a grade of 2.0 or higher in each course in the approved program of study. The student must repeat any course for which the grade earned was below 2.0.
2. **Cumulative Grade–Point Average**. The student must maintain a cumulative grade–point average of at least 3.00 in the courses in the approved program of study.
3. **Probational Status**. A student is placed on probational status if the student's cumulative grade–point average for the courses in the approved program of study is below 3.00. A student in probational status is not allowed to carry more than 7 credits per semester or to enroll in any course the primary focus of which is independent study.
4. **Retention In and Dismissal From the Program**.
   a. **Cumulative Grade–Point Average**. Should a student's cumulative grade–point average fall below 3.00 after having completed 16 or more credits in courses in the approved program of study, the student may be enrolled in probational status in the master's degree program for one additional semester. If at the end of the additional semester the student's cumulative grade–point average is 3.00 or higher, the student may continue to enroll in the master's degree program. If at the end of the additional semester the student's cumulative grade–point average is still below 3.00, the student will be dismissed from the program.
   b. **Academic Progress and Professional Potential**. Each student's academic progress and professional potential are evaluated by March 15 of each year. A student who in the judgment of the faculty is making satisfactory academic progress and has professional potential may continue to enroll in the master's degree program. A student who in the judgment of the faculty is not making satisfactory academic progress or lacks professional potential will be dismissed from the program.

Transfer Credits

As a member of the Michigan Coalition for Engineering Education (MCEE), MSU will accept up to one less than half of the course credits required for the Master of Science degree program in the College of Engineering in transfer from other MCEE member institutions provided that (1) the student earned a grade of at least 3.0, or the equivalent, in the related courses; (2) the credits were not earned in research or thesis courses; and (3) the total number of credits accepted in transfer from MCEE member institutions and from other institutions does not exceed one less than half of the credits required.

Doctor of Philosophy

In addition to meeting the requirements of the University as described in the Graduate Education section of this catalog, students must meet the requirements specified below.

Admission

Regular Status. Admission to a doctoral degree program with regular status may be granted by the department, subject to the availability of resources and to the approval of the dean, upon consideration of the likelihood that the applicant will be able to pursue a doctoral program successfully without taking collateral courses. As evidence of eligibility for admission, the student may offer any of the following:

a. The possession of a master's degree in engineering or a related field.
b. The completion of the equivalent of a master's degree program in the major field.
c. Evidence of ability and resolution to complete a doctoral program, as attested by the department upon review of the applicant's academic record, test scores, experience, reference statements, professional qualifications, proposed studies, and other relevant information.

Admission to the doctoral program without a master's degree, or the equivalent thereof, will require special consideration by the department and the dean.

Provisional Status. Admission to a doctoral degree program with provisional status may be granted by the department, subject to the approval of the dean:

a. To an applicant qualified for regular admission except that collateral courses are deemed necessary, or
b. To an applicant whose record is incomplete.

If collateral courses are required, the minimum acceptable grades and the semesters by which those courses must be completed will be specified on the admission form. The provisional status will be changed to regular status when the conditions specified on the admission form have been met, as determined by the department and approved by the dean.

Guidance Committee

The student's guidance committee is appointed by the department chairperson in consultation with the student and the appropriate faculty members, and with the approval of the dean. At least two members of the guidance committee shall be from the major department and at least one member shall be from a department outside of the college. The chairperson of the guidance committee will be appointed by the department chairperson after consultation with the student and the person recommended to chair the committee.

Guidance Committee Report

The student's program of study shall be submitted for approval to the department and to the Dean by no later than the end of the student's second semester of enrollment in the doctoral program. For any independent study or selected topics course that is included in the student's program of study, the subject material and the instructor must be specified.

The student's program of study must be approved in order for the student to continue to enroll in the doctoral degree program beyond the second semester.

Modification of Program

With reference to the student's approved guidance committee report, none of the following types of changes will be approved:

1. Adding or deleting a course for which a grade has already been assigned under any of the three grading systems (numerical, Pass–No Grade, or Credit–No Credit).
2. Adding or deleting a course for which grading was postponed by the use of the DF–Deferred marker.
3. Adding or deleting a course which the student dropped after the middle of the semester and for which “W” or “N” or “0.0" was designated.
4. Adding or deleting a course during the final semester of enrollment in the doctoral degree program.

Requirements for the Doctor of Philosophy Degree

The student must:

1. Pass the qualifying examination administered by the student's department. It is the student's responsibility to obtain detailed information about this examination from the department.
2. Pass the doctoral comprehensive examination at least six months prior to the final oral examination in defense of the dissertation. The examination may be retaken no more than twice. It is the student's responsibility to obtain detailed information about this examination from the department.
3. Provide to the major professor and to the department a hard–bound copy of the dissertation made from the original unbound manuscript submitted to the Office of the Graduate School. Arrangements for delivery of the copies shall be made when the original manuscript is submitted to the Office of The Graduate School.

Academic Standards

1. **Grades**. The student must earn a grade of 2.0 or higher in each course in the approved guidance committee report, including collateral courses and courses accepted in transfer. The student must repeat any course for which the grade earned was below 2.0.
2. **Cumulative Grade–Point Average**. The student must maintain a cumulative grade–point average of at least 3.00 in courses in the approved guidance committee report, with the exception of collateral courses and courses accepted in transfer.
3. **Deferred Grades**. A student may accumulate no more than 3 deferred grades (identified by the DF–Deferred marker) in courses other than those courses the primary focus of which is independent study.
4. **Probational Status**. A student is placed on probational status if either or both of the following conditions apply:
   a. The student's cumulative grade–point average for the courses in the approved guidance committee report is below 3.00.
   b. The student has accumulated more than three deferred grades (identified by the DF–Deferred marker) in courses other than those courses the primary focus of which is independent study.

   A student in probational status is not allowed to carry more than 7 credits per semester or to enroll in any course the primary focus of which is independent study.
5. **Retention In and Dismissal From the Program**.
   a. **Cumulative Grade–point Average**. Should a student's cumulative grade–point average fall below 3.00 after having completed half of the courses in the approved guidance committee report, the student may be enrolled in probational status in the doctoral degree program for one additional semester. If at the end of the additional semester the student's cumulative grade–point average is 3.00 or higher, the student may continue to enroll in the doctoral degree program. If at the end of the additional semester the student's cumulative grade–point average is still below 3.00, the student will be dismissed from the program.
   b. **Deferred Grades**. Should a student accumulate more than 3 deferred grades (identified by the DF–Deferred marker) in courses other than those courses the primary focus of which is independent study, the student may be enrolled on probational status in the doctoral degree program for one additional semester. If at the end of the additional semester the student has no more than 3 deferred grades, the student may continue to enroll in the doctoral degree program. If at the end of the additional semester the student still has more than 3 deferred grades, the student will be dismissed from the program.
   c. **Academic Progress and Professional Potentia**l. Each student's academic progress and professional potential are evaluated by March 15 of each year. A student who in the judgment of the faculty is making satisfactory academic progress and has professional potential may continue to enroll in the doctoral degree program. A student who in the judgment of the faculty is not making satisfactory academic progress or lacks professional potential will be dismissed from the program.

GRADUATE SPECIALIZATION IN ENVIRONMENTAL TOXICOLOGY

The College of Engineering, the College of Agriculture and Natural Resources, the College of Natural Science, and the College of Veterinary Medicine administer the Graduate Specialization in Environmental Toxicology. The College of Agriculture and Natural Resources is the primary administrative unit. For additional information, refer to the *Graduate Specialization in Environmental Toxicology* statement in the *College of Agriculture and Natural Resources* section of this catalog.

DEPARTMENT of AGRICULTURAL ENGINEERING

Ajit Srivastava, Chairperson

The Department of Agricultural Engineering is administered jointly by the College of Engineering and the College of Agriculture and Natural Resources.

UNDERGRADUATE PROGRAM

The department offers a Bachelor of Science degree program with a major in biosystems engineering through the College of Engineering. That program is described below.

The department also offers a Bachelor of Science degree program with a major in building construction management through the College of Agriculture and Natural Resources. For information about that program, refer to the statement on the *Department of Agricultural Engineering* in the *College of Agriculture and Natural Resources* section of this catalog.

Students who are enrolled in the Bachelor of Science degree program with a major in biosystems engineering may elect a Specialization in Agricultural and Natural Resources Biotechnology. For additional information, refer to the *Specialization in Agricultural and Natural Resources Biotechnology* statement in the *College of Agriculture and Natural Resources* section of this catalog.

BIOSYSTEMS ENGINEERING

Bachelor of Science

The biosystems engineering program is for students who are interested in designing and managing complex biosystems. The program emphasizes the search for sustainable solutions to problems related to the production and processing of food, efficient use of natural resources, and protection of the environment. The biosystems engineering program integrates the basic sciences of biology, chemistry, mathematics, and physics with engineering and systems sciences and engineering design.

Biosystems engineers are employed in companies that design and manufacture equipment to make food and biologically-based products; in government agencies that protect the environment and food supply; and in consulting firms in the areas of waste management, water quality control, and bioprocess engineering.

Requirements for the Bachelor of Science Degree in Biosystems Engineering

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 128 credits, including general elective credits, are required for the Bachelor of Science degree in Biosystems Engineering.

   The University's Tier II writing requirement for the Biosystems Engineering major is met by completing Biosystems Engineering 487. That course is referenced in item 3. a below.

   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.

   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

				CREDITS
a.	All of the following courses:			39
	BE	130	Engineering Design Fundamentals for Biological Systems	2
	BE	230	Principles of Biosystems Engineering	3
	BE	331	Machinery Principles in Biosystems Engineering	3
	BE	333	Biosystems Engineering Laboratory	1
	BE	350	Heat and Mass Transfer in Biosystems	3
	BE	351	Environmental Thermodynamics	3
	BE	485	Biosystems Design Techniques	2
	BE	487	Biosystems Design Project (W)	3
	CE	321	Introduction to Fluid Mechanics	4
	CEM	143	Survey of Organic Chemistry	4
	CEM	161	Chemistry Laboratory I	1
	EC	210	Economic Principles Using Calculus	3
	ECE	345	Electronic Instrumentation and Systems	3
	MSM	206	Introduction to Solid Mechanics	4
	Chemistry 251 may be used as a substitute for Chemistry 143.			
b.	Three of the following courses:			9
	BE	430	Power and Control Hydraulics	3
	BE	431	Resource Optimization	3
	BE	438	Design and Machinery Structures	3
	BE	453	Engineering Principles of the Plant Environment	3
	BE	456	Electric Power and Control	3
	BE	457	Postharvest Engineering	3
	BE	477	Food Engineering	3
	BE	481	Agricultural and Small Watershed Hydrology	3
c.	Engineering Electives: The student must complete a minimum of 6 credits of approved courses.			6
d.	Cognate. The student must complete a minimum of 15 credits in an approved cognate that includes courses in the College of Agriculture and Natural Resources, in the College of Engineering, or in the biological science areas of the College of Natural Science.			15

The courses that are used to satisfy the Engineering Electives requirement and the Cognate requirement must be chosen to form a career objective. Those courses must be approved by the student's academic adviser.

GRADUATE STUDY

The department offers Master of Science and Doctor of Philosophy programs in biosystems engineering through the College of Agriculture and Natural Resources. For information about those programs, refer to the statement on the *Department of Agricultural Engineering* in the *College of Agriculture and Natural Resources* section of this catalog.

Students who are enrolled in Master of Science degree programs in the Department of Agricultural Engineering may elect a Specialization in Food Safety. For additional information, refer to the statement on the specialization in the *College of Veterinary Medicine* section of this catalog.

DEPARTMENT of CHEMICAL ENGINEERING and MATERIALS SCIENCE

Martin Hawley, Acting Chairperson

UNDERGRADUATE PROGRAMS

Chemical engineers convert raw materials to finished products via pathways involving both chemical and physical changes. The principles of mass, energy, and momentum conservation, chemical reactions, thermodynamics, and economics are utilized in designing and operating large–scale manufacturing processes. These principles are in turn based on the sciences of chemistry, physics, mathematics, and biology which form the underlying foundation of the discipline.

The work of the chemical engineer may be in the production of chemicals, plastics, petroleum products, pharmaceuticals, textiles, foods, energy, specialty materials of construction, and other products. Within these areas, chemical engineers work in research and development and in design, construction, and operation of equipment, processes, and manufacturing plants. Principles developed in the chemical engineering curriculum also prepare the student for a wide variety of alternate career choices including medicine, law, business, and education.

In the past several years, there has been increasing interest in the application of chemical engineering principles to biological processes and to the production of high–strength materials. In response to this, the Department offers special course sequences that address these topics from a chemical engineering viewpoint.

Requirements for the Bachelor of Science Degree in Chemical Engineering

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 128 credits, including general elective credits, are required for the Bachelor of Science degree in Chemical Engineering.

   The University's Tier II writing requirement for the Chemical Engineering major is met by completing Chemical Engineering 316 and 433. Those courses are referenced in item 3. a. below.

   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.

   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

				CREDITS
a.	All of the following courses:			63
	CEM	151	General and Descriptive Chemistry	4
	CEM	152	Principles of Chemistry	3
	CEM	161	Chemistry Laboratory I	1
	CEM	162	Chemistry Laboratory II	1
	CEM	351	Organic Chemistry I	3
	CEM	352	Organic Chemistry II	3
	CEM	355	Organic Laboratory I	2
	CEM	391	Molecular Thermodynamics	3
	CEM	392	Quantum Chemistry	3
	CHE	201	Material and Energy Balances	3
	CHE	301	Chemical Engineering as a Profession	1
	CHE	311	Fluid Flow and Heat Transfer	4
	CHE	312	Mass Transfer and Separations	4
	CHE	316	Unit Operations Laboratory	3
	CHE	321	Thermodynamics for Chemical Engineering	4
	CHE	422	Transport Phenomena	3
	CHE	431	Chemical Reaction Engineering	3
	CHE	432	Process Dynamics and Control	3
	CHE	433	Process Design and Optimization I	4
	CHE	434	Process Design and Optimization II	2
	CHE	473	Chemical Engineering Principles in Polymers and Material Systems	3
	ECE	345	Electronic Instrumentation and Systems	3
	STT	351	Probability and Statistics for Engineering	3
b.	One of the following courses:			3
	CHE	472	Composite Materials Processing	3
	CHE	481	Biochemical Engineering	3
c.	One of the following courses:			3 or 4
	BS	111	Cells and Molecules	3
	MMG	205	Allied Health Microbiology	3
	MMG	301	Introductory Microbiology	3
	PSL	250	Introductory Physiology	4
d.	At least 3 credits in an Engineering Science course.			3
e.	Electives.			

NOTE: Elective courses must be taken at the 200 level or higher with the following exception: 100 level courses may be taken if they are prerequisites for higher level required courses for the major in which they are offered.

Options in Chemical Engineering

In response to increasing interest in the application of chemical engineering principles to related fields, the Department of Chemical Engineering and Materials Science offers options in biochemical engineering, environmental engineering, food science, and polymer science and engineering to students wishing an area of specialization in the degree. Options are available to, but not required of, any student enrolled in the Bachelor of Science degree program in chemical engineering.

NOTE: Completing the Bachelor of Science degree in chemical engineering with an option may require more than 128 credits.

Biochemical Engineering Option

To earn a Bachelor of Science degree in Chemical Engineering with a biochemical engineering option, students must complete requirements 1., 2., 3. a., and 3.e. above and the following:

All of the following courses:			13
BMB	401	Basic Biochemistry	4
BS	111	Cells and Molecules	3
CHE	481	Biochemical Engineering	3
MMG	301	Introductory Microbiology	3
One of the following courses:			3
CHE	491	Selected Topics in Chemical Engineering	3
CHE	882	Advanced Biochemical Engineering	3

Environmental Option

To earn a Bachelor of Science degree in Chemical Engineering with an environmental option, the student must complete requirements 1., 2., and 3. a. above and the following:

All of the following courses:			9
CE	280	Introduction to Environmental Engineering	3
CHE	481	Biochemical Engineering	3
MMG	205	Allied Health Microbiology	3
Three of the following courses:			9
CE	481	Environmental Engineering Chemistry	3
CE	483	Water and Wastewater Treatment	3
CE	485	Solid and Hazardous Waste Management	3
CE	487	Microbiology for Environmental Health Engineering	3

Food Science Option

To earn a Bachelor of Science degree in Chemical Engineering with a food science option, students must complete requirements 1., 2., 3. a. and 3. b. above and all of the following:

All of the following courses:			15
BE	477	Food Engineering	3
FSC	401	Food Chemistry	3
FSC	421	Food Laws and Regulations	3
FSC	440	Food Microbiology	3
MMG	205	Allied Health Microbiology	3

Polymer Science and Engineering Option

To earn a Bachelor of Science degree in Chemical Engineering with a polymer science and engineering option, students must complete requirements 1., 2., 3. a., 3. c., and 3.e. above and all of the following:

All of the following courses:			9
CHE	472	Composite Materials Processing	3
MSM	205	Statics	3
MSM	211	Mechanics of Deformable Solids	3
One of the following courses:			3 or 4
CHE	871	Material Surfaces and Interfaces	3
CHE	872	Polymers and Composities: Manufacturing, Structure and Performance	3
MSM	380	Polymeric Materials	3
MSM	444	Introduction to Composite Materials	3
PKG	323	Packaging with Plastics	4

Upon completion of the required courses for one of these options, the student should contact the Department of Chemical Engineering and Materials Science and request certification for the completion of the option. After the certification is approved by the chairperson of the department and the Dean of the College of Engineering, the Office of the Registrar will enter on the student's academic record the name of the option and the date that it was completed. This certification will appear on the student's transcript.

MATERIALS SCIENCE and ENGINEERING

Materials science and engineering is the study of the structure and composition of materials ranging from atomic and molecular to microscopic scales. The field is concerned with development of new materials, improvement of traditional materials, and synthesis and processing of materials through an understanding of structure and composition of materials. Evaluation of material performance is another very important aspect of the field. Investigation of structure requires such techniques as optical microscopy and image analysis, x–ray diffraction, and transmission and scanning electron microscopy. Processing of materials includes traditional techniques as well as the more modern microwave, plasma, and high–energy laser processing. Performance evaluation requires mechanical testing of various kinds and mechanics of materials. Technology related to the processing and fabrica-

tion of engineered materials such as composites, super alloys for jet engines, high–temperature superconductors, and materials for microelectronics is of great national importance. Thus, materials science and engineering will continue to enjoy challenging opportunities.

Requirements for the Bachelor of Science Degree in Materials Science and Engineering

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 128 credits, including general elective credits, are required for the Bachelor of Science degree in Materials Science and Engineering.

   The University's Tier II writing requirement for the Materials Science and Engineering major is met by completing Materials Science and Engineering 499. That course is referenced in item 3. a. below.

   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.

   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

				CREDITS
a.	All of the following courses:			58
	CEM	152	Principles of Chemistry	3
	CEM	161	Chemistry Laboratory I	1
	ECE	345	Electronic Instrumentation and Systems	3
	ME	221	Statics	3
	ME	222	Mechanics of Deformable Solids	3
	ME	477	Manufacturing Systems I	3
	MSE	250	Materials Science and Engineering	3
	MSE	351	Thermochemistry of Materials	3
	MSE	352	Diffusion in Solids	3
	MSE	355	Mechanical Behavior of Materials	3
	MSE	365	Physical Metallurgy I	3
	MSE	375	Materials Science Laboratory I	1
	MSE	376	Materials Science Laboratory II	1
	MSE	380	Polymeric Materials	3
	MSE	426	Introduction to Composite Materials	3
	MSE	454	Ceramic and Refractory Materials	3
	MSE	455	Theory of Solids	3
	MSE	465	Design and Application of Engineering Materials	3
	MSE	466	Failure Analysis	3
	MSE	499	Senior Research and Design Project (W)	6
	PHY	192	Physics Laboratory for Scientists, II	1
b.	One of the following courses:			3
	CEM	251	Organic Chemistry I	3
	CEM	351	Organic Chemistry I	3
	PHY	215	Thermodynamics and Modern Physics	3
c.	Option: The student must complete *one* of the following four options:			12

Biomaterials Engineering

(1) All of the following courses (9 credits):

BME	424	Biomaterials and Biocompatibility	3
MSE	451	X-Ray Crystallography	3
STT	351	Probability and Statistics for Engineers	3

(2) At least 3 credits from the following courses:

BME	441	Tissue Mechanics	3
BME	445	Biomechanical Design	3
BME	491	Special Topics (MTC)	3
ME	496	Biodynamics	3
MSE	491	Selected Topics	1 to 3

Mechanics of Solids

(1) All of the following courses (9 credits):

ME	423	Intermediate Mechanics of Deformable Solids	3
ME	425	Experimental Mechanics	3
MTH	314	Matrix Algebra with Applications	3

(2) At least one of the following courses (3 credits):

ME	361	Dynamics	3
ME	424	Computational Mathematics	3

Physical Metallurgy

(1) Both of the following courses (6 credits):

MSE	451	X-Ray Crystallography	3
STT	351	Probability and Statistics for Engineering	3

(2) The following course (3 credits):

MSE	476	Physical Processing of Materials	3

(3) At least one of the following courses:

MSE	356	Deformation Mechanisms	3
MSE	476	Physical Processing of Materials	3
MSE	480	Chemical Processing of Materials	3
MSE	483	Environmental Effects on Materials	3

Materials Science and Engineering 476 may be used to satisfy *either* the requirement referenced in item (2) *or* the requirement referenced in item (3), but not both of those requirements.

Processing and Manufacturing

(1) Both of the following courses (6 credits):

MSE	451	X-Ray Crystallography	3
STT	351	Probability and Statistics for Engineering	3

(2) At least one of the following courses (3 credits):

CHE	472	Composite Materials Processing	3
ME	478	Product Development	3
MSE	356	Deformation Mechanisms	3
MSE	476	Physical Processing of Materials	3
MSE	480	Chemical Processing of Materials	3
MSE	483	Environmental Effects on Materials	3

(3) At least one of the following courses (3 credits):

ACC	230	Survey of Accounting Concepts	3
EC	210	Economics Principles Using Calculus	3
GBL	323	Introduction to Business Law	3
STT	471	Statistics for Quality and Productivity	3

GRADUATE STUDY

The Department of Chemical Engineering and Materials Science offers Master of Science and Doctor of Philosophy degree programs in chemical engineering.

The Department of Materials Science and Mechanics offers programs leading to the Master of Science and Doctor of Philosophy degrees. From a wide range of course offerings and research activities, an individual program can be designed to fit the background, capabilities, and aims of the student. Studies in the department may be supplemented with courses offered by other departments in the College of Engineering and in other colleges. For all fields, special emphasis is placed on the mastery of basic principles and methods. Courses and research opportunities are available in the following areas:

MATERIALS SCIENCE AND ENGINEERING: biomaterials, ceramic materials, composite materials, electron microscopy, high–temperature superconductors, impact damage, intermetallic alloys, laser processing of metals, mechanical and physical metallurgy, phase transformation, polymer materials, processing of ceramics, polymers and their composites, shape memory alloys, surface modification of metals and polymers, structural thin film, and superplasticity of metals.

ENGINEERING MECHANICS: applied mathematics, biomechanics, buckling, computational mechanics, continuum mechanics, dynamics, experimental mechanics, fracture mechanics, linear and nonlinear elasticity, mechanics of fatigue, mechanics of composite materials, micromechanics, optical methods of measurement, plasticity, stochastic methods in mechanics, thermoelasticity, vibration, and wave propagation.

CHEMICAL ENGINEERING

Emphasis in the graduate programs in chemical engineering is placed upon a fundamental approach to chemical engineering principles and the applications of chemistry and advanced mathematics. Selected topics in chemical engineering are developed from a fundamental viewpoint, with opportunity for study and research in such areas as process analysis, chemical engineering thermodynamics, chemical reaction engineering, composite materials, polymers, heat transfer, mass transfer, distillation, absorption, extraction, transport phenomena, diffusion, and biochemical engineering.

Master of Science

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

An applicant for admission to the master's degree program in chemical engineering must hold a bachelor's degree in chemical

engineering or a related field and must have a grade–point average that would indicate success in graduate study.

International applicants must submit their scores on the Graduate Record Examination General Test.

Students who are admitted to the program with a bachelor's degree in a field related to chemical engineering will be required to complete the following collateral courses, in addition to the courses that are required for the master's degree:

			CREDITS
CHE	432	Process Systems Control	3
CHE	433	Process Design and Optimization I	3
CHE	804	Thermodynamics and Kinetics in Chemical Engineering	3
CHE	805	Transport and Separation Processes	3

Equivalent undergraduate–level chemical engineering courses may be substituted for Chemical Engineering 804 and 805.

Requirements for the Master of Science Degree in Chemical Engineering

The students must complete a total of 30 credits for the degree under Plan A (with thesis) or a total of 36 credits for the degree under Plan B (without thesis), and meet the requirements specified below:

Requirements for Both Plan A and Plan B:

				CREDITS
1.	Core Courses. All of the following courses:			15
	CHE	801	Advanced Chemical Engineering Calculations	3
	CHE	821	Advanced Chemical Engineering Thermodynamics	3
	CHE	822	Transport Phenomena	3
	CHE	831	Advanced Chemical Reaction Engineering	3
	CHE	892	Seminar	3
2.	Supporting Courses. Six credits in courses outside the Department of Chemical Engineering and Materials Science approved by the student's academic adviser. This requirement is waived for those students who are admitted to the master's degree program with a bachelor's degree in a discipline related to chemical engineering.			6

Additional Requirements for Plan B

Six to 9 credits in a coordinated technical minor.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

An applicant for admission to the Ph.D. degree program in chemical engineering must hold a bachelor's or master's degree in chemical engineering or a related field and must have a grade–point average that would indicate success in graduate study.

International applicants must submit their scores on the Graduate Record Examination General Test.

Requirements for the Doctor of Philosophy Degree in Chemical Engineering

The guidance committee report must be proposed by the student and approved by the student's major professor, the student's guidance committee, the chairperson of the Department of Chemical Engineering and Materials Science, and the Dean of the College of Engineering.

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified by their guidance committees.

MATERIALS SCIENCE AND ENGINEERING

Master of Science

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

The department welcomes applications from students who possess a bachelor's degree in a related engineering or science discipline.

Students who are admitted to the master's program with a degree in a discipline other than materials science and engineering and who have not completed Materials Science and Engineering 351, 355, 365, and 451 or equivalent courses may be admitted with provisional status. Such students will be required to demonstrate proficiency in the material in the courses referenced above, either by completing each of those courses with a grade of at least 3.0 or by passing an examination on the material in those courses sanctioned by the Department Graduate Studies Committee. Of the courses referenced above, only Materials Science and Engineering 451 may be counted toward the requirements for the master's degree.

Requirements for the Master of Science Degree in Materials Science and Engineering

The student must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis) and meet the requirements specified below:

Requirements for Both Plan A and Plan B:

The student must complete:

1. The following core courses in materials science and engineering: Materials Science and Engineering 851, 855, and 862 or 865.
2. At least **one** of the following core courses in engineering mechanics: Mechanical Engineering 825, 861, 820, or 821.
3. At least one credit of Materials Science and Engineering 885.
4. At least one course in mathematics or statistics at the 400–level or above approved by the student's academic adviser.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

An applicant for admission must identify at least one prospective faculty adviser that he or she would like to direct his or her program of study. Admission to the Ph.D. program is contingent on a faculty adviser accepting the student as an advisee.

Requirements for the Doctor of Philosophy Degree in Materials Science and Engineering

The student must complete:

1. At least **one** of the following core courses in engineering mechanics: Mechanical Engineering 825, 861, 820, or 821.

2. At least one course in mathematics or statistics at the 400–level or above.

These requirements are waived for those students who completed equivalent courses prior to enrolling in the doctoral program.

DEPARTMENT of CIVIL and ENVIRONMENTAL ENGINEERING

Ronald S. Harichandran, Chairperson

UNDERGRADUATE PROGRAM

The civil engineering major is designed to provide graduates with a broad understanding of the physical factors involved in the planning, design, and operation of public and private facilities.

The bachelor's degree program in civil engineering is oriented to the application of engineering principles to several areas of specialization, including transportation, structures, geotechnical engineering, environmental engineering, water resources, and pavements and materials. An Environmental Engineering Option is available as an elective to students in the program.

Requirements for the Bachelor of Science Degree in Civil Engineering

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 128 credits, including general elective credits, are required for the Bachelor of Science degree in Civil Engineering.

   The University's Tier II writing requirement for the Civil Engineering major is met by completing Civil Engineering 321 and 341. The University's Tier II writing requirement for students who elect the Environmental Engineering Option is met by completing Civil Engineering 321. Those courses are referenced in item 3. a. below.

   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.

   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

				CREDITS
a.	All of the following courses:			35
	CE	280	Introduction to Environmental Engineering	3
	CE	305	Introduction to Structural Analysis and Design	4
	CE	312	Soil Mechanics	4
	CE	321	Introduction to Fluid Mechanics	4
	CE	337	Civil Engineering Materials I	4
	CE	341	Transportation Engineering	3
	CEM	161	Chemistry Laboratory I	1
	MSM	205	Statics	3
	MSM	211	Mechanics of Deformable Solids	3
	MSM	306	Dynamics	3
	STT	351	Probability and Statistics for Engineering	3
	Students who complete the Environmental Engineering Option do not have to complete Civil Engineering 337.			
b.	One of the following courses:			3
	BE	351	Environmental Thermodynamics	3
	ECE	345	Electronic Instrumentation and Systems	3
	ME	201	Thermodynamics	3
	Students who complete the Environmental Engineering Option do not have to complete this requirement.			
	All of these courses may be used to satisfy either the requirement referenced in item 3.b. or the requirement referenced in item 3.c. but not both of those requirements.			
c.	One of the following courses:			3 or 4
	BE	351	Environmental Thermodynamics	3
	CE	271	Engineering Surveying	4
	ECE	345	Electronic Instrumentation and Systems	3
	ME	201	Thermodynamics	3
	MSM	250	Materials Science and Engineering	3
	Students who complete the Environmental Engineering Option do not have to complete this requirement.			
	Biosystems Engineering 351, Electrical and Computer Engineering 345, and Mechanical Engineering 201 may be used to satisfy either the requirement referenced in item 3.b. or the requirement referenced in item 3.c. but not both of those requirements.			
d.	Four courses, selected from four of the six areas listed below:			12 to 15
	Structures			
	CE	400	Structural Mechanics	3
	CE	405	Design of Steel Structures	3
	CE	406	Design of Concrete Structures	3
	Geotechnical			
	CE	418	Geotechnical Engineering	4
	Hydraulics/Hydrology			
	CE	421	Engineering Hydrology	3
	CE	422	Applied Hydraulics	3
	These courses may be used to satisfy both the requirements for the Bachelor of Science in Civil Engineering and the requirements for the Environmental Engineering Option.			
	Pavements			
	CE	431	Pavement Design and Analysis I	4
	CE	432	Pavement Rehabilitation	3
	Transportation			
	CE	444	Principles of Traffic Engineering	3
	CE	448	Transportation Planning	3
	CE	449	Highway Design	4
	Environmental			
	CE	481	Environmental Engineering Chemistry	3
	CE	483	Water and Wastewater Treatment	3
	CE	485	Solid and Hazardous Waste Management	3
	CE	487	Microbiology for Environmental Health Engineering	3
	These courses may be used to satisfy both the requirements for the Bachelor of Science in Civil Engineering and the requirements for the Environmental Engineering Option.			
e.	A minimum of one course selected from the list below or from c. or d. above (a minimum of one credit):			1 to 4
	CE	480	Water and Wastewater Analysis Laboratory	1
	CE	490	Independent Study	1 to 3
	CE	491	Civil Engineering Design Project	1 to 4
	CE	492	Selected Topics in Civil Engineering	1 to 4
	Students who complete the Environmental Engineering Option do not have to complete this requirement.			

Environmental Engineering Option

The environmental engineering option is available to students who are enrolled in the Bachelor of Science degree program in civil engineering. For students who satisfy the requirements for the Environmental Engineering option, 3 of the credits that are required for the option may also be used to satisfy the 3 credits in engineering science that are required for the Bachelor of Science degree with a major in Civil Engineering. Students who elect this option must complete the following courses:

				CREDITS
1.	All of the following courses:			23
	CE	480	Water and Wastewater Analysis Laboratory	1
	CE	481	Environmental Engineering Chemistry	3
	CE	483	Water and Wastewater Treatment	3
	CE	485	Solid and Hazardous Waste Management	3
	CE	487	Microbiology for Environmental Health Engineering	3
	CEM	151	General and Descriptive Chemistry	4
	CEM	152	Principles of Chemistry	3
	CHE	201	Material and Energy Balances	3
	Civil Engineering 483 and 485 may be used to satisfy both the requirements for the Environmental Engineering Option and the requirements for the Bachelor of Science in Civil Engineering.			
2.	One of the following courses:			3 or 4
	BE	351	Environmental Thermodynamics	3
	CHE	321	Thermodynamics for Chemical Engineering	4
	ME	201	Thermodynamics	3
	Biosystems Engineering 351 and Mechanical Engineering 201 may be used to satisfy both the requirements for the Environmental Engineering Option and the requirements for the Bachelor of Science in Civil Engineering.			
3.	One of the following courses:			3
	CE	421	Engineering Hydrology	3
	CE	422	Applied Hydraulics	3
	These courses may be used to satisfy both the requirements for the Environmental Engineering Option and the requirements for the Bachelor of Science in Civil Engineering.			
4.	One of the following courses:			3
	CEM	251	Organic Chemistry I	3
	CEM	351	Organic Chemistry I	3

Upon completion of the required courses, the student should contact the Department of Civil and Environmental Engineering and request certification for the completion of the Environmental Engineering Option. After the certification is approved by the chairperson of the department and the Dean of the College of Engineering, the Office of the Registrar will enter on the student's academic record the name of the option and the date that it was completed. This certification will appear on the student's transcript.

GRADUATE STUDY

The Department of Civil and Environmental Engineering offers the graduate degree programs that are listed below:

Master of Science
- Civil Engineering
- Environmental Engineering

Doctor of Philosophy
- Civil Engineering
- Environmental Engineering
- Environmental Engineering—Environmental Toxicology

Descriptions of the degree programs, organized by fields of study in alphabetical order, are presented below.

Students who are enrolled in Master of Science degree programs in the Department of Civil and Environmental Engineering may elect a Specialization in Environmental Toxicology. For additional information, refer to the *Graduate Specialization in Environmental Toxicology* statement in the *College of Agriculture and Natural Resources* section of this catalog.

CIVIL ENGINEERING

Students in the master's and doctoral degree programs in civil engineering may pursue advanced study in the areas of structures, fluid mechanics and hydraulics, geotechnical engineering, pavements, and transportation.

Master of Science

The student plans a program of study with the help of his or her academic adviser and subject to the approval of the adviser.

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

An applicant for admission to the master's degree program in civil engineering should have a bachelor's degree in civil engineering or a related field and should have a grade–point average that would indicate success in graduate study. Examples of fields that are related to civil engineering are other engineering professional fields, physics, computer science, urban planning, and chemistry.

Depending on their undergraduate programs and their specialties within civil engineering, students who are admitted to the master's degree program with bachelor's degrees in fields related to civil engineering may be required to complete collateral courses.

All applicants are encouraged to submit their scores from the Graduate Record Examination General Test.

Requirements for the Master of Science Degree in Civil Engineering

The student must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis).

A student under Plan A must complete at least 4, but not more than 8, credits of Civil Engineering 899. Should the student complete more than 8 credits of Civil Engineering 899, no more than 8 credits may be counted toward the requirements for the degree.

A student under Plan B may choose to complete a research project or a design project as part of the 30 credits required for the degree. A student who elects either of these options must complete at least 1, but not more than 3, credits of Civil Engineering 892 or at least 3, but not more than 5, credits of Civil Engineering 893.

Doctor of Philosophy

Admission

All applicants are encouraged to submit their scores from the Graduate Record Examination General Test.

Requirements for the Doctor of Philosophy Degree in Civil Engineering

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified by their guidance committees.

ENVIRONMENTAL ENGINEERING

Students in the master's and doctoral degree programs in environmental engineering may pursue advanced study in the areas of biological and chemical treatment of hazardous substances in soils, leachates, industrial wastes, and groundwater; the fate and movement of chemical contaminants in surface water, groundwater, and soils; and environmental chemistry.

Master of Science

The student plans a program of study with the help of his or her academic adviser and subject to the approval of the adviser.

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

Applicants for admission are expected to have a level of competency equivalent to that achieved by earning an undergraduate degree in environmental engineering, or in civil engineering with an environmental engineering specialization. The undergraduate program should have included courses in mathematics through differential equations, chemistry, physics (mechanics), fluid mechanics, computer programming, and the design of water and wastewater treatment processes.

Depending on their undergraduate programs and their specialties within environmental engineering, students who are admitted to the master's degree program with bachelor's degrees in fields related to environmental engineering may be required to complete collateral courses.

All applicants are encouraged to provide their scores from the Graduate Record Examination General Test.

Requirements for the Master of Science Degree in Environmental Engineering

The student must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis).

A student under Plan A must complete at least 4, but not more than 8, credits of Environmental Engineering 899. Should the student complete more than 8 credits of Environmental Engineering 899, no more than 8 credits may be counted toward the requirements for the degree.

A student under Plan B may choose to complete a research project or a design project as part of the 30 credits required for the degree. A student who elects either of these options must complete at least 1, but not more than 3, credits of Environmental Engineering 892 or at least 3, but not more than 5, credits of Environmental Engineering 893.

Doctor of Philosophy

Admission

All applicants are encouraged to submit their scores from the Graduate Record Examination General Test.

Requirements for the Doctor of Philosophy Degree in Environmental Engineering

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified by their guidance committees.

ENVIRONMENTAL ENGINEERING—ENVIRONMENTAL TOXICOLOGY

Doctor of Philosophy

For information about the Doctor of Philosophy degree program in environmental engineering—environmental toxicology, refer to the statement on *Multidepartmental Doctoral Programs in Environmental Toxicology* in the *Graduate Education* section of this catalog.

DEPARTMENT of COMPUTER SCIENCE and ENGINEERING

Wayne R. Dyksen, Chairperson

UNDERGRADUATE PROGRAM

Computer science encompasses the broad areas of information processing and problem solving using digital computers. Students learn to analyze, design, and build integrated software and hardware digital systems that process, transmit, and reason about information in order to solve problems. Computer science graduates are employed in essentially all areas of industry, government, and education. They serve as system analysts involved with problems in business and research, designers and planners of process and production control software systems, computer component and system designers, programmers, and teachers.

The Bachelor of Science program provides both a theoretical foundation in computer science, required for continued success in this rapidly changing field, as well as practical experience with current tools and techniques. To achieve these goals, students take diverse courses that span a spectrum of knowledge ranging from theoretical foundations, which enable rigorous analysis of computational problems and solutions, to applied design and engineering methods. At the upper level, students choose from a wide range of elective courses including those focusing on computer networks, computer architecture, artificial intelligence, database systems, and computer graphics. The senior year culminates with a team-oriented, open-ended, design course building on much of what one has learned throughout the undergraduate experience. A critical component to the program's success is that most courses, including the first programming course, provide active learning opportunities in small scheduled laboratories. Complementing these major areas, the cognate provides an excellent opportunity to develop an individually selected area of interest.

Students majoring in computer science with interests in other areas have the opportunity to consult and work with interested faculty from a wide range of academic disciplines.

Requirements for the Bachelor of Science Degree in Computer Science

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 120 credits, including general elective credits, are required for the Bachelor of Science degree in Computer Science.
   The University's Tier II writing requirement for the Computer Science major is met by completing Computer Science and Engineering 498, referenced in item 3. b. below.
   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement.
2. The requirements of the College of Engineering for the Bachelor of Science degree.
   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

	CREDITS
a. Bioscience - Courses may not be used to satisfy both (1) and (2) below	4 or 5
(1) One of the following courses:	
BS 110 Organisms and Populations	4
BS 111 Cells and Molecules	3
ENT 205 Pests, Society and Environment	3
MMG 205 Allied Health Microbiology	3
PLB 105 Plant Biology	3
PSL 250 Introductory Physiology	4
ZOL 141 Introductory Human Genetics	3
Biological Science 110 satisfies both requirement 3.a.(1) and 3.a.(2).	

(2) Two of the following courses:
BS 111L Cell and Molecular Biology Laboratory 2
CEM 161 Chemistry Laboratory I 1
CEM 162 Chemistry Laboratory II 1
MMG 206 Allied Health Microbiology Laboratory 1
PHY 191 Physics Laboratory for Scientists, I 1
PHY 192 Physics Laboratory for Scientists, II 1
PLB 106 Plant Biology Laboratory 1

b. All of the following courses: 38
CSE 232 Introduction to Programming II 4
CSE 260 Discrete Structures in Computer Science 4
CSE 320 Computer Organization and Assembly Language Programming 4
CSE 331 Algorithms and Data Structures 4
CSE 370 Software Engineering 4
CSE 410 Operating Systems 4
CSE 498 Collaborative Design (W) 4
STT 351 Probability and Statistics for Engineering 3

c. One of the following courses: . . . . . 3 or 4
CSE 450 Translation of Programming Languages 4
CSE 452 Organization of Programming Languages 4
CSE 460 Computability and Formal Language Theory 3
Any of these courses may be used to satisfy either the requirement in 3. c. or 3.d. but not both of those requirements.

d. At least two of the following courses totaling 7 to 8 credits: . . . . . 7 to 8
CSE 420 Computer Architecture 4
CSE 422 Computer Networks 4
CSE 440 Artificial Intelligence and Symbolic Programming 4
CSE 450 Translation of Programming Languages 4
CSE 452 Organization of Programming Languages 4
CSE 460 Computability and Formal Language Theory 3
CSE 471 Media Processing and Multimedia Computing . . . 4
CSE 472 Computer Graphics 4
CSE 480 Database Systems 4
MTH 416 Introduction to Algebraic Coding 3
MTH 451 Numerical Analysis I 3
MTH 481 Discrete Mathematics I 3
Computer Science and Engineering 450, 452 and 460 may be used to satisfy either the requirement in 3.c. or 3.d. but not both of those requirements.

e. Required Cognate: 15
A minimum of four courses totaling 15 or more credits outside the College of Engineering.
Option A: At least 6 of the 15 credits must be in courses at the 300-400 level.
Option B: A sequence of at least four courses in a foreign language.
Option C: Business Cognate:
All of the following courses:
ACC 230 Survey of Accounting Concepts 3
EC 210 Economics Principles Using Calculus 3
FI 320 Introduction to Finance 3
GBL 323 Introduction to Business Law 3
MSC 327 Introduction to Marketing 3
Both the cognate and the related courses must be approved by the academic adviser of the Department of Computer Science and Engineering. The cognate should enhance the student's ability to apply analytic procedures in a specific subject area. Cognates in the following areas are available to students in Computer Science: business, communication arts, foreign language, mathematics, the natural sciences, philosophy, psychology, the social sciences, and telecommunication. Students may complete cognates in other areas with the approval of the Department of Computer Science and Engineering academic adviser.

TEACHER CERTIFICATION OPTION

A computer science disciplinary minor is available for teacher certification.

Students who elect the computer science disciplinary minor must contact the Department of Computer Science and Engineering.

For additional information, refer to the statement on *TEACHER CERTIFICATION* in the *Department of Teacher Education* section of this catalog.

GRADUATE STUDY

The Department of Computer Science and Engineering offers programs leading to the Master of Science and Doctor of Philosophy degrees. Advanced study is available in the areas of computer architecture, design automation, distributed systems, computer networks, artificial intelligence, knowledge-based systems, database systems, parallel systems and algorithms, pattern recognition, image processing, computer vision, software engineering, and theory of computing. Interdisciplinary work with other departments is encouraged.

The Department operates a number of different laboratories with a variety of modern computing equipment. The Artificial Intelligence and Knowledge Based Systems Laboratory is supported by Sun and Macintosh workstations. The Pattern Recognition and Image Processing Laboratory provides multiple systems for digitizing and processing both intensity and range images and provides a workstation environment for users. The Advanced Computing Systems Laboratory supports a 640 node nCUBE parallel processor, a 96–node BBN Butterfly GP–1000 parallel processor, and access to an array of other parallel machines at the Advanced Computer Research Facility of Argonne National Laboratory.

The instructional laboratories include a digital system simulation laboratory for the design and modeling of digital circuits, as well as several open laboratories equipped with networked workstations and terminals. All computer science graduate students have a permanent email address. Via computer networks, students can keep in contact with colleagues, research groups, data bases, and agencies throughout the world. Other college and university resources include the Case Center for Computer–Aided Design and Manufacturing, the Electronics Research and Development Laboratory for VLSI design, an IBM 3090/180E vector processor, and a quad processor Convex C–240 system.

Students who are enrolled in master's or doctoral degree programs in the Department of Computer Science and Engineering may elect an Interdepartmental Specialization in Cognitive Science. For additional information, refer to the statement on *Interdepartmental Graduate Specializations in Cognitive Science* in the *College of Social Science* section of this catalog. For additional information, contact the Department of Computer Science and Engineering.

Master of Science

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

Applicants for admission should possess a bachelor's degree in computer science or a related field such as mathematics, physics, or electrical engineering. All applicants must submit their scores from the Graduate Record Examination (GRE) General Test. They must also submit their scores from the GRE Subject Test in Computer Science or a closely related field.

Requirements for the Master of Science Degree in Computer Science

The student must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis) and meet the requirements specified below:

Requirements for Both Plan A and Plan B:

The student must complete:
1. At least one semester of a graduate seminar.
2. A minimum of 20 credits in 800–900 level courses, excluding Computer Science and Engineering 890.

Additional Requirements for Plan A:

The student must complete:
1. At least **one** course from **each** of the following groups of courses:

a. Computer Science and Engineering 802, 803, 841. Computer Science and Engineering 845 and 846 combined may be substituted for one of those courses.
b. Computer Science and Engineering 807, 808, 814, 880.
c. Computer Science and Engineering 812, 820, 822, 838.
d. Computer Science and Engineering 830, 835, 860, 862.

2. At least 6, but not more than 8, credits of CSE 899 Master's Thesis Research.

Additional Requirements for Plan B:

The student must complete **one** of the following two options:

Option 1:
A minimum of 30 credits in courses approved by the student's academic adviser.

Option 2:
a. At least **one** course from **each** of the following groups of courses:
   (1) Computer Science and Engineering 802, 803, 841. Computer Science and Engineering 845 and 846 combined may be substituted for one of those courses.
   (2) Computer Science and Engineering 807, 808, 814, 880.
   (3) Computer Science and Engineering 812, 820, 822, 838.
   (4) Computer Science and Engineering 830, 835, 860, 862.
b. A supervised project while enrolled in 4 credits of Computer Science and Engineering 898.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

Applicants should be in the top 25 percent of their master's degree classes and should have a grade–point average of at least 3.50 on a scale of 4.0. For persons who are enrolled in MSU's master's degree program in computer science, their progress in the Ph.D. Qualifying Examination will also be considered.

Applicants must submit their scores on the Graduate Record Examination General Test and Subject Test in Computer Science. A score of 85 percent or higher on the Computer Science Subject Test is required for admission.

Applicants who have a Bachelor of Science degree and who demonstrate exceptional potential for graduate study may be accepted for admission to the doctoral program.

Requirements for the Doctor of Philosophy Degree in Computer Science

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified by their guidance committees. All courses that are used to satisfy the requirements for the degree must have been completed under the numerical grading system.

DEPARTMENT of ELECTRICAL and COMPUTER ENGINEERING

Satish S. Udpa, Chairperson

UNDERGRADUATE PROGRAMS

COMPUTER ENGINEERING

Computer engineering is concerned with the organization and design of computers and computer systems. The study of computer hardware and software, and their integration and application, is emphasized. The undergraduate program in computer engineering integrates studies in mathematics, basic sciences, engineering sciences, and engineering design. The program is structured to establish analytical and design skills in areas such as computer architecture, digital logic design, computer communication networks, digital computer control, integrated circuit engineering, software engineering, operating systems, data structures and algorithms, computer–aided engineering, and electronic design automation. Complementing these fundamentals, the program also provides opportunities for specialization in individually selected areas of interest.

Requirements for the Bachelor of Science Degree in Computer Engineering

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 128 credits, including general elective credits, are required for the Bachelor of Science degree in Computer Engineering.
   The University's Tier II writing requirement for the Computer Engineering major is met by completing Electrical and Computer Engineering 480. That course is referenced in item 3. b. below.
   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.
   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

				CREDITS
a.	One of the following courses:			1
	CEM	161	Chemistry Laboratory I	1
	PHY	191	Physics Laboratory for Scientists, I	1
b.	All of the following courses:			50
	CSE	231	Introduction to Programming I	4
	CSE	232	Introduction to Programming II	4
	CSE	260	Discrete Structures in Computer Science	4
	CSE	410	Operating Systems	4
	CSE	420	Computer Architecture	4
	ECE	200	Electric Circuits	4
	ECE	230	Digital Logic Fundamentals	3
	ECE	302	Electronic Circuits	3
	ECE	303	Electronics Laboratory	1
	ECE	313	Control Systems	3
	ECE	331	Microprocessors and Digital Systems	4
	ECE	360	Signals and Linear Systems	4
	ECE	480	Senior Design	5
	STT	351	Probability and Statistics for Engineering	3
c.	One of the following courses:			3
	ME	201	Thermodynamics	3
	ME	221	Statics	3

d.	One of the following three groups of courses:			8
	(1) ECE 410	VLSI Design	4	
	ECE 411	Electronic Design Automation	4	
	(2) CSE 370	Software Engineering	4	
	CSE 450	Translation of Programming Languages	4	
	(3) CSE 422	Computer Networks	4	
	ECE 457	Communication Systems	3	
	ECE 458	Communication Systems Laboratory	1	
e.	Technical electives selected from an approved list in consultation with the student's academic adviser			7 to 9

ELECTRICAL ENGINEERING

The program provides both required and elective studies in communications, computers, control systems, electromagnetics, electronics, materials processing, power, signals, solid state, and biomedical engineering. It places emphasis on the fundamentals of science and mathematics and their application to the solution of contemporary problems that are within the purview of professional electrical engineers. The program is designed to establish a sound scientific basis for continuous growth in professional competence.

Requirements for the Bachelor of Science Degree in Electrical Engineering

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 128 credits, including general elective credits, are required for the Bachelor of Science degree in Electrical Engineering.
   The University's Tier II writing requirement for the Electrical Engineering major is met by completing Electrical and Computer Engineering 480. That course is referenced in item 3. b. below.
   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.
   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

				CREDITS
a.	One of the following courses:			1
	CEM 161	Chemistry Laboratory I	1	
	PHY 191	Physics Laboratory for Scientists, I	1	
b.	All of the following courses:			30
	CSE 231	Introduction to Programming I	4	
	ECE 200	Electric Circuits	4	
	ECE 230	Digital Logic Fundamentals	3	
	ECE 302	Electronic Circuits	3	
	ECE 303	Electronics Laboratory	1	
	ECE 305	Electromagnetic Fields and Waves I	3	
	ECE 360	Signals and Linear Systems	4	
	ECE 480	Senior Design	5	
	STT 351	Probability and Statistics for Engineering	3	
c.	One of the following courses:			3
	ME 201	Thermodynamics	3	
	MSM 205	Statics	3	
d.	Four of the following courses:			13 or 14
	ECE 306	Electromagnetic Fields and Waves II	4	
	ECE 313	Control Systems	3	
	ECE 320	Energy Conversion and Power Electronics	3	
	ECE 331	Microprocessors and Digital Systems	4	
	ECE 474	Principles of Electronic Devices	3	
e.	At least 9 credits in at least three of the following courses, including at least one course that has a laboratory:			9 to 12
	ECE 410	VLSI Design	4	
	ECE 411	Electronic Design Automation	4	
	ECE 418	Algorithms of Circuit Design	3	
	ECE 421	Power System Analysis	4	
	ECE 435	Electromagnetic Waves and Applications	4	
	ECE 457	Communication Systems	3	
	ECE 458	Communication Systems Laboratory	1	
	ECE 466	Digital Signal Processing and Filter Design	3	
	ECE 476	Electro–Optics	3	
	ECE 477	Microelectronic Fabrication	3	
	ECE 484	Applications of Analog Integrated Circuits	4	
	ECE 485	Digital Control and Robotics	4	
f.	At least 9 credits from a list of approved technical electives available from the Department of Electrical and Computer Engineering			9

GRADUATE STUDY

The Department of Electrical and Computer Engineering offers programs leading to the Master of Science and Doctor of Philosophy degrees. Programs for advanced study are available in the areas of signal processing, communication sciences, digital circuits and computers, electromagnetics (radiation, scattering, interactions), plasmas, electronic materials and devices, electronic circuits and instrumentation, VLSI design, systems and control, power, robotics, and neural networks.

Master of Science

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

Applicants for admission should possess a Bachelor of Science degree in electrical engineering or a related field such as physics, mathematics, or computer science, and should have a grade–point average that would indicate success in graduate study.

Students who are admitted without a Bachelor of Science degree in electrical engineering may be required to complete collateral courses.

International applicants are required to submit Graduate Record Examination General Test scores.

Requirements for the Master of Science Degree in Electrical Engineering

The student must complete a total of 30 credits under either Plan A (with thesis) or Plan B (without thesis) and meet the requirements specified below:

Requirements for Both Plan A and Plan B:

1. **Core Courses**. At least **one** course from at least **three** of the following six areas:
   a. Communication and Signal Processing: Electrical and Computer Engineering 847, 863, 864.
   b. Digital Circuits and Computers: Electrical and Computer Engineering 809, 813, 820.
   c. Electromagnetics: Electrical and Computer Engineering 835, 836, 841, 850.
   d. Electronic Devices and Circuits: Electrical and Computer Engineering 831, 874, 875.
   e. Systems and Control: Electrical and Computer Engineering 826, 827, 829.
   f. Power Systems: Electrical and Computer Engineering 823, 824, 825.
2. **Supporting Courses**: At least 6 credits in approved courses in areas such as mathematics, statistics, or physics.

Doctor of Philosophy

Admission

International applicants are required to submit Graduate Record Examination General Test scores.

Requirements for the Doctor of Philosophy Degree in Electrical Engineering

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified by their guidance committees. All courses that are used to satisfy the requirements for the degree must have been completed under the numerical grading system.

DEPARTMENT of MECHANICAL ENGINEERING

Ronald Rosenberg, Chairperson

UNDERGRADUATE PROGRAMS

ENGINEERING MECHANICS

Mechanics is an engineering science dealing with the behavior of matter under the action of external environments such as forces, pressures, and thermal effects. Its role in engineering lies in the application of physics, mathematics, and experimental techniques to some complex problems of modern technology. Mechanics applications are found in all areas of engineering and in many interdisciplinary fields, such as biomechanics, geomechanics, and environmental science.

Many of the techniques of applied mathematics were developed simultaneously with the science of mechanics, and to this day the application of the principles of mechanics requires a strong capability in applied mathematics. Concurrently, modern experimental measurement and data acquisition, and reduction techniques, are also important. This curriculum recognizes these needs, and requires a balanced program in the classical and modern principles of mechanics, mathematics, and experimental methods. The program is designed to develop in the student the ability to model the behavior of matter mathematically, to predict its responses to forces, and to understand it physically through the use of experimental methods.

This program provides flexibility to enable undergraduates to build a strong background in mechanics and to develop a minor in one of the allied areas of the traditional professional fields.

Requirements for the Bachelor of Science Degree in Engineering Mechanics

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 128 credits, including general elective credits, are required for the Bachelor of Science degree in Engineering Mechanics.

   The University's Tier II writing requirement for the Engineering Mechanics major is met by completing Mechanical Engineering 492. That course is referenced in item 3. a. below.

   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.

   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

				CREDITS
a.	All of the following courses:			38
	CEM	152	Principles of Chemistry	3
	CEM	161	Chemistry Laboratory I	1
	ECE	345	Electronic Instrumentation and Systems	3
	ME	180	Engineering Graphic Communications	3
	ME	221	Statics	3
	ME	222	Mechanics of Deformable Solids	3
	ME	361	Dynamics	3
	ME	423	Intermediate Mechanics of Deformable Solids	3
	ME	424	Computational Mechanics	3
	ME	492	Senior Research and Design Project (W)	6
	MSE	250	Materials Science and Engineering	3
	MTH	314	Matrix Algebra with Applications	3
	PHY	192	Physics Laboratory for Scientists, II	1
b.	One of the following courses:			4
	CE	321	Introduction to Fluid Mechanics	4
	CHE	311	Fluid Flow and Heat Transfer	4
	ME	332	Fluid Mechanics	4
c.	One of the following courses:			3
	ME	201	Thermodynamics	3
	MSE	351	Thermochemistry of Materials	3
d.	One of the following courses:			3
	ME	425	Experimental Mechanics	3
	ME	464	Intermediate Dynamics	3
	ME	496	Biodynamics	3

Mechanical Engineering 425, 464, and 496 may be used to satisfy *either* the requirement referenced in item 3. d. *or* the requirements for the **Experimental Mechanics** option, but not both of those requirements.

Mechanical Engineering 425 may be used to satisfy *either* the requirement referenced in item 3. d. *or* the requirements for the **Computational Mechanics** option, but not both of those requirements.

e. Option: The student must complete *one* of the following five options: . . . . . 22 to 34

(1) **Biomechanics** (22 or 23 credits):

(a) All of the following courses (16 credits):

BME	424	Biomaterials and Biocompatibility	3
BME	441	Tissue Mechanics	3
BME	445	Biomechanical Design	3
ME	496	Biodynamics	3
PSL	250	Introductory Physiology	4

(b) One of the following courses (3 or 4 credits):

BS	110	Organisms and Populations	4
BS	111	Cells and Molecules	3

(c) One of the following courses (3 credits):

MTH	424	Applied Advanced Calculus	3
STT	351	Probability and Statistics for Engineering	3

(2) **Computational Mechanics** (25 or 26 credits):

(a) All of the following courses (10 credits):

ME	461	Mechanical Vibrations	4
MSE	426	Introduction to Composite Materials	3
MSE	466	Failure Analysis	3

(b) Three of the following courses (9 or 10 credits):

ME	410	Heat Transfer	3
ME	425	Experimental Mechanics	3
ME	432	Intermediate Fluid Mechanics	3
ME	440	Aerospace Engineering Fundamentals	3
ME	451	Control Systems	4
MSE	355	Mechanical Behavior of Materials	3
MSE	356	Deformation Mechanisms	3
PHY	480	Computational Physics	3

Mechanical Engineering 425 may be used to satisfy *either* the requirement referenced in item 3. d. *or* the requirements for the **Computational Mechanics** option, but not both of those requirements.

Only *one* of the following courses may be used to satisfy the requirements for the **Computational Mechanics** option: Mechanical Engineering 410 or 432 or 440 or 451.

(c) Two of the following courses (6 credits):

MTH	424	Applied Advanced Calculus	3
MTH	443	Boundary Value Problems for Engineers	3
MTH	451	Numerical Analysis I	3
STT	351	Probability and Statistics for Engineering	3

(3) **Experimental Mechanics** (33 or 34 credits):

(a) All of the following courses (11 credits):

MSE	355	Mechanical Behavior of Materials	3
MSE	376	Materials Science Laboratory II	1
MSE	466	Failure Analysis	3
PHY	191	Physics Laboratory for Scientists, I	1
STT	351	Probability and Statistics for Engineering	3

(b) One of the following courses (3 credits):

ME	425	Experimental Mechanics	3
ME	464	Intermediate Dynamics	3
ME	496	Biodynamics	3

Mechanical Engineering 425, 464, and 496 may be used to satisfy *either* the requirement referenced in item 3. d. *or* the requirements for the **Experimental Mechanics** option, but not both of those requirements.

(c) Fourteen credits from the following courses:

BME	441	Tissue Mechanics	3
BME	445	Biomechanical Design	3
MSE	375	Materials Science Laboratory I	1
MSE	426	Introduction to Composite Materials	3

PHY 440 Electronics 4
STT 471 Statistics for Quality and Productivity . . 3

(d) One of the following *groups* of courses (5 or 6 credits):

Group 1
ME 410 Heat Transfer 3
ME 412 Heat Transfer Laboratory 2

Group 2
PHY 215B Thermodynamics and Modern Physics, CBI 3
PHY 431 Optics I 3

(4) **Mechanics of Manufacturing** (24 credits):

(a) All of the following courses (15 credits):
EC 201 Introduction to Microeconomics 3
ME 477 Manufacturing Processes 3
MSE 355 Mechanical Behavior of Materials 3
MSE 466 Failure Analysis 3
STT 351 Probability and Statistics for Engineering 3

(b) One of the following courses (3 credits):
ACC 230 Survey of Accounting Concepts 3
EC 202 Introduction to Macroeconomics 3
GBL 323 Introduction to Business Law 3

(c) Two of the following courses (6 credits):
BME 445 Biomechanical Design 3
BME 491 Special Topics (MTC) 3
CHE 472 Composite Materials Processing 3
ME 478 Product Development 3
MSE 356 Deformation Mechanisms 3
MSE 426 Introduction to Composite Materials . . . 3
STT 471 Statistics for Quality and Productivity . . 3

(5) **Mechanics of Materials** (23 credits):

(a) All of the following courses (17 credits):
MSE 355 Mechanical Behavior of Materials 3
MSE 356 Deformation Mechanisms 3
MSE 365 Physical Metallurgy I 3
MSE 375 Materials Science Laboratory I 1
MSE 376 Materials Science Laboratory II 1
MSE 380 Polymeric Materials 3
MSE 454 Ceramic and Refractory Materials 3

(b) Two of the following courses (6 credits):
BME 445 Biomechanical Design 3
MSE 426 Introduction to Composite Materials . . . 3
MSE 455 Theory of Solids 3
MSE 465 Design and Application of Engineering Materials 3
MSE 466 Failure Analysis 3

MANUFACTURING ENGINEERING

The Bachelor of Science degree program in manufacturing engineering emphasizes the merging of the engineering design of a product with the process design for its manufacture, often referred to as concurrent (or simultaneous) engineering. The program is targeted to prepare students for the Master of Science degree in Manufacturing and Engineering Management offered by The Eli Broad College of Business. Students who meet the admission requirements of that program are encouraged to apply during their first semester of their senior year.

In addition to meeting the requirements of the University for bachelor's degrees, and of the College of Engineering for the Bachelor of Science degree, the student must meet the requirements specified below.

Requirements for the Bachelor of Science Degree in Manufacturing Engineering

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 121 credits, including general elective credits, are required for the Bachelor of Science degree in Manufacturing Engineering.

   The University's Tier II writing requirement for the Manufacturing Engineering major is met by completing Mechanical Engineering 477 and 478. Those courses are referenced in item 3. a. below.

   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Science that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.

   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major:

CREDITS

a. All of the following courses (49 credits):
CEM 161 Chemistry Laboratory I 1
EC 210 Economics Principles Using Calculus 3
ECE 313 Control Systems 3
ECE 345 Electronic Instrumentation and Systems 3
ECE 415 Computer Aided Manufacturing 3
EGR 393 Engineering Cooperative Education 3
ME 180 Engineering Graphic Communication 3
ME 201 Thermodynamics 3
ME 221 Statics 3
ME 222 Mechanics of Deformable Solids 3
ME 361 Dynamics 3
ME 371 Mechanical Design I 3
ME 477 Manufacturing Processes 3
ME 478 Manufacturing Product Development 3
MSE 250 Materials Science and Engineering 3
MSE 355 Mechanical Behavior of Materials 3
STT 351 Probability and Statistics for Engineering 3
Economics 201 and 202 may be substituted for Economics 210.

b. Engineering or Business Electives 9
Elective credits chosen from an approved list in consultation with the student's academic adviser.

Requirements for the Master of Science Degree in Manufacturing and Engineering Management

Refer to the Department of Marketing and Supply Chain Management statement in *The Eli Broad College of Business and The Eli Broad Graduate School of Management* section of this catalog.

MECHANICAL ENGINEERING

Mechanical engineers apply the fundamental principles of mechanics, thermosciences, and design to the needs of people. These principles are delineated in the subjects of solid and fluid mechanics, thermodynamics, heat transfer, design, systems analysis and simulation, and material science. Practicing mechanical engineers work in a broad area of application which includes such industries as automotive, chemical, foundry, power plants, food processing, aerospace and aircraft, computer, machine tool, and many others.

The undergraduate mechanical engineering program is directed to emphasize fundamental principles, to develop analytical and experimental capabilities of students to model and solve engineering problems, to use appropriate mathematical language, and to introduce students to design, experimental methods, computers, and systems.

For students who desire an international experience as part of their education, the department sponsors the Mechanical Engineering in Aachen Program. During the spring semester a small group of juniors, escorted by a faculty member, travels to Aachen, Germany, to pursue their normal studies overseas at the Technical University of Aachen. Students have outstanding opportunities to participate in German research, explore industrial activities, and experience German culture and life–style.

Students admitted to the mechanical engineering major who have strong academic records in their first two years are invited to participate in the Mechanical Engineering Honors Program. The purpose of the program is to provide an enriched, research–oriented experience. No additional credits are required for the degree.

Requirements for the Bachelor of Science Degree in Mechanical Engineering

1. The University requirements for bachelor's degrees as described in the *Undergraduate Education* section of this catalog; 128 credits, including general elective credits, are required for the Bachelor of Science degree in Mechanical Engineering.

   The University's Tier II writing requirement for the Mechanical Engineering major is met by completing Mechanical Engineering 332, 412, 451, 461, and 481. Those courses are referenced in item 3. b. (1) below.

   Students who are enrolled in the College of Engineering may complete the alternative track to Integrative Studies in Biological and Physical Sciences that is described in item 1. under the heading **Graduation Requirements for All Majors** in the College statement. Certain courses referenced in requirement 3. below may be used to satisfy the alternative track.
2. The requirements of the College of Engineering for the Bachelor of Science degree.

   The credits earned in certain courses referenced in requirement 3. below may be counted toward College requirements as appropriate.
3. The following requirements for the major: . . . . . CREDITS

a. All of the following courses outside the Department of Mechanical Engineering: 22

CEM	161	Chemistry Laboratory I	1
ECE	345	Electronic Instrumentation and Systems	3
MSM	160	Engineering Graphics Communications	3
MSM	205	Statics	3
MSM	211	Mechanics of Deformable Solids	3
MSM	250	Materials Science and Engineering	3
MSM	306	Dynamics	3
STT	351	Probability and Statistics for Engineering	3

b. The following courses in the Department of Mechanical Engineering: 44

All of the following courses (32 credits):

ME	201	Thermodynamics	3
ME	332	Fluid Mechanics	4
ME	371	Mechanical Design I	3
ME	391	Mechanical Engineering Analysis	3
ME	410	Heat Transfer	3
ME	412	Heat Transfer Laboratory	2
ME	451	Control Systems	4
ME	461	Mechanical Vibrations	4
ME	471	Mechanical Design II	3
ME	481	Mechanical Engineering Design Projects	3

Senior Electives (a minimum of 12 credits with at least 3 credits from b. below):

a.

ME	442	Introduction to Combustion	3
ME	432	Intermediate Fluid Mechanics	3
ME	433	Intermediate Fluid Mechanics Laboratory	1
ME	444	Automotive Engines	3
ME	490	Independent Study in Mechanical Engineering	1 to 3
ME	491	Selected Topics in Mechanical Engineering	1 to 4

b. Design-intensive courses (a minimum of 3 credits):

ME	414	Vehicle Thermal System Design	3
ME	416	Computer Assisted Design of Thermal Systems	3
ME	442	Turbomachinery	3
ME	445	Automotive Powertrain Design	3
ME	475	Computer Aided Design of Automotive Structures	3

GRADUATE STUDY

The Department of Mechanical Engineering offers programs leading to Master of Science and Doctor of Philosophy degrees, both in mechanical engineering and in engineering mechanics. Individual programs can be designed from a wide range of courses to suit the background, capabilities and aims of the student. Studies in the department may be supplemented by courses offered by other departments in the College of Engineering and in other colleges. Courses and research opportunities are available in the following areas: fluid mechanics, combustion, heat transfer, thermodynamics, bioengineering, internal combustion engines, turbomachinery, computational fluid dynamics, system dynamics, controls, vibrations, nonlinear dynamics, mechatronics, manufacturing, computational design, computational solid mechanics, mechanics and processing of composite materials, elasticity, nonlinear elasticity, plasticity, experimental mechanics, and micromechanics.

ENGINEERING MECHANICS

Master of Science

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

The department welcomes applications from students who possess a bachelor's degree in a related engineering or science discipline.

Students who are admitted to the master's program with a degree in a discipline other than engineering mechanics and who have not completed Mechanical Engineering 221, 222, 361, and 423 or equivalent courses may be admitted with provisional status. Such students will be required to demonstrate proficiency in the material in the courses referenced above, either by completing each of those courses with a grade of at least 3.0 or by passing an examination on the material in those courses sanctioned by the Department Graduate Studies Committee. Of the courses referenced above, only Mechanical Engineering 423 may be counted toward the requirements for the master's degree.

Requirements for the Master of Science Degree in Engineering Mechanics

The student must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis) and must meet the requirements specified below:

Requirements for Both Plan A and Plan B:

1. The following core courses in engineering mechanics: Mechanical Engineering 825 or 861, 820, and 821.
2. At least **one** of the following core courses in mechanical engineering: Materials Science and Engineering 851, 855, 862, or 865.
3. At least one credit of Materials Science and Engineering 885.
4. At least one course in mathematics or statistics at the 400–level or above approved by the student's academic adviser.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

An applicant for admission must identify at least one prospective faculty adviser that he or she would like to direct his or her program of study. Admission to the Ph.D program is contingent on a faculty adviser accepting the student as an advisee.

Requirements for the Doctor of Philosophy Degree in Engineering Mechanics

The student must complete:

1. At least **one** of the following core courses in materials science and engineering: Materials Science and Engineering 851, 855, 862, or 865.
2. At least one course in mathematics or statistics at the 400–level or above.

These requirements are waived for those students who completed equivalent courses prior to enrolling in the doctoral program.

MECHANICAL ENGINEERING

Master of Science

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

An applicant should possess a bachelor's degree in mechanical engineering or a related field.

The applicant must submit scores from the Graduate Record Examination General Test.

Requirements for the Master of Science Degree in Mechanical Engineering

The student must complete a total of 30 credits for the degree under either Plan A (with thesis) or Plan B (without thesis) and meet the requirements specified below:

Requirements for Both Plan A and Plan B:

The student must:

1. Complete at least one course in three of the following four areas:
   a. Dynamical Systems: Mechanical Engineering 852 and 860.
   b. Fluid Mechanics: Mechanical Engineering 830
   c. Solid and Structural Mechanics: Materials Science and Mechanics 810 and 815.
   d. Thermal Sciences: Mechanical Engineering 802 , 812 and 814.
2. Complete at least 6 additional credits in Mechanical Engineering courses at the 800-900 level, not including Mechanical Engineering 898 or 899.

Additional Requirements for Plan A:

The student must:

1. Complete at least 20 credits in courses at the 800–900 level including at least 6, but not more than 8, credits in Mechanical Engineering 899.
2. Submit a brief thesis proposal for approval by the student's academic adviser early in the student's program of study.

Additional Requirements for Plan B:

The student must complete at least 22 credits in courses at the 800–900 level.

Doctor of Philosophy

In addition to meeting the requirements of the University and of the College of Engineering, students must meet the requirements specified below.

Admission

The applicant must submit scores from the Graduate Record Examination General Test.

Requirements for the Doctor of Philosophy Degree in Mechanical Engineering

In addition to meeting the requirements of the University and the College of Engineering, students must meet the requirements specified by their guidance committees.