College of ENGINEERING

Satish Udpa, DEAN

The College of Engineering prepares its students to solve technical, as well as social, economic, and global problems while instilling the essence of engineering – the iterative process of designing, predicting performance, building, and testing. Since engineering deals with the adaptation of nature's forces, materials, and energies for the benefit of society, our engineering programs are planned to provide future engineers 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, computing, and the sciences as the tools of the engineer. An engineering education provides a teams-based, systems approach to societal problems and therefore prepares students for a wide range of career options, including those outside engineering.

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.

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, 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 or applied engineering sciences. Flexibility is provided in the selection of major and minor subject matter areas for computer science, 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 computer science program with supporting studies from non-engineering areas such as business management, the social and behavioral or physical sciences, or a foreign language.

The Applied Engineering Sciences major is an interdisciplinary program that enables students to develop a broad foundation in the engineering sciences and core engineering disciplines and apply it to one of the available cognate areas. Opportunities are available for interaction between the College of Engineering, the Department of Supply Chain Management in The Eli Broad College of Business, and the Department of Telecommunication, Information Studies and Media in the College of Communication Arts and Sciences.

Engineering Study Abroad

The field of engineering increasingly requires a global perspective. Many outstanding study abroad opportunities exist within the College of Engineering for students to study in a variety of countries. Students often take major and university requirements during their semester abroad, so the international experience does not delay a student's progress toward graduation. Students interested in studying abroad should contact the Engineering Study Abroad office as early as possible.

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 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. Major-specific options in biomedical engineering are also offered as electives to students in several majors. These include the Biomedical Option in Chemical Engineering, the Biomedical Materials Engineering Option in Materials Science and Engineering, and the Biomechanical Engineering Option in Mechanical Engineering. Students may not be awarded both the general Biomedical Engineering Option in the College of Engineering and a major-specific option in biomedical engineering in various departments as noted above.

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.	Both of the following courses (7 credits):			
	BS	111	Cells and Molecules	3
	PSL	250	Introductory Physiology	4
2.	At least three of the following courses (9 credits):			
	BME	401	Quantitative Human Biology	3
	BME	490	Independent Study	3
	BME	491	Special Topics	3
	ME	494	Biofluid Mechanics and Heat Transfer	3
	ME	495	Tissue Mechanics	3
	ME	497	Biomechanical Design	3
	MSE	425	Biomaterials and Biocompatibility	3

Upon completion of the requirements for the biomedical engineering option, the student should contact the Office of 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 Associate 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.

Specializations

Students who are enrolled in bachelor's degree programs in The Eli Broad College of Business, the College of Communication Arts and Sciences, and the College of Engineering may elect a *Specialization in Information Technology*. For additional information, refer to the statement on *Specialization in Information Technology* in *The Eli Broad College of Business* section of this catalog or contact The Eli Broad College of Business.

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 usually 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, participation 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.

Certification in 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, as early as possible.

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 the adviser's 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 ABET, Inc.: Biosystems Engineering, Chemical Engineering, Civil Engineering, Computer Engineering, Electrical Engineering, 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 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 admitted to the University are enrolled as Undergraduate University Division students, but may declare a pre-engineering major preference in the College of Engineering. Such students are assigned a professional adviser from the College. Students interested in engineering but not yet sure of a major may be an Engineering No-Preference major for up to two years, but students are encouraged to make their major selection as early as possible. Special attention should be given to **program re-**

quirements so the first year or so may be used to become acquainted with the opportunities offered by the various engineering areas best suited to a student's talents.

Students who elect a pre-engineering major preference should be strongly prepared in mathematics and sciences. Additional work in these areas 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 entering the University. However, such students will need additional time to complete the work for the degree.

Admission to the College

Admission to the College of Engineering and a specific major provides access to enroll in certain courses required for the major. Enrollments in the College of Engineering are limited.

Admission is based on the cumulative grade–point average of all courses taken and a grade–point average calculated on mathematics, physical and biological sciences, and engineering courses.

For additional information, students should contact the Office of the Associate Dean for Undergraduate Studies, College of Engineering.

Minimum criteria for admission to the College are:

1. Completion of at least 12 credits of MSU courses, including at least 6 credits in mathematics, physical and biological sciences, and engineering for freshmen and sophomores, and at least 10 credits in mathematics, physical and biological sciences, and engineering for juniors and seniors.
2. Completion of Mathematics 132 and 133.
3. A minimum grade-point average of 2.00 in all mathematics courses.
4. Completion of Chemistry 141 or 151 or approved substitution or waiver.
5. Completion of Physics 183.
6. Completion of Computer Science and Engineering 131 or 231 or approved substitution or waiver.

Freshmen and sophomores who have declared specific engineering majors (excluding Engineering No-Preference) are automatically reviewed at the end of every semester, and are either admitted or informed of their progress. Others may apply for admission during each semester, and applications will be reviewed after the end of each semester. Students must be admitted to a degree-granting college at the time they have completed 56 credits.

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.

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 Applied Engineering Sciences, 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; Plant Biology 105; Entomology 205; Microbiology and Molecular Genetics 201, 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; Plant Biology 106; Chemistry 161; 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.

APPLIED ENGINEERING SCIENCES

It is the intent of the Applied Engineering Sciences major to provide educational opportunities for the undergraduate student who wishes to gain a broad foundation in the engineering sciences, core engineering disciplines, and their applications. The program is designed to develop individuals who bring (to the workplace) a knowledge of business, management, and logistics with a solid foundation in calculus, basic sciences, and engineering sciences; can apply the rigor of their education and training to a diverse set of problems; are prepared to work in the areas where planning, design, production, and procurement interface with marketing, distribution, sales, and management; can effectively communicate across diverse professional disciplines; and are knowledgeable of contemporary technological and societal issues and can facilitate the effective deployment of new technologies.

This program is designed to develop a uniquely qualified individual capable of functioning in a variety of employment contexts using technical competencies combined with applied knowledge from a cognate area. A few of the cross–disciplinary employment areas include: technical sales, technical journalism, communications, telecommunications, industrial management, operations management, procurement, sourcing, and logistics management, as well as public administration, urban applications, environmental issues, political analysis, and law.

Requirements for the Bachelor of Science Degree in Applied Engineering Sciences

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 Applied Engineering Sciences.

   The University's Tier II writing requirement for the Applied Engineering Sciences major is met by completing Engineering 300 and 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:			31
	CE	221	Statics	3
	CEM	161	Chemistry Laboratory I	1
	EGR	300	Technology, Society and Public Policy	2
	EGR	410	System Methodology	2
	ME	180	Engineering Graphics Communications	3
	ME	222	Mechanics of Deformable Solids	4
	MGT	325	Management Skills and Processes	3
	MSE	250	Materials Science and Engineering	3
	PSY	101	Introductory Psychology	4
	PSY	255	Industrial and Organizational Psychology	3
	STT	351	Probability and Statistics for Engineering	3
b.	One of the following courses:			
	ECE	201	Circuits and Systems I	3
	ECE	230	Digital Logic Fundamentals	3
	ECE	345	Electronic Instrumentation and Systems	3
c.	One of the following courses:			3
	BE	230	Engineering Analysis of Biological Systems	3
	CE	280	Principles of Environmental Engineering and Science	3
	CHE	201	Material and Energy Balances	3
d.	One of the following courses:			
	ME	201	Thermodynamics	3
	MSE	310	Phase Equilbria in Materials	3
e.	Cognate:			27 or 30

Cognates in Business-Supply Chain Management and Telecommunication are available to majors in Applied Engineering Sciences. 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				27
a.	All of the following courses:			
	ACC	201	Principles of Financial Accounting	3
	ACC	202	Principles of Management Accounting	3
	EC	210	Economics Principles Using Calculus	3
	FI	320	Introduction to Finance	3
	GBL	323	Introduction to Business Law	3
	MSC	303	Introduction to Supply Chain Management	3
	MSC	327	Introduction to Marketing	3
	MSC	372	Manufacturing Planning and Control	3
b.	One of the following courses:			
	BE	431	Bio-resource Optimization	3
	ME	477	Manufacturing Processes	3
	ME	497	Biomechanical Design	3
	MSE	425	Biomaterials and Biocompatibility	3
	MSE	426	Introduction to Composite Materials	3
	STT	471	Statistics for Quality and Productivity	3
Telecommunication				30
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		Data Communication	3
TC	463		Network Design and Implementation I	3
TC	465		Network Design and Implementation II (W)	3

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.

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 Biosystems and 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 major department. 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 BIOSYSTEMS and AGRICULTURAL ENGINEERING

Ajit Srivastava, Chairperson

The Department of Biosystems and 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 technology systems management through the College of Agriculture and Natural Resources. For information about that program, refer to the statement on the *Department of Biosystems and 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

Biosystems engineers design solutions to technical problems that involve a critical biological component. They apply quantitative skills to create products, processes, and systems that improve human existence. Working at the interface of engineering and biology, biosystems engineers are engaged in the most important challenges of our time.

There are a wide variety of job functions and application areas for our graduates, including ecosystems protection, food safety, bioenergy, biosecurity, and human health. Biosystems engineers may, for example, design sterilization and pasteurization processes to eliminate microbial pathogens and maximize the nutritional value of our food. Other graduates may design constructed wetlands, which utilize biological systems to capture pollutants and protect our precious fresh water resources. Biosystems engineers are sought after by a wide variety of employers including food manufacturers, environmental consulting firms, health industries, and government agencies who need creative individuals to integrate principles of engineering and biology successfully.

The Bachelor of Science Degree program in Biosystems Engineering is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone (410) 347-7700.

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:			46
	BE	130	Engineering Design Fundamentals for Biological Systems . . . 2	
	BE	230	Engineering Analysis of Biological Systems . . . 3	
	BE	332	Engineering Properties of Biological Materials . . . 3	
	BE	333	Biosystems Engineering Laboratory . . . 1	
	BE	350	Heat and Mass Transfer in Biosystems . . . 3	
	BE	351	Environmental Thermodynamics . . . 3	
	BE	431	Bio-resource Optimization . . . 3	
	BE	485	Biosystems Design Techniques . . . 3	
	BE	487	Biosystems Design Project (W) . . . 3	
	BS	110	Organisms and Populations . . . 4	
	CE	221	Statics . . . 3	
	CE	321	Introduction to Fluid Mechanics . . . 4	
	CEM	143	Survey of Organic Chemistry . . . 4	
	CEM	161	Chemistry Laboratory I . . . 1	
	ECE	345	Electronic Instrumentation and Systems . . . 3	
	STT	351	Probability and Statistics for Engineering . . . 3	
b.	One of the following courses:			
	BS	111	Cells and Molecules . . . 3	
	MMG	201	Fundamentals of Microbiology . . . 3	
	PLB	105	Plant Biology . . . 3	
c.	Two of the following courses:			6
	BE	456	Electric Power and Control . . . 3	
	BE	477	Food Engineering: Fluids . . . 3	
	BE	478	Food Engineering: Solids . . . 3	
	BE	481	Land and Water Conservation Engineering . . . 3	
	BE	482	Non-point Source Pollution Control . . . 3	
d.	Engineering Electives: . . . The student must complete a minimum of 6 credits of approved courses.			6
e.	Cognate. . . . A cognate consists of carefully selected courses that support a career objective involving the application of engineering skills to challenges with critical biological components. The cognate allows for breadth of interest and depth of learning for a given student. The cognate must include at least one biological science course beyond the requirements in 3. a. and 3. b. above, at least one quantitative/technical course, and must include 300- and 400-level courses to achieve depth in a particular area. Engineering electives cannot simultaneously satisfy the cognate requirement. Courses that are used to satisfy the engineering electives requirement and the cognate requirement must be chosen to form a career objective and be approved by the student's academic adviser.			12

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 Biosystems and 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 Biosystems and 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, Chairperson

UNDERGRADUATE PROGRAMS

Chemical engineers convert raw materials to finished products via pathways involving chemical and physical changes. The principles of mass, energy, and momentum conservation, chemical reactions, thermodynamics, and economics are used to develop new products and to design and operate manufacturing facilities to produce products that benefit society. Chemical engineering principles are, in turn, based on the sciences of chemistry, biology, mathematics, and physics, which form the underlying foundation of the discipline.

The work of the chemical engineer may be in the production of industrial chemicals, plastics, petroleum products, pharmaceuticals, textiles, food, electronics, sensors, consumer goods, medical products and devices, specialty materials of construction, or other products. Within these product areas, chemical engineers are involved in research and development of products and processes, in the design and operation of manufacturing facilities, and in management and product quality control.

Students in this degree program will study the application of chemical engineering principles to biological systems, medical products, nanoscale devices, and high-strength materials. Principles of sustainability, environmentally-friendly "green" processing, and entrepreneurship and other emerging topics are also addressed in courses and options.

The Bachelor of Science Degree program in Chemical Engineering is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone (410) 347-7700.

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:		61
	BS 111	Cells and Molecules	3
	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
	CHE 201	Material and Energy Balances	3
	CHE 210	Modeling and Analysis of Transport Phenomena	3
	CHE 301	Chemical Engineering as a Profession	1
	CHE 311	Fluid Flow and Heat Transfer	3
	CHE 312	Mass Transfer and Separations	4
	CHE 316	Laboratory Practice and Statistical Analysis	4
	CHE 321	Thermodynamics for Chemical Engineering	4
	CHE 431	Chemical Reaction Engineering	4
	CHE 432	Process Analysis 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
b.	One of the following:		4 or 6
	(1) BMB 401	Basic Biochemistry	4
	(2) BMB 461	Biochemistry I	3
	BMB 462	Biochemistry II	3
c.	One of the following courses:		3
	CHE 472	Composite Materials Processing	3
	CHE 481	Biochemical Engineering	3

d. Technical Electives.
   Students must complete at least 6 credits of technically oriented subject-related courses approved by the student's adviser. Acceptable subjects include, but are not limited to, composites processing or biochemical engineering (in addition to that required in 3. c. above), electronic materials, environment, advanced mathematics, transport phenomena, advanced chemistry, foods, legal and regulatory issues, advanced materials, advanced biology, statistics, biomedical engineering, and polymers.

e. Electives.
   NOTE: Elective courses in item 3. d. must include at least 3 credits of engineering topics, which includes courses taught in the College of Engineering as well as courses taught in advanced mathematics, advanced chemistry, advanced biology, advanced statistics, and advanced physics. Biochemistry and Molecular Biology 462 taken to fulfill requirement 3.b. counts as technical elective credit in item 3.d.

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, biomedical 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., 3.d., and 3.e. above and the following:

Both of the following courses:			6
CHE 481	Biochemical Engineering	3	
MMG 301	Introductory Microbiology	3	
One of the following:			4 or 6
(1) BMB 401	Basic Biochemistry	4	
(2) BMB 461	Biochemistry I	3	
BMB 462	Biochemistry II	3	

Two or three of the following courses. Students who chose BMB 401 above must choose three courses. Students who chose BMB 461 and 462 above must choose two courses:

BMB 829	Methods of Macromolecular Analysis and Synthesis	2
CHE 882	Advanced Biochemical Engineering	3
CHE 883	Multidisciplinary Bioprocessing Laboratory	3
MMG 409	Eukaryotic Cell Biology	3
MMG 421	Prokaryotic Cell Physiology	3
MMG 431	Microbial Genetics	3
MMG 445	Basic Biotechnology	3

Biomedical Engineering Option

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

All of the following courses: 9
CHE 481 Biochemical Engineering 3
MMG 409 Eukaryotic Cell Biology 3
PSL 431 Human Physiology I 3
Two of the following courses: 6
BME 401 Quantitative Human Biology 3
BMB 471 Biochemistry Laboratory (W) 3
CHE 883 Multidisciplinary Bioprocessing Laboratory. 3
ME 494 Biofluid Mechanics and Heat Transfer 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., 3.b., and 3.e. above and the following:

Both of the following courses: 6
CE 280 Principles of Environmental Engineering and Science 3
CHE 481 Biochemical Engineering 3
Three of the following courses: 9
CE 481 Environmental Engineering Chemistry 3
CE 483 Water and Wastewater Treatment 3
CE 485 Landfill Design 3
EEP 225 Ecological Economics. 3
EEP 320 Environmental Economics 3
EEP 405 Corporate Environmental Management 3
NSC 448 Ecology, Law and Economics. 3
RD 201 Environmental and Natural Resources. 3
RD 430 Law and Resources 3
RD 446 Environmental Issues and Public Policy 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., 3. b., 3.c., and 3.e. above and all of the following:

All of the following courses: 9
FSC 401 Food Chemistry 3
FSC 440 Food Microbiology 3
MMG 301 Introductory Microbiology 3
One of the following courses. . . . . 3 or 4
BE 477 Food Engineering: Fluids 3
BE 478 Food Engineering: Solids 3
FSC 325 Food Processing: Unit Operations 4
FSC 421 Food Law and Regulations. 3
FSC 455 Food Analysis 3
FSC 470 Integrated Approaches to Food Product Development. 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. b., and 3.e. above and all of the following:

All of the following courses: 10
CE 221 Statics. 3
CHE 472 Composite Materials Processing 3
ME 222 Mechanics of Deformable Solids 4
Two of the following courses: . . . . . 6 or 7
CHE 871 Material Surfaces and Interfaces 3
CHE 872 Polymers and Composities: Manufacturing, Structure and Performance 3
MSE 370 Physical Processing of Materials 3
MSE 426 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 a multidisciplinary field that often functions at the interface between disciplines. Materials Science and Engineering majors learn to create and/or specify materials used to realize design concepts in engineering fields such as bioengineering, microelectronics and aerospace. They also learn how to coax the elements of matter into the atomic arrangements that insure efficient and cost-effective materials performance, demanded by today's advanced applications.

In the Materials Science and Engineering core, students gain the scientific and engineering foundation needed to design metallic, ceramic, polymeric, and composite materials; they learn about the processes used to manufacture components from these materials.

Students may enhance the knowledge they gain in metals, ceramics, and polymers by completing an option in biomedical materials, manufacturing, polymers, or metallurgy. Completion of an option will prepare students to enter particular engineering enterprises and work on multi-disciplinary teams. Or, they may choose to enroll for electives in complementary fields such as business, electronic materials or statistics.

Students may choose to use remaining elective credits to work with a faculty member on a research project, a student design competition project, or a project sponsored by an industrial partner. These optional projects are integral to the senior capstone design course, Materials Science and Engineering 465, in which students learn to develop strategies for optimal material selection, production, and production problem-solving.

The Bachelor of Science Degree program in Materials Science and Engineering is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone (410) 347-7700.

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 465. 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:		41 to 44
	CE 221	Statics 3	
	CEM 152	Principles of Chemistry 3	
	CEM 161	Chemistry Laboratory I 1	
	ECE 345	Electronic Instrumentation and Systems. 3	
	ME 222	Mechanics of Deformable Solids. 4	
	MSE 250	Materials Science and Engineering. 3	
	MSE 310	Phase Equilibria in Materials. 3	
	MSE 320	Mechanical Properties of Materials 3	
	MSE 331	Materials Characterization Methods I 1	
	MSE 350	Electronic Structure and Properties of Materials. . 3	
	MSE 360	Fundamentals of Microstructural Design. 3	
	MSE 370	Physical Processing of Materials. 3	
	MSE 381	Materials Characterization Methods II. 2	
	MSE 466	Design and Failure Analysis (W). 3	
	MSE 477	Manufacturing Processes 3	
	STT 351	Probability and Statistics for Engineering 3	
	Electrical and Computer Engineering 302 and 303 may be substituted for Electrical and Computer Engineering 345.		
b.	Two of the following courses:		6
	MSE 454	Ceramic and Refractory Materials. 3	
	MSE 465	Design and Application of Engineering Materials 3	
	MSE 476	Physical Metallurgy of Ferrous and Alluminum Alloys 3	
c.	Complete at least 5 credits from 400-level courses within the College of Engineering.		
d.	Complete at least 7 credits in courses selected from a list of approved technical electives available from the Department of Chemical Engineering and Materials Science.		

Options in Materials Science and Engineering

Students may elect to complete a more focused set of courses to enhance their ability to function at the interface with another scientific, engineering, or business discipline. Options are available to, but not required of, any student enrolled in the Bachelor of Science degree in Materials Science and Engineering. Completing the Bachelor of Science degree in Materials Science and Engineering with an option may require more than 128 credits.

Biomedical Materials Engineering Option

To gain interdisciplinary skills in human biology and earn a Bachelor of Science degree in Materials Science and Engineering with a biomedical materials engineering option, students must complete requirement 3. a. above and the following (27 credits):

1. All of the following courses (15 credits):

ANTR	350	Human Gross Anatomy and Structural Biology	3
BME	401	Quantitative Human Biology	3
CEM	351	Organic Chemistry I	3
ME	495	Tissue Mechanics	3
MSE	425	Biomaterials and Biocompatibility	3

2. One of the following courses (3 credits):

MSE	454	Ceramics and Refractory Materials	3
MSE	465	Design and Application of Engineering Materials	3
MSE	476	Physical Metallurgy of Ferrous and Aluminum Alloys	3

3. At least 6 credits from a list of approved technical electives 6

Manufacturing Engineering Option

To gain interdisciplinary skills with business and design engineers for manufacturing projects and earn a Bachelor of Science degree in Materials Science and Engineering with a manufacturing engineering option, students must complete requirement 3. a. above and the following (18 credits):

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

ECE	415	Computer Aided Manufacturing	3
ME	478	Product Development	3
MSE	465	Design and Application of Engineering Materials	3

2. Three of the following courses (9 credits):

GBL	323	Introduction to Business Law	3
MSE	426	Introduction to Composite Materials	3
MSE	454	Ceramic and Refractory Materials	3
MSE	476	Physical Metallurgy of Ferrous and Aluminum Alloys	3
STT	471	Statistics for Quality and Productivity	3

Completion of this option fulfills requirement 2. of the admission requirements for the Master of Science degree in Manufacturing and Engineering Management offered by The Eli Broad College of Business.

Metallurgical Engineering Option

To enhance the student's ability to characterize, process, and design with metals in association with mechanical engineers and earn a Bachelor of Science degree in Materials Science and Engineering with a metallurgical engineering option, students must complete requirement 3. a. above and the following (18 credits):

1. All of the following courses (12 credits):

ME	423	Intermediate Mechanics of Deformable Solids	3
ME	475	Computer Aided Design of Structures	3
MSE	465	Design and Application of Engineering Materials	3
MSE	476	Physical Metallurgy of Ferrous and Aluminum Alloys	3

2. One of the following courses (3 credits):

MSE	426	Introduction to Composite Materials	3
STT	471	Statistics for Quality and Productivity	3

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

ME	425	Experimental Mechanics	3
MSE	451	Microscopic and Diffraction Analysis of Materials	3

Polymeric Engineering Option

To gain interdisciplinary skills to facilitate interactions with chemical engineers and earn a Bachelor of Science degree in Materials Science and Engineering with a polymeric engineering option, students must complete requirement 3. a. above and the following (18 credits):

All of the following courses (18 credits):

CEM	351	Organic Chemistry I	3
CHE	311	Fluid Flow and Heat Transfer	3
CHE	472	Composite Materials Processing	3
CHE	473	Chemical Engineering Principles in Polymers and Materials Systems	3
MSE	426	Introduction to Composite Materials	3
STT	471	Statistics for Quality and Productivity	3

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.

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 un-

der 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.

The Bachelor of Science Degree program in Civil Engineering is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone (410) 347-7700.

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:			40
	CE	221	Statics	3
	CE	271	Introduction to Civil Engineering	4
	CE	280	Principles of Environmental Engineering and Science	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
	CE	495	Senior Design in Civil Engineering	3
	CEM	161	Chemistry Laboratory I	1
	ME	222	Mechanics of Deformable Solids	4
	STT	351	Probability and Statistics for Engineering	3

Students who complete the Environmental Engineering Option do not have to complete Civil Engineering 337, 341, 461, or Mechanical Engineering 361.

b.	One of the following courses (3 credits):			
	CE	461	Computational Methods in Civil Engineering	3
	ME	361	Dynamics	3
c.	One of the following courses:			3
	BE	351	Environmental Thermodynamics	3
	ECE	345	Electronic Instrumentation and Systems	3
	ME	201	Thermodynamics	3
	MSE	250	Materials Science and Engineering	3

Students who complete the Environmental Engineering Option do not have to complete this requirement.

d. Four courses, selected from four of the seven areas listed below (12 credits)

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	3
CE	485	Landfill Design	3

Civil Engineering 485 may be counted as a geotechnical or an environmental course, but not both.

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	3
CE	432	Pavement Rehabilitation	3

Transportation

CE	444	Principles of Traffic Engineering	3
CE	448	Transportation Planning	3
CE	449	Highway Design	3

Environmental

CE	481	Environmental Engineering Chemistry	3
CE	483	Unit Operations and Processes in Environmental Engineering	3
CE	485	Landfill Design	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.

Civil Engineering 485 may be counted as a geotechnical or an environmental course, but not both.

Construction Engineering and Management

CE	471	Construction Engineering-Equipment, Methods and Planning	3
CMP	411	Construction Project Scheduling	3
CMP	415	Cost Estimating Analysis	3
CMP	423	Construction Project Management	3

Environmental Engineering Option

The environmental engineering option is available to students who are enrolled in the Bachelor of Science degree program 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	Landfill Design	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 or 4
	CE	337	Civil Engineering Materials I	4
	CE	341	Transportation Engineering	3
	CEM	251	Organic Chemistry I	3
	CEM	351	Organic Chemistry I	3
5.	One of the following courses (3 credits):			
	CE	461	Computational Methods in Civil Engineering	3
	ME	361	Dynamics	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 *Doctoral Program in Environmental and Integrative Toxicological Sciences* in the *Graduate Education* section of this catalog.

DEPARTMENT of COMPUTER SCIENCE and ENGINEERING

Laura K. Dillon, 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 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 focusing on computer networks, computer architecture, artificial intelligence, database systems, computer security, software engineering, and computer graphics. The senior year culminates with a team-oriented design course building on much of what one has learned throughout the undergraduate experience. 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.

Students who are enrolled in the Bachelor of Science degree program with a major in computer science may elect a Specialization in Game Design and Development. For additional information, refer to the *Specialization in Game Design and Development* statement in the *Department of Telecommunication, Information Studies and Media* section of this catalog.

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 to 6
	(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) One 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:			27
	CSE	232	Introduction to Programming II	4
	CSE	260	Discrete Structures in Computer Science	4
	CSE	320	Computer Organization and Architecture	3
	CSE	331	Algorithms and Data Structures	3
	CSE	335	Object-Oriented Software Design	3
	CSE	410	Operating Systems	3
	CSE	498	Collaborative Design (W)	4
	STT	351	Probability and Statistics for Engineering	3
c.	An additional five courses selected from the following:			15
	CSE	420	Computer Architecture	3
	CSE	422	Computer Networks	3
	CSE	435	Software Engineering	3
	CSE	440	Introduction to Artificial Intelligence	3
	CSE	450	Translation of Programming Languages	3
	CSE	452	Organization of Programming Languages	3
	CSE	460	Computability and Formal Language Theory	3
	CSE	471	Media Processing and Multimedia Computing	3
	CSE	472	Computer Graphics	3
	CSE	480	Database Systems	3
	MTH	416	Introduction to Algebraic Coding	3
	MTH	451	Numerical Analysis I	3
	MTH	481	Discrete Mathematics I	3
d.	Required Cognate:			15
	A minimum of four courses totaling 15 or more credits outside the College of Engineering selected from three options below.			
	(1) At least 6 of the 15 credits must be in courses at the 300-400 level.			
	(2) A sequence of at least four courses in a foreign language.			
	(3) 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 Com-			

puter 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 four general areas: software systems, intelligent systems, networking and ubiquitous computing, and biological computing. Consult the department website at *www.egr.msu.edu* for more details.

The Department operates a number of different laboratories with a variety of modern computing and networking equipment.

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:

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

Timothy Grotjohn, Acting 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, analog and mixed-signal circuits, 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.

The Bachelor of Science Degree program in Computer Engineering is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone (410) 347-7700.

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:			56
	CSE	231	Introduction to Programming I	4
	CSE	232	Introduction to Programming II	4
	CSE	260	Discrete Structures in Computer Science	4
	CSE	331	Algorithms and Data Structures	3
	CSE	410	Operating Systems	3
	ECE	201	Circuits and Systems I	3
	ECE	202	Circuits and Systems II	3
	ECE	203	Electric Circuits and Systems Laboratory	1
	ECE	230	Digital Logic Fundamentals	3
	ECE	280	Electrical Engineering Analysis	3
	ECE	302	Electronic Circuits	3
	ECE	303	Electronics Laboratory	1
	ECE	331	Microprocessors and Digital Systems	4
	ECE	390	Ethics, Professionalism and Contemporary Issues	1
	ECE	480	Senior Design	4
c.	**Electives**			
	Complete 24 credits of electives as specified below. At least 18 credits must be from core and focus track electives combined. Additional credits to meet the 24 credit requirement may be taken from other courses listed below, any 400-level Computer Science and Engineering (CSE) or Electrical and Computer Engineering (ECE) courses, or by completing an approved 3 or 4 credit experiential, out-of-classroom education experience obtained through engineering cooperative education or independent study.			
	Core			
	At least 6 credits from the following:			
	CSE	420	Computer Architecture	3
	CSE	422	Computer Networks	3
	ECE	410	VLSI Design	4
	Focus Track			
	At least 12 credits from the following:			
	Hardware			
	ECE	402	Applications of Analog Integrated Circuits	4
	ECE	411	Electronic Design Automation	4
	ECE	412	Introduction to Mixed-Signal Circuit Design	4
	Software			
	CSE	335	Object-oriented Software Design	3
	CSE	450	Translation of Programming Languages	3
	CSE	471	Media Processing and Multimedia Computing	3
	ECE	366	Introduction to Signal Processing	3
	Recommended Electives			
	ECE	305	Electromagnetic Fields and Waves I	4
	ECE	313	Control Systems	3
	ECE	404	Radio Frequency Electronic Circuits	4
	ECE	415	Computer Aided Manufacturing	3
	ECE	416	Digital Control	3
	ECE	457	Communication Systems	3
	ECE	458	Communication Systems Laboratory	1
	ECE	466	Digital Signal Processing and Filter Design	3
	ECE	474	Principles of Electronics Devices	3

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.

The Bachelor of Science Degree program in Electrical Engineering is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone (410) 347-7700.

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:			43
	CSE	231	Introduction to Programming I	4
	ECE	201	Circuits and Systems I	3
	ECE	202	Circuits and Systems II	3
	ECE	203	Electric Circuits and Systems Laboratory	1
	ECE	230	Digital Logic Fundamentals	3
	ECE	280	Electrical Engineering Analysis	3
	ECE	302	Electronic Circuits	3
	ECE	303	Electronics Laboratory	1
	ECE	305	Electromagnetic Fields and Waves I	4
	ECE	313	Control Systems	3
	ECE	320	Energy Conversion and Power Electronics	3
	ECE	331	Microprocessors and Digital Systems	4
	ECE	366	Introduction to Signal Processing	3
	ECE	390	Ethics, Professionalism and Contemporary Issues	1
	ECE	480	Senior Design	4

c. One of the following courses: 3
CE 221 Statics 3
ME 201 Thermodynamics. 3

d. A minimum of six courses totaling a minimum of 18 credits, of 3 or 4 credits each, selected from at least four different areas. A laboratory course must be included. Students may substitute, for one of the six required courses, a 3 or 4 credit experiential education experience obtained in a minimum of three out-of-classroom experiences through engineering cooperative education or independent study. Students interested in the experiential education experience must contact the department for approval.

Electromagnetics
ECE 405 Electromagnetic Fields and Waves II 4
ECE 407 Electromagnetic Compatibility. 4
Power
ECE 420 Machines and Power Laboratory. 1
ECE 423 Power System Analysis. 3
Integrated Circuits/VLSI
ECE 402 Applications of Analog Integrated Circuits 4
ECE 404 Radio Frequency Electronic Circuits 4
ECE 410 VLSI Design 4
ECE 411 Electronic Design Automation. 4
ECE 412 Introduction to Mixed-Signal Circuit Design 4
Solid-State Electronics/Electro-optics
ECE 474 Principles of Electronic Devices 3
ECE 476 Electro-Optics 4
ECE 477 Microelectronic Fabrication 3
Communications/Signal Processing
ECE 457 Communication Systems 3
ECE 458 Communication Systems Laboratory 1
ECE 466 Digital Signal Processing and Filter Design 3
Control/Robotics
ECE 415 Computer Aided Manufacturing 3
ECE 416 Digital Control 3

GRADUATE STUDY

The Department of Electrical and Computer Engineering offers programs leading to the Master of Science and Doctor of Philosophy degrees. Graduate study in the department in organized into three groups: computer engineering including computer architecture, computer networks, and VLSI/microelectronics; electrosciences including electromagnetics and electronic materials and devices; and systems including control and robotics, biomedical engineering, power, and signal processing and communications. An interdisciplinary approach marks many of the research projects that faculty share with graduate students.

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:

CREDITS

Requirements for Both Plan A and Plan B:

1. **Core Courses**. Complete a minimum of four Electrical and Computer Engineering courses at the 800 or 900-level totaling at least 12 credits. Two of the courses must be selected from the following:

ECE 813 Advanced VLSI Design 3
ECE 820 Advanced Computer Architecture 3
ECE 821 Advanced Power Electronics and Applications 3
ECE 826 Linear Control Systems. 3
ECE 835 Advanced Electromagnetic Fields and Waves I 3
ECE 863 Analysis of Stochastic Systems 3
ECE 874 Physical Electronics 3

Electrical and Computer Engineering 801 cannot be used to fulfill this requirement

2. **Supporting Courses**: At least 6 credits in approved courses in areas such as mathematics, statistics, or physics.
3. **Seminar Requirement**. First-year graduate students are reuqired to attend seven seminars from the graduate seminar series.

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.

1. The doctoral program must include a minimum of 36 credits, in addition to 24 credits of Electrical and Computer Engineering 999.
2. No 800-900 level independent study credits taken beyond the bachelor's degree may be counted towards the doctoral degree.
3. A minimum of 3 credits must be taken outside of the College of Engineering in disciplinary areas such as mathematics, statistics, or physics.
4. All courses that are used to satisfy the requirements for the degree must have been completed under the numerical grading system.
5. Students may request up to 3 credits of master's thesis research be applied towards this requirement.
6. First year graduate students are required to attend seven seminars from the graduate seminar series.

DEPARTMENT of MECHANICAL ENGINEERING

Eann Patterson, Chairperson

UNDERGRADUATE PROGRAMS

MECHANICAL ENGINEERING

Mechanical engineers apply the fundamental principles of motion (mechanics) and energy (thermosciences) to serve the needs of people through the creative problem-solving process known as engineering design. These principles are represented in the subjects of solid and fluid mechanics, thermodynamics, heat transfer, mechanical systems, and material science. Practicing mechanical engineers work in many application areas, which include such industries as automotive, chemical, energy, consumer product, aerospace, computer and electronic, and biomedical.

The undergraduate mechanical engineering program prepares its graduates for the mechanical engineering profession through a foundation of engineering fundamentals; the development of

analytical, computational, and experimental capabilities to recognize, model, and solve engineering problems; and the application of the engineering design method. Communication and teaming skills are integrated throughout the program.

For students who desire an international experience as part of their education, the department sponsors various programs such as "Mechanical Engineering in Aachen, Germany." During the spring semester, a small group of juniors and seniors pursue their normal studies abroad at the Technical University of Aachen where they have outstanding opportunities to participate in advanced research, explore industrial activities, and experience European culture and lifestyle.

The Bachelor of Science Degree program in Mechanical Engineering is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone (410) 347-7700.

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: 23

CE	221	Statics	3
CEM	161	Chemistry Laboratory I	1
ECE	345	Electronic Instrumentation and Systems	3
ME	180	Engineering Graphic Communications	3
ME	222	Mechanics of Deformable Solids	4
ME	361	Dynamics	3
MSE	250	Materials Science and Engineering	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	422	Introduction to Combustion	3
	ME	423	Intermediate Mechanics of Deformable Solids	3
	ME	425	Experimental Mechanics	3
	ME	426	Introduction to Composite Materials	3
	ME	432	Intermediate Fluid Mechanics	3
	ME	440	Aerospace Engineering Fundamentals	3
	ME	444	Automotive Engines	3
	ME	457	Mechatronic System Modeling and Simulation	3
	ME	464	Intermediate Dynamics	3
	ME	477	Manufacturing Processes	3
	ME	478	Product Development	3
	ME	486	International Networked Teams for Engineering Design	3
	ME	490	Independent Study in Mechanical Engineering	1 to 3
	ME	491	Selected Topics in Mechanical Engineering	1 to 4
	ME	494	Biofluid Mechanics and Heat Transfer	3
	ME	495	Tissue Mechanics	3
	ME	497	Biomechanical Design	3
b.	Design-intensive courses (a minimum of 3 credits):			
	ME	416	Computer Assisted Design of Thermal Systems	3
	ME	417	Design of Alternative Energy Systems	3
	ME	442	Turbomachinery	3
	ME	445	Automotive Powertrain Design	3
	ME	456	Mechatronic System Design	3
	ME	465	Computer Aided Optimal Design	3
	ME	475	Computer Aided Design of Structures	3

Option in Biomechanical Engineering

An option in Biomechanical Engineering is available to, but not required of, any student enrolled in the Bachelor of Science degree in Mechanical Engineering. Completing the Bachelor of Science degree in Mechanical Engineering with an option in biomechanical engineering may require more than 128 credits.

Biomechanical Engineering Option

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

			CREDITS
Both of the following courses:			7
BS	111	Cells and Molecules	3
PSL	250	Introductory Physiology	4
Nine credits from the following courses:			9
BME	401	Quantitative Human Biology	3
ME	494	Biofluid Mechanics and Heat Transfer	3
ME	495	Tissue Mechanics	3
ME	497	Biomechanical Design	3
ME	490	Independent Study in Mechanical Engineering	1 to 4
ME	491	Selected Topics in Mechanical Engineering	1 to 4
MSE	425	Biomaterials and Biocompatibility	3

Upon completion of the required courses for the option, the student should contact the Department of Mechanical Engineering and request certification for the completion of the option. After the certification is approved 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.

Option in Engineering Mechanics

An option in Engineering Mechanics is available to, but not required of, any student enrolled in the Bachelor of Science degree in Mechanical Engineering. Completing the Bachelor of Science degree in Mechanical Engineering with an option in engineering mechanics may require more than 128 credits.

Engineering Mechanics Option

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

			CREDITS
The following course:			3
ME	423	Intermediate Mechanics of Deformable Solids	3
Three of the following courses:			9
ME	425	Experimental Mechanics	3
ME	432	Intermediate Fluid Mechanics	3
ME	464	Intermediate Dynamics	3
ME	475	Computer Aided Design of Structures	3

Upon completion of the required courses for the option, the student should contact the Department of Mechanical Engineering and request certification for the completion of the option. After the certification is approved 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.

Option in Manufacturing Engineering

An option in Manufacturing Engineering is available to, but not required of, any student enrolled in the Bachelor of Science degree in Mechanical Engineering. Completing the Bachelor of Science degree in Mechanical Engineering with an option in manufacturing engineering may require more than 128 credits.

Manufacturing Engineering Option

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

			CREDITS
All of the following courses:			10
EC	210	Economics Principles Using Calculus	3
ME	372	Machine Tool Laboratory	1
ME	477	Manufacturing Processes	3
ME	478	Product Development	3
One of the following courses:			3
CHE	472	Composite Materials Processing	3
ECE	415	Computer Aided Manufacturing	3
MSE	426	Introduction to Composite Materials	3

Upon completion of the required courses for the option, the student should contact the Department of Mechanical Engineering and request certification for the completion of the option. After the certification is approved 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 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.