College of Engineering Bulletin

The online Bulletin reflects the most up-to-date information available and is updated as changes are made to the curriculum. To view past versions of the College Bulletin in Adobe Acrobat format, please visit our archives.

Michigan Engineering

For students excited about the potential of technology, there's no better place to learn and explore than the University of Michigan College of Engineering. Michigan Engineering offers a rare combination of high-quality engineering scholarship, a broad scope of college and university opportunities, and large-scale impact.

Michigan Engineers-at the graduate and undergraduate levels-learn how to apply the latest developments in technological thinking to the world's major problems. Students learn about and participate in pioneering research in a variety of disciplines, including nanotechnology and integrated microsystems, cellular and molecular biotechnology, and information technology. With 11 departments, interdisciplinary and international programs, ten student team projects and nearly 60 liberal arts minors to choose from, the College offers future engineers an unparalleled range of opportunities. As a result, students leave Michigan prepared for leadership roles in traditional engineering functions as well as in business, medicine, law and teaching.

The College's faculty is composed of scholars who are among the best in their fields, including 51 National Science Foundation Career Award recipients and 22 current or emeritus faculty members of the National Academy of Engineering. Faculty research possibilities are expanded by the University's 19 schools, colleges and divisions. Interdisciplinary research is a hallmark of Michigan Engineering, particularly between the College and the schools of Medicine, Business, and Information. (Michigan is one of only two universities in the nation with top-ranked engineering, medical and business schools.) This research and other research within the College make a practical difference in society. The College's Technology Transfer Office works closely with faculty to put research into the hands of people.

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Greetings!

Welcome to the University of Michigan, one of our country's great public universities. Our university community is committed to excellence in all our programs, which encompass a broad array of scholarly and creative disciplines - and so many of them are in the College of Engineering.

Our University, of course, does not operate in isolation, but within a network of other prestigious research universities, a state that supports us, and a world that depends on our graduates and our discoveries. Our global society - social, political, economic and technological - compels us to recognize a teeming variety of values and perspectives.

Because of these shifts in the social and technological landscape, the frontiers of knowledge are continually expanding. The single laboratory and the solitary scholar are often supplemented by collaborative endeavors. Academic discoveries are emerging from the intersection of our disciplines and will become more intertwined with the world we serve. Our University, with its highly ranked departments and prominent scholars in so many fields, is well placed to provide leadership as we move into the future. The University of Michigan continues to define the great public university of the world.

Our university community is committed to excellence in all our programs, which encompass a broad array of scholarly and creative disciplines - and so many of them are in the College of Engineering.

The University is in the midst of a major fundraising campaign to support the forward momentum of our students, faculty and staff. Our donors, many of them alumni, are providing critical funding for student scholarships and fellowships, for faculty chairs, for new and expanded programs, and for the next generation of facilities that will enhance our academic endeavors. The fruits of this campaign already are evident across the College of Engineering, with new laboratories and buildings, increased financial aid for students, and support for faculty. Our campaign is "The Michigan Difference," and every day, I become more aware of how profound that difference is - for our students, our alumni, and the world we serve.

Sincerely,

Mary Sue Coleman
President
University of Michigan

Welcome

We live in an increasingly complex world, both socially and technologically. Therefore, individuals who are comfortable with technology, and know how to use it for various purposes, are well-prepared for the future no matter what directions their careers take. Those pursuing engineering careers are expected to enjoy promising opportunities for the long-term future. But even individuals seeking careers in medicine, law or business will find that an undergraduate degree in engineering is an excellent foundation. Michigan Engineering will provide you with a superior technological education and much more.

I like to think of engineering as the application of scientific principles to improve our world. Engineers best can be thought of as creators, innovators, problem solvers, builders, fixers and leaders. At Michigan, we strive to help our students become contributors to society in all of these ways. You will learn how to think logically, deal with uncertainty and change, apply technology in a socially and environmentally responsible manner, communicate effectively and collaborate with others. And, you will have many opportunities to develop and use these skills both inside and outside the classroom. For example, you may wish to become part of one of our nationally competitive teams, such as Solar Car or Steel Bridge, or to become involved in one of our several dozen student organizations.

Engineers can best be thought of as creators, innovators, problem solvers, builders, fixers and leaders.

If you are a graduate student or prospective graduate student, I am sure you are aware that Michigan is one of the nation's premier research universities, where we are actively engaged in the creation of new knowledge. Michigan Engineering students have the opportunity to engage in leading research throughout their programs of study. All of our students can interact with individual faculty members who are at the forefront of their fields.

The University of Michigan is a multidimensional university noted not only for outstanding technical education, and leaders who make a difference, but also for exceptional liberal arts, fine arts and extracurricular offerings. As a result, our students can take advantage of immense educational diversity to pursue countless interests in addition to engineering. I am confident that you will find your experience here exciting, challenging, rewarding and enjoyable!

Best regards,

David C. Munson, Jr.
Robert J. Vlasic Dean of Engineering
Professor of Electrical Engineering and Computer Science

Dear fellow College of Engineering student,

As students, we will all start the year with different lifelong goals. We will ultimately define success in many different ways, whether it's judged by the amount of money we make, the quality of the products we manufacture, or the number of lives we affect. Our goals may change throughout time, but we will always be aiming for something. Despite our differences, we are all here at the College of Engineering for one common reason, and that is to learn. As we progress through each day, we encounter challenges that we may have never seen before and may initially perceive to be insurmountable. It is our ability to conquer these challenges that strengthens us and teaches us valuable lessons.

Many of these lessons will be learned in the classes that you will be taking this year. I will not emphasize the prestige of our academic curriculum at the College of Engineering, as I'm sure that you are aware of the credentials. Instead, I would like to encourage you to take advantage of what is presented to you. The quantity of resources at the University of Michigan that can help students is overwhelming. Countless numbers of students, professors, and graduate student instructors will be more than willing to help you in your academic endeavors and your quest for education.

However, certain parts of your college education cannot be obtained from a textbook. There is more to becoming a great engineer than merely having academic knowledge. At the College of Engineering, there are over 100 student organizations and numerous project teams that can enrich your college experience. Organizations can provide academic support, leadership development, career networking contacts and lifelong friendships. I highly encourage you to explore these options, as they provide benefits that cannot be acquired through the classroom. The number of activities available guarantee you that you should never have a dull moment here at the College of Engineering.

Our goals may change throughout time, but we will always be aiming for something. Despite our differences, we are all here at the College of Engineering for one common reason, and that is to learn.

Years from now, you may look back and wonder if you are any closer to reaching your own goals. As long as we maintain our receptive mindsets, our sense of ethics and our dynamic ambitions, we will always move towards our individual goals. The University of Michigan will provide an excellent environment for you to learn. Please take the time to explore the available resources around you to learn more about engineering disciplines, extracurricular activities and yourself. I am honored that we are able to work together this year to become better engineers, better leaders, and better people.

Best of luck,

John Zhang
2006 University of Michigan Engineering Council President
Chemical Engineering

Academic Calendar 2006-2007
University of Michigan-Ann Arbor Campus
Registrar's Office: 734-764-6280

Fall 2006

Registration (for students not pre-registered)	Sept 1, Fri
Labor Day (Holiday)	Sept 4, Mon
Classes begin	Sept 5, Tues
Fall Study Break	Oct 16-17, Mon-Tues
Thanksgiving recess 5:00 p.m.	Nov 22, Wed
Classes resume 8:00 a.m.	Nov 27, Mon
Classes end	Dec 13, Wed
Study Days	Dec 14, Thurs & Dec 16-17, Sat-Sun
Examinations	Dec 15, Fri & Dec 18-22, Mon-Fri
Commencement	Dec 17, Sun
Winter 2007	
Registration (for students not pre-registered)	Jan 3, Wed
Classes begin	Jan 4, Thurs
Martin Luther King, Jr. Day University Symposia. No Regular Classes.	Jan 15, Mon
Vacation begins 12:00 noon	Feb 24, Sat
Classes resume	Mar 5, Mon
University Honors Convocation	Mar 18, Sun
Classes end	Apr 17, Tues
Study Days	Apr 18, Wed & Apr 21-22, Sat-Sun
Examinations	Apr 19-20, Thurs-Fri & Apr 23-26, Mon-Thurs
Commencement Activities	Apr 27-29, Fri-Sun
Spring/Summer 2007	
Registration (Full and Spring Half Terms)	April 30, Mon
Classes begin	May 1, Tues
Memorial Day (Holiday)	May 28, Mon
Classes end (Spring Half Term)	5:00 p.m. June 18, Mon
Study Days	June 19-20, Tues-Wed
Examinations	June 21-22, Thurs-Fri
Spring Half Term ends	June 22, Fri
Registration (Summer Half Term)	June 26, Tues
Classes begin (Summer Half Term)	June 27, Wed
Independence Day (Holiday)	July 4, Wed
Classes end (Summer and Spring/Summer Term)	5:00 p.m. Aug 14, Tues
Study Day	Aug 15, Wed
Examinations	Aug 16-17, Thurs-Fri
Full & Summer Half Terms end	Aug 17, Fri

Students enrolling in Business Administration, Dentistry, Law,and Medicine should check with their respective schools for academic calendar information, including registration. This calendar is subject to change.

Undergraduate Drop/Modify Deadlines 2006-2007

Fall Term 2006

Fall Term begins, Tuesday, September 5th
Fall Term, drop deadline w/o W's, Monday, September 25th
Fall Term, drop/pass/fail deadline w/o petition, Friday, November 10th

First Half Term (7 week course) begins Tuesday, September 5th
First Half Term (7 week course) drop deadline w/o W's Monday, September 25th
First Half Term (7 week course) drop/pass/fail deadline w/o petition, Thursday, October 5th
First Half Term (7 week course) ends Tuesday, October 24th (revised)

Second Half Term (7 week course) begins, Wednesday, October 25th (revised)
Second Half Term (7 week course) drop deadline w/o W's, Monday, November 13th
Second Half Term (7 week course) drop/pass/fail deadline w/o petition, Wednesday, November 22nd
Fall Term ends Tuesday, December 22nd (revised)

Winter Term 2007

Winter Term begins, Thursday, January 4th
Winter Term drop deadline w/o W's, Wednesday, January 24th
Winter Term drop/pass/fail deadline w/o petition, Friday, March 16th

First Half Term (7 week course) begins Thursday, January 4th
First Half Term (7 week course) drop deadline w/o W's, Wednesday, January 24th
First Half Term (7 week course) drop/pass/fail w/o petition Friday, February 2nd
First Half Term (7 week course) ends, Wednesday, February 21st (revised)

Second Half Term (7 week course) begins Thursday, February 22nd (revised)
Second Half Term (7 week course) drop deadline w/o W's, Friday, March 23rd
Second Half Term (7 week course) drop /pass/fail deadline w/o petition, Friday, April 6th
Winter Term ends Thursday, April 26th

Spring Term 2007

Spring Term begins, Tuesday, May 1st
Spring Term drop deadline w/o W's, Monday, May 14
Spring Term drop/pass/fail deadline w/o petition, Friday, June 2nd
Spring Term ends, Friday, June 22nd

Spring/Summer Term 2007

Spring/Summer Term begins Tuesday, May 1st
Spring/Summer drop deadline w/o W's, Monday, May 21st
Spring/Summer drop /pass/fail deadline w/o petition, Friday, July 6th
Spring/Summer Term ends, Friday, August 17th

Summer Term 2007

Summer Term begins, Wednesday, June 27th
Summer Term drop deadline w/o W's, Tuesday, July 10th
Summer Term, drop/pass/fail deadline w/o petition, Friday, July 27th
Summer Term ends, Friday, August 17th

These deadlines are subject to change.

Academic Calendar 2005-2006

University of Michigan–Ann Arbor Campus
Registrar's Office: 734-764-6280

Fall 2005

Registration (for students not pre-registered)	Sept 2, Fri
Labor Day (Holiday)	Sept 5, Mon
Classes begin	Sept 6, Tues
Fall Study Break	Oct 17-18, Mon-Tues
Thanksgiving recess	5:00 p.m. Nov 23, Wed
Classes resume	8:00 a.m. Nov 28, Mon
Classes end	Dec 13, Tues
Study Days	Dec 14, Wed Dec 17-18, Sat-Sun
Examinations	Dec 15-16 Thurs-Fri & Dec 19-22, Mon-Thurs
Commencement	Dec 18, Sun

Winter 2006

Registration (for students not pre-registered)	Jan 4, Wed
Classes begin	Jan 5, Thurs
Martin Luther King, Jr. Day University Symposia. No Regular Classes.	Jan 16, Mon
Vacation begins	12:00 noon Feb 25, Sat
Classes resume	Mar 6, Mon
University Honors Convocation	Mar 19, Sun
Classes end	Apr 18, Tues
Study Days	Apr 19, Wed & Apr 22-23, Sat-Sun
Examinations	Apr 20-21, Thurs-Fri & Apr 24-27, Mon-Thurs
Commencement Activities	Apr 28-30, Fri-Sun

Spring/Summer 2006

Registration (Full and Spring Half Terms)	May 1, Mon
Classes begin	May 2, Tues
Memorial Day (Holiday)	May 29, Mon
Classes end (Spring Half Term)	5:00 p.m. June 19, Mon
Study Days	June 20-21, Tues-Wed
Examinations	June 22-23, Thurs-Fri
Spring Half Term ends	June 23, Fri
Registration (Summer Half Term)	June 27, Tues
Classes begin (Summer Half Term)	June 28, Wed
Independence Day (Holiday)	July 4, Tues
Classes end (Summer and Spring/Summer Term)	5:00 p.m. Aug 15, Tues
Study Day	Aug 16, Wed
Examinations	Aug 17-18, Thurs-Fri
Full & Summer Half Terms end	Aug 18, Fri

Students enrolling in Business Administration, Dentistry, Law, and Medicine should check with their respective schools for academic calendar information, including registration. This calendar is subject to change.

Undergraduate Drop/Modify Deadlines 2005-2006

Fall Term 2005

Fall Term begins, Tuesday, September 6th
Fall Term, drop deadline w/o W's, Monday, September 26th
Fall Term, drop/pass/fail deadline w/o petition, Friday, November 11th

First Half Term (7 week course) begins Tuesday, September 6th
First Half Term (7 week course) drop deadline w/o W's Monday, September 26th
First Half Term (7 week course) drop/pass/fail deadline w/o petition, Thursday, October 6th
First Half Term (7 week course) ends Thursday, October 25th (revised)

Second Half Term (7 week course) begins, Wednesday, October 26th (revised)
Second Half Term (7 week course) drop deadline w/o W's, Monday, November 14th
Second Half Term (7 week course) drop/pass/fail deadline w/o petition, Wednesday, November 23rd
Fall Term ends Tuesday, December 13th (revised)

Winter Term 2006

Winter Term begins, Thursday, January 5th
Winter Term drop deadline w/o W's, Wednesday, January 25th
Winter Term drop/pass/fail deadline w/o petition, Friday, March 17th

First Half Term (7 week course) begins Thursday, January 5th
First Half Term (7 week course) drop deadline w/o W's, Wednesday, January 25th
First Half Term (7 week course) drop/pass/fail w/o petition Friday, February 3rd
First Half Term (7 week course) ends, Tuesday, February 21st (revised)

Second Half Term (7 week course) begins Wednesday, February 22th (revised)
Second Half Term (7 week course) drop deadline w/o W's, Friday, March 24th
Second Half Term (7 week course) drop /pass/fail deadline w/o petition, Friday, April 7th
Winter Term ends Thursday, April 27th

Spring Term 2006

Spring Term begins, Tuesday, May 2nd
Spring Term drop deadline w/o W's, Monday, May 15
Spring Term drop/pass/fail deadline w/o petition, Friday, June 2nd
Spring Term ends, Friday, June 23rd

Spring/Summer Term 2006

Spring/Summer Term begins Tuesday, May 2nd
Spring/Summer drop deadline w/o W's, Monday, May 22nd
Spring/Summer drop /pass/fail deadline w/o petition, Friday, July 7th
Spring/Summer Term ends, Friday, August 18th

Summer Term 2006

Summer Term begins, Wednesday, June 28th
Summer Term drop deadline w/o W's, Tuesday, July 11th
Summer Term, drop/pass/fail deadline w/o petition, Friday, July 28th
Summer Term ends, Friday, August 18th

These deadlines are subject to change.

The Nature of Engineering

Engineers solve real-life problems. They find the best solutions through the application of their combined knowledge, experience and judgment. Every day of every year, engineers help to define our way of life by providing innovative, higher-performance, safer, cleaner or more comfortable methodologies for more and more people.

Engineers seek improvement through the processes of invention, design, manufacture and construction. Throughout all of these steps, they continually assess the use of human power and the impact of engineering on society.

The by-products of discovery are sometimes positive, sometimes negative. Water, air, and noise pollution result from the same engineering marvels of decades ago. Even in "benign" engineering, the effects of technology can be challenging, such as the burgeoning need for larger and more efficient information storage and retrieval systems in modern communication.

The engineer's problem-solving approach grows in importance as the world's social and technological problems become more closely related. For example, the problem of air pollution cannot be solved by analyzing the physical causes alone. What social, legal, political, and ethical conflicts does it generate? How will available technological solutions affect individual and group interests and well-being?

In many ways, the study of engineering provides students with the true "liberal education" of our technology-based future-an education which provides the technical understanding and problem-solving skills that will allow an almost unlimited range of opportunities in the complex challenges of tomorrow.

Michigan Engineering Mission

To be the place of choice for engineering education and research...A Michigan institution that challenges its students, faculty and staff to learn, to grow, to achieve and to serve the needs of society...A place where excellence, excitement, innovation and impact define the style and substance of its activities.

Michigan Engineering Goals

1. To provide a continuously improving educational and research environment in which faculty, administrators, students and staff work together to educate our students to lead, to have impact, and to make significant contributions to their professions, industry, government, academia and society.
2. To attract diverse, outstanding students, and to motivate and educate them to reach their full potential as leaders in engineering professions.

History

The University of Michigan began educating engineers in 1854, when fewer than a half-dozen other American universities were providing opportunities for a formal, degree-granting course of study in engineering. U-M was the first public university to award degrees in engineering.

As early as 1852, U-M President Henry P. Tappan proposed "a scientific course parallel to the classical course," containing "besides other branches, Civil Engineering, Astronomy with the use of an observatory, and the application of chemistry and other sciences to agriculture and the industrial arts generally." The early curriculum included mathematics, graphics, physics, natural science, elements of astronomy, language, philosophy, and engineering subjects including plane geodetics, railroad and mining surveying, leveling, the nature and strength of materials, theory of construction, architecture, machines (particularly the steam engine and locomotive) and motors, particularly steam and water.

The College of Engineering established itself as a significant engineering school with some of the nation's earliest engineering programs, in metallurgical engineering (1854), naval architecture and marine engineering (1881), electrical engineering (1889), chemical engineering (1898), aeronautical engineering (1916), nuclear engineering (1953) and computer engineering (1965).

Michigan Engineering Today

Today, the College of Engineering at the University of Michigan is consistently ranked among the top engineering schools in the world. All of its undergraduate degree programs ranked by *U.S. News* and nearly all of its graduate degree programs are rated in the top ten nationwide. Approximately 1,200 bachelor's degrees and 1,100 master's and doctoral degrees are awarded annually. The opportunities for study have expanded so that students may choose from more than 1,000 engineering courses.

There were 306 teaching faculty, 79 research faculty, 4,943 undergraduate students, and 2,579 graduate students in the College of Engineering in Fall 2005.

The College of Engineering expended $132 million dollars last year in total research-nearly one fifth of the total University's research funds. The College has more than 150 research laboratories, many of which operate with budgets of over a half-million dollars, including two National Science Foundation Engineering Research Centers.

Degree Programs

The College of Engineering offers undergraduate and graduate programs through the doctoral level. The undergraduate program consists typically of a four-year schedule leading to a bachelor's degree. There are 14 courses of study that lead to the Bachelor of Science in Engineering degree (B.S.E.) and one that leads to the Bachelor of Science degree (B.S.). By careful planning, an additional bachelor's degree (B.S. or A.B.) can be earned within the College of Engineering or in combination with another college within the University of Michigan in about one year beyond the time required for a single degree. Completion of both an engineering baccalaureate and a master's degree in approximately five years is also possible. A complete list of graduate programs is found in the Graduate Studies portion of this *Bulletin*.

Areas of undergraduate study at the College of Engineering include:

- Aerospace Engineering
- Atmospheric, Oceanic and Space Sciences
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Computer Science
- Electrical Engineering
- Engineering Physics
- Industrial and Operations Engineering
- Interdisciplinary Program
- Materials Science and Engineering
- Mechanical Engineering
- Naval Architecture and Marine Engineering
- Nuclear Engineering and Radiological Sciences

Accreditation

The Computer Science program is accredited by the Computing Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

The Aerospace, Chemical, Civil, Computer Engineering, Electrical, Industrial and Operations, Materials Science and Engineering, Mechanical, Naval Architecture and Marine Engineering, and Nuclear Engineering and Radiological Sciences programs are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Facilities

The offices and facilities used for instruction and research in engineering are located in the following buildings on the North and Central campuses:

North Campus

- Advanced Technology Laboratories (ATL)
- Aerospace Wind Tunnel Laboratories
- Ann and Robert H. Lurie Biomedical Engineering Building
- Bonisteel Interdisciplinary Research Building
- Carl A. Gerstacker Building
- Chrysler Center for Continuing Engineering Education
- Computer Science and Engineering Building
- Dow Connector Building
- Electrical Engineering and Computer Science Building (EECS)
- Engineering Programs Building (EPB)
- Engineering Research Building
- Environmental and Water Resources Engineering Building (EWRE)
- François-Xavier Bagnoud Building (FXB)
- George Granger Brown Laboratories (GGB)
- Herbert H. Dow Building
- Industrial and Operations Engineering Building (IOE)
- James and Anne Duderstadt Center
- Michigan Ion Beam Laboratory
- Mortimer E. Cooley Building
- Naval Architecture and Marine Engineering Building (NAME)
- Phoenix Memorial Laboratory
- Robert H. Lurie Engineering Center (LEC)
- Space Research Building
- Walter E. Lay Automotive Engineering Laboratory
- Walter E. Wilson Student Team Project Center

Central Campus

- West Hall: Naval Architecture and Marine Engineering Hydrodynamics Laboratories

Laboratories and other facilities are described within the sections on Undergraduate Degree Programs.

The Robert H. Lurie Engineering Center (LEC)
The Robert H. Lurie Engineering Center, the College of Engineering's "front door," is the center for undergraduate student support including central student services, admissions, records, scholarships, first-year and undeclared advising, and specialized academic support such as the Engineering Advising Center, Minority Engineering Program Office, the Women in Engineering Office and the Ameritech Engineering Learning Resource Center. LEC also houses the deans' offices and provides lounge, meeting and conference space for the College.
LEC, named in honor of the late Robert H. Lurie (BSE IOE '64, MSE '66), was made possible by a $12 million gift from Ann Lurie, Bob's wife. Bob and his partner, Sam Zell (AB '63, JD '66), worked together in commercial real estate and other ventures, such as the Chicago Bulls and the White Sox.
The Ann and Robert H. Lurie Tower, which stands on the North Campus Diag, and the new Ann and Robert H. Lurie Biomedical Engineering Building are also the result of generous gifts by Ann Lurie.

The James and Anne Duderstadt Center
The James and Anne Duderstadt Center (formerly the Media Union) is a 255,000 square-foot integrated technology instruction center that represents a new concept for universities-a place to house collections of information resources that are normally found in a traditional library, and also a center that provides high-tech equipment to further explore the physical and simulated world. Users are invited to the Duderstadt Center to locate information, create new artifacts and make the results of their own inquiries available to others.
Within the Duderstadt Center, users will find studios equipped with the latest technologies for visualization and virtual reality, design, digital video and audio creation, distance learning and collaboration. The Duderstadt Center is predicated on the knowledge that information will increasingly be created and stored digitally; therefore, any new center for the storage of, and access to, information needs to accommodate this digital future. To that end, the environment has network connectivity, from casual seating to teaching facilities. The Duderstadt Center also houses the library collections of the College of Engineering, the College of Architecture and Urban Planning, and the School of Art & Design.

Walter E. Wilson Student Team Project Center
One of the best ways for College of Engineering students to gain critical hands-on design experience as well as important team, organizational, and management skills is through engineering design/build competitions. Student team projects provide practical design and fabrication experience that complements classroom instruction, in addition to real-life lessons in working cooperatively with others.
The Walter E. Wilson Student Team Project Center, named for University of Michigan College of Engineering alumnus Walter E. Wilson (BSE ME '33), provides students with designated space for student teams involved in national competitions.
This 10,000-square-foot center, located behind the François-Xavier Bagnoud Building and adjacent to the Wave Field, houses space and equipment for design, assembly, machining, electronics, composite lay-up and painting and is accessible to students 24 hours a day, seven days a week. A lecture room, offices and a student lounge round out the center.

Use of Facilities
Laboratory, classroom and office equipment, shops, the library and the computer labs are examples of a wide variety of facilities that serve as aids for instruction and research. Their use is limited to the purpose for which they are made available and any misuse will be subject to disciplinary action.
Student identification cards are required for entrance to many campus facilities, especially certain laboratories and libraries. These cards are issued at the Student Activities Building (SAB) in Room 100 and Room 1000, the Central Campus Recreation building in Room 3269, the Wolverine Tower in Room 2506 or the North Campus Entrée Plus Office in room B430 of the Pierpont Commons on North Campus.

Computing
The College of Engineering's Office of Information Technology and CAEN provide the College with a comprehensive set of computing technologies that support its instructional, research, administrative and service missions. CAEN's high performance desktop computers, up-to-date data network, software library and overall information technology environment improve the quality of education and research throughout the College. Talented staff and the aggressive pursuit of innovative technologies ensure that CAEN remains a leader among its peers in academia and industry.
The College computing environment is comprised of an integrated set of resources at the College, department and lab levels that together total over 10,000 network attached devices. CAEN-supported student computing labs provide over 1,000 desktop computers available to students on a drop-in basis, 24 hours a day. These computing labs offer a large array of software for engineering design and analysis, software development and personal productivity. This lab environment is complemented by high-performance computing clusters maintained jointly by CAEN and the Center for Advanced Computing (CAC). CAEN also provides web services to the College community as well as instructional and collaborative technology support throughout many of the labs, classrooms and conference rooms in the College.
A modern college-wide network infrastructure provides the College with robust wired and wireless networks. Wireless Ethernet is available across nearly 100% of the College. All network wall jacks provide at least 100 Megabit Ethernet connectivity and many locations provide Gigabit Ethernet as well. High speed network backbones connect all of the buildings in the College and also provide high speed connectivity to the rest of campus, the Internet and Internet2.

Library Resources
The Art, Architecture and Engineering Library and staff are located in the Duderstadt Center on North Campus. It is one of more than 19 divisional libraries in the University Library system. The Duderstadt Center is open 24 hours a day, seven days a week during the academic year. The library's collection of over 600,000 volumes covers all fields of engineering and is considered one of the largest in the country. The library subscribes to almost 2,000 journals and e-journal titles. The library maintains a large collection of technical reports, standards, government documents, U.S. and foreign patents and reserve materials for coursework.
The library subscribes to many online resources such as books, conference proceedings, reports and reference materials. These online resources can be accessed from on and off campus. The subject specialist librarians and staff also provide electronic course reserves, course related instruction programs, and computerized reference searching to help students, faculty and researchers make effective use of information resources available both on the University campus and from around the world. More information on library resources can be found at http://www.lib.umich.edu/aael.

Who May Apply

To be admitted at the freshman level, an applicant must be at least 16 years old and a graduate of an accredited secondary school. Graduates of unaccredited schools will be asked to take College Board Achievement Tests or the American College Test.

Home-schooled students and students attending unaccredited high schools should contact the Office of Undergraduate Admissions prior to September of their senior year to determine if additional credentials such as SAT II Subject Exams should be submitted.

For older students, the results of the General Education Development (GED) test may be presented in place of a high school diploma.

The University of Michigan Nondiscrimination Policy Statement
The University of Michigan, as an equal opportunity/affirmative action employer, complies with all applicable federal and state laws regarding nondiscrimination and affirmative action, including Title IX of the Education Amendments of 1972 and Section 504 of the Rehabilitation Act of 1973. The University of Michigan is committed to a policy of nondiscrimination and equal opportunity for all persons regardless of race, sex*, color, religion, creed, national origin or ancestry, age, marital status, sexual orientation, disability, or Vietnam-era veteran status in employment, educational programs and activities, and admissions. Inquiries or complaints may be addressed to the Senior Director for Institutional Equity and Title IX/Section 504 Coordinator, Office for Institutional Equity, 2072 Administrative Services Building, Ann Arbor, Michigan 48109-1432, 734-763-0235, TTY 734-647-1388. For other University of Michigan information call 734-764-1817.
*Includes discrimination based on gender identity and gender expression.

Admission as a First-Year Student
Freshman students are admitted to the College of Engineering by the University of Michigan's Office of Undergraduate Admissions. Appropriate forms and instructions are available by contacting:

Office of Undergraduate Admissions
1220 Student Activities Building
The University of Michigan
Ann Arbor, MI 48109-1316 /(734) 764-7433
http://www.admissions.umich.edu/

Applications for admission can be requested from a high school counselor or by contacting the Undergraduate Admissions Office. Applicants are encouraged to use the online application which is available (see URL above). Please note that first-year students are admitted to the College of Engineering and not to a specific degree program. Students applying for first-year admission must submit the application and all required credentials by February 1 in order to receive equal consideration. Allow sufficient time for other offices to process requests for official documents and for mail services to deliver materials to the Undergraduate Admissions office prior to the deadline. Applications will be considered after these dates only if space is available.
Freshman applicants are encouraged to apply as early as possible in the fall of their senior year. Schools and colleges, including the College of Engineering, may close admissions before the "equal consideration" date.

Admitted students are encouraged to submit their enrollment deposit prior to May 1. All admitted students have until May 1 to notify the University of their intention to enroll for fall term. Students submitting enrollment deposits that are received after the May 1 deadline may not be allowed to enroll due to space considerations. Enrollment is contingent upon completion of the student's high school program with grades consistent with those on which admission was granted.

Both the Office of Undergraduate Admissions and the College of Engineering welcome the opportunity to provide information for prospective first-year students and to host them and their families for information sessions and tours. Online tour reservations are available at http://www.admissions.umich.edu/visiting/

Criteria
The admission requirements are designed to assure that each student who is admitted to the College of Engineering has aptitude for the profession of engineering as well as intellectual capacity, interest, and motivation to pursue college work successfully. Students' qualifications in these respects vary widely, and from long experience it is evident that no single criterion is sufficient to judge the ability of every applicant.

The admission application review, therefore, takes into account the following criteria for admission:
• subjects studied in high school
• scholastic performance
• standardized test scores
• high school counselor and teacher recommendations
• student's essay

1. Subjects Studied in High School

A unit for admission is defined as a course covering a school year of at least 120 sixty-minute hours of classroom work. Two or three hours of laboratory, drawing, or shop work are counted as equivalent to one hour of recitation.

The following subjects and units are minimum requirements for admission:

Subject	CoE Requirements	CoE Recommendations
English	4 Units of English required	4 Units including 2 rigorous writing courses
Math	4 Units of Math required including Trigonometry	4 Units of Math including Trigonometry and Calculus
Science	3 Units of Science required including 1 Unit of Chemistry	4 Units of Science recommended, including 1 Unit each of Chemistry and Physics
Social Studies	3 Units Required	
Computer-Science		Recommend 1 Unit
Pre-Engineering		Recommend 1 Unit in Drafting, CAD, or Computer-related/Tech Courses
Extracurricular	General Extracurricular	Recommend one Club/Activity related to Math, Science or Engineering such as Science Fair, Science Olympiad, F.I.R.S.T., Math/Computer/Tech Club
Foreign Language		2 Units strongly recommended

2. Scholastic Performance

The student's grades, particularly in mathematics, laboratory sciences, and courses that indicate verbal ability, together with the standing in the class, are considered important in determining admission to study engineering. Interest and high achievement in these subjects will also help the student to decide whether or not the right choice of career is being made as well as predicting the likelihood of success in the engineering profession.

3. Standardized Testing

Tests in verbal and mathematical abilities have proven helpful for predicting success in engineering courses. Applicants are required to take the College Entrance Examination Board Scholastic Assessment Test (SAT I) or American College Testing (ACT) during their junior and/or senior year in high school. (The writing section is required for either test.) SAT II scores are not required, but will be considered if provided. For information and time schedules on the Scholastic Assessment Test, students should consult with their high school advisor or write to the College Entrance Examination Board, Box 592, Princeton, NJ 08540, or to Box 1025, Berkeley, CA 94701. For information and time schedules on the ACT test, students should consult with a high school advisor or write to The American College Testing Program, Iowa City, IA 52240.

4. High School Recommendations

Statements by representatives of the applicant's high school are taken into account. This may relate to such qualities as the character and seriousness of purpose of the applicant, interests and attainments (both scholastic and extracurricular), intellectual promise, and potential for success. A counselor's recommendation and a teacher's recommendation are required as a part of the application for admission.

5. Essay

Brief essays will be required that pertain to specific questions asked on the admissions application. There are also opportunities to include your activities, interests, accomplishments, and talents. Such information provides additional background that may not be evident from the other criteria listed above.

Advanced Placement

Many students take Advanced Placement courses through the Advanced Placement Program in their high schools. Credit for these courses can be applied toward a degree, provided the student has performed satisfactorily on the Advanced Placement Program examination conducted nationally by the College Entrance Examination Board.

Any questions regarding the examination, scores or results should be directed to the Advanced Placement Program.

http://www.collegeboard.org/ap/students/index.html

By Mail: Advanced Placement Program
PO Box 6671
Princeton, NJ 08541-6671
By Telephone:(609) 771-7300 or (888) CALL-4AP
By Fax:(609) 530-0482
By TTY: (609) 882-4118 *(for the hearing impaired)*
By Email: apexams@info.collegeboard.org

All other questions about Advanced Placement should be referred to Engineering Advising Center, 1009 Lurie Engineering Center, College of Engineering, University of Michigan, Ann Arbor, MI 48109-2102. (Phone # 734-647-7106)

The following Web site lists the satisfactory scores required to receive credit in the College of Engineering.
http://www.engin.umich.edu/students/prospective/undergraduate/admissions/apibtransfer.html

University Placement Examinations

There are a number of courses for which credit may be received by getting a satisfactory score on a Placement Examination offered by a department of the University.

Note: No credit is granted for math and chemistry placement exams given before or during orientation. The purpose of these exams is to determine your preparation for these entry level courses.

1. Foreign Languages

A student may take an examination in a foreign language regardless of how the language skills were developed. To receive credit by examination, the foreign exam must have both a written and listening component in order to be granted credit. Credit by U-M examination, Advanced Placement, A-Levels of IB examination will be granted up to a maximum of 8 credits. If the language credit earned is at the first-year level, then the credit hours may be used only as unrestricted electives. If the language credit earned is at the second-year level, then the credit hours may be used as humanities or unrestricted elective credits. Students may not receive foreign language credit by exam above the second-year level. Students earning language credit by completing qualifying courses at the University of Michigan, designated by LR or HU, or by transfer credit of equivalent courses from any other institution of higher learning, may apply all credits earned towards humanities.

2. Credit By Examination for Engineering 101

Credit for Engineering 101 (Introduction to Computers & Programming) can be earned by taking the U-M College of Engineering Placement examination during the student's Orientation. This exam is only available during the student's orientation session.

3. Transfer Credit for Entering Freshmen Students

Incoming freshmen who took a course(s) at a college or university while dually enrolled in high school may potentially receive transfer credit. The guidelines for transferring credit in these situations include that the courses must:

a.) be taken at an accredited college or university
b.) be taken on a college/university campus
c.) be taken with other college/university students
d.) not be counted toward high school completion

Students seeking approval to transfer credit are required to submit a letter from their high school counselor verifying the above information. This will need to be submitted to the Office of Recruitment and Admissions at 1221 Beal Avenue; Robert H. Lurie Engineering Center, Ann Arbor, MI 48109-2106.

Admission as a Transfer Student

To transfer from an accredited college, including another unit at the University of Michigan-Ann Arbor, applicants should contact the College of Engineering's Office of Recruitment and Admissions, 1108 Lurie Engineering Center, 1221 Beal Avenue, Ann Arbor, MI 48109-2102, (734) 647-7101. The online application is available at **https://apply.embark.com/ugrad/umich/eng/**. Applicants are required to submit official transcripts of both secondary school and college course work. Applicants from another school or college on the University of Michigan-Ann Arbor campus are not required to submit U-M transcripts.

Application Deadlines

Applications for admission should be submitted before March 1 for the fall term and prior to October 1 for winter term. Applications received after the deadline dates will be accepted only if space is available.

General Admission Requirements and Information

For admission consideration, an applicant must provide transcripts for all courses taken after completion of secondary education. The official college transcript(s) must list the subjects elected, the number of credit hours and grades earned in each subject, and the basis upon which grades were assigned. Results of any aptitude tests that were taken in high school or college are helpful but not required.

The academic background of an applicant must demonstrate his or her ability to meet the requirements of the College of Engineering for graduation. The grades earned in subjects related to the program elected by the applicant are of critical significance and will be important in making the admission decision. An overall scholastic average that is satisfactory for good standing at the previous institution(s) may not in itself be sufficient. Admission standards are based on departmental guidelines to specific programs that include meeting the departmental grade point average (GPA) requirements. Transfer guidelines are available on our web site.

Prerequisite and Basic Courses Taken at Another Institution

Most programs require the same basic pre-engineering courses for transfer admission. These include mathematics, chemistry, physics, english composition, and a computer programming course with "C++" as the preferred language. Generally, such courses are offered as a complete two-year program to meet the requirements for study in many engineering colleges (e.g., a mathematics sequence requiring four semesters or six quarters). Also, in many institutions students are able to satisfy the requirements of economics and some elective courses in humanities and social sciences. Students may also be able to elect engineering courses if equivalent course content is covered.

A student in another college or university who desires to transfer should carefully examine the program that he or she plans to elect at the College of Engineering and arrange the course selections accordingly. Many course requirements can be found at the following Web site: http://www.engin.umich.edu/transferdatabase/index.jsp

Combined Programs with Other Institutions

The College of Engineering cooperates with other institutions in providing an opportunity to earn two bachelor's degrees (A.B. or B.S. and B.S.E.) in approximately five to five-and-one-half years by satisfying the requirements for both degrees. Representative institutions providing this opportunity are:

Adrian College
Albion College
Alma College
Atlanta University Center Dual Degree in Engineering Program: (Clark-Atlanta University, Morehouse College, and Spelman College)
Beloit College
Hope College
Kalamazoo College
Lawrence University (Wisconsin)
Virginia Union University

An interested student would enroll at one of these institutions for the first three years and include in the elections a pre-engineering program that, under conditions of satisfactory performance, will transfer as substantially equivalent to two or two-and-one-half years of the requirements of the College of Engineering.

Transfer Credit

An evaluation of the previous record of a student transferring from a college or university will be made, at the time of application review, to indicate tentatively the credit that will be transferred toward a bachelor's degree in the program specified by the applicant. This appraisal is subject to review by representatives of the several departments involved and by the student's intended program advisor. The transfer credit may be revised if the academic progress of the student indicates that the student is unable to continue successfully because of an inadequate preparation.

Credits are granted only for transferable courses in which a grade of "C" or better is earned. A "C-" will only be accepted if earned on the University of Michigan-Ann Arbor Campus for courses other than math, science, engineering, or other prerequisites for admission.

Classification level is determined by the number of hours transferred.

The U-M transcript of transfer students will not reflect grades earned while enrolled in another college. The transfer student's GPA is determined solely by the grades earned while enrolled in the College of Engineering. This does not apply to students transferring from other academic units located on the Ann Arbor campus of the University. If, at any time, a transfer student has questions regarding the adjustment of credit, the Office of Recruitment and Admissions should be consulted.

Transfer Credit for Enrolled Students (Guest Application Process)

Currently enrolled students can transfer credit from classes taken at other institutions within the United States by conducting the Guest Application Process. The Guest Application can be completed and submitted online at http://www.engin.umich.edu/students/current/. A review of the Guest Application typically takes two to four weeks and results in the notification of courses, their transferability, and the credit hours that will be earned upon completion of the course(s) with a grade of "C" or better. This information along with important rules to keep in mind can be found on the website shown above. Questions can be directed to the Office of Recruitment and Admissions.

Currently enrolled students must consult the International Programs in Engineering (IPE) office regarding credit transfer for classes taken outside the United States. The IPE Course Evaluation Form is available in the IPE Office, 245 Chrysler Center, 2121 Bonisteel Blvd., Ann Arbor, MI 48109-2092 or online at http://www.engin.umich.edu/ipe/studyabroad/courseeval.html .

Admission of Graduates of Other Colleges/ Admission of Students via Prescribed Program

Students who have completed an undergraduate degree or applicants for transfer admissions who have completed a substantial number of the requirements for the bachelor's degree in engineering can be admitted via a *prescribed program*. The prescribed program is a detailed outline of the courses that must be taken for completion of the engineering degree, and is determined by the program advisor for students who could satisfy degree requirements in 30 to 40 credit hours at Michigan (at least 30 of which must be at the 300-level or higher). The student must attain a "C" or better in each course of his/her prescribed program. For questions contact the Office of Recruitment and Admissions.

Cross-Campus Transfer Re-Registration Policy (Previously titled Residency Policy)

Admitted cross-campus transfer students to the CoE are held accountable to the following policy:

1. Admitted cross-campus students must re-register under their Engineering program status. The re- registration of courses must be done no later than 3 weeks after the first day of classes of the admitted term:

- Students who do not re-register their classes will be discontinued from the College of Engineering.
- Once a student is discontinued they will then have to reapply to the College of Engineering, which may involve being held accountable to new admission standards.
- A student who reapplies after being discontinued and is admitted must be reinstated to the original term of the College of Engineering admission. This will involve having all of the student's classes re-registered to that original term of admission and the student being billed for the differences in tuition and College of Engineering fees accordingly.

2. Students who want to be admitted to the College of Engineering who are near graduation and receive approval from an engineering department are held to the following:

- The engineering department will determine under which past term the student should have been admitted. The student's classes will then be re-registered back to that term for admission and the student will be billed for the differences in tuition and College of Engineering fees accordingly.
- A department will have the authority to go back as many past terms as they deem appropriate for the student's admission.
- Departments must go back a minimum number of terms so that the student satisfies the College of Engineering rule that 30 of their last 36 credits are completed in the College of Engineering.

International Student Admissions

International Freshman Students

International students without previous college experience whose command of the English language is equal to that of students educated in the United States should apply for admission as first-year students to the University of Michigan College of Engineering through the Office of Undergraduate Admissions (OUA), 1220 Student Activities Building, Ann Arbor, MI 49109-1316.

International applicants are urged to request the brochure titled "International Admissions Information" from the Office of Undergraduate Admissions.

International Transfer Students

International students wishing to transfer from an approved accredited college must complete the same basic college prerequisite subjects required of all transfer applicants. Application is made to the College of Engineering's Office of Recruitment and Admissions. See "Admission as a Transfer Student: General Admission Requirements and Information".

International students are also held accountable to several other requirements for receipt of their I-20 for F-1 or J-1 student visas. International students requesting this visa or other student visa classification should contact the Office of Recruitment and Admissions, 1108 Lurie Engineering Center, 1221 Beal Avenue, Ann Arbor, MI 48109-2102, (734) 647-7101, or enginrta@umich.edu for additional requirements.

English Proficiency Requirements

International applicants must also meet the prescribed standards of proficiency in English. Each student whose native language is not English is required to submit, before admission, the results of either the Michigan English Language Assessment Battery (MELAB) or Test of English as Foreign Language (TOEFL). These tests are administered abroad as well as in the United States. For MELAB registration information, write to The Testing Division, English Language Institute, Ann Arbor, Michigan, 48109-1057, USA; phone (734) 764-2416. For TOEFL registration information, write CN6154, Princeton, NJ, 08541-2416, USA; phone (609) 921-9000.

A score of 80-85, with no section scores below 80, is required on the MELAB test. A computer TOEFL score of at least 230, with no subscore below 23, is required for admission. A minimum of 570 with no subscore below 57 is required for the paper version of the TOEFL. Regardless of tests taken previously, the College of Engineering reserves the right to require testing after arrival at the University of Michigan.

Required Documents

International students must provide proof of their ability to finance their entire education at the College of Engineering. The College of Engineering Financial Resource Statement (FRS) along with proof of financial backing is required. Scholarships available are very limited to international students. The student's sponsor should submit an official bank statement or have their financial backing institution certify Section II on the FRS. Applicants requesting the Student F-1 Visa or the Exchange Visitor J-1 Visa are instructed in procedures for documenting financial resources.

If a student is attending a U.S. institution, then a copy of their I-20, the latest I-94, a copy of passport pages showing student's biographical information and expiration date or other visa must be supplied.

Finances

When an international applicant accepts an offer of admission, the applicant should clearly understand the financial obligations assumed. If assistance is needed, necessary arrangements must be made before the applicant leaves his or her country. Financial aid/scholarships are very limited from the University for undergraduate international students.

International Student Registration Rules /International Students and Scholars

A new regulation now applies to non-immigrants who are nationals or citizens of Iran, Iraq, Libya, Syria and Sudan. (A non-immigrant is anyone who is not a citizen or permanent resident of the United States; for example, F-1 students and J-1 students and scholars are non-immigrants.) The new regulation also applies to other non-immigrants who may be deemed by a consular officer or by an INS officer at a port of entry to require closer monitoring. If this regulation might apply to you, please read this entire announcement carefully.

Who Must Register

Special registration procedures currently pertain ONLY to those non-immigrant visitors who were registered upon their arrival into the United States by INS inspections officers at ports of entry and notified at that time of the requirement to appear at an INS office for an interview.

Non-immigrant visitors who have been admitted into the United States without being registered by INS immigration officials are NOT special registrants, and therefore are NOT required to follow special registration procedures.

The registration requirement does not apply to people who entered the United States BEFORE 9/11/02. However, if they leave and re-enter the United States (even from a short trip to Canada), the special registration requirements will apply upon re-entry.

Special Registration Requirements

The rule requires the above non-immigrants to be fingerprinted and photographed at U. S. ports of entry and to make regular reports to the INS approximately 30 days after arrival, every 12 months after arrival, and upon certain events, such as changes of address, employment or school. Registered non-immigrants will also be subject to certain departure control requirements, and they will be required to depart through ports specifically designated for departure control. The INS has announced that, at the time of admission, it will provide registered non-immigrants with information packets to assist in compliance with the registration rule.

Legal Immigration Information

To remain current on legal information about immigration, go to the websites listed below.
F-1 Student: Important Information
http://www.umich.edu/~icenter/intlstudents/legalinfo/f-1overview.html
J-1 Student: Important Information
http://www.umich.edu/~icenter/intlstudents/legalinfo/j-1overview.html
For other information, visit the International Center Website at http://www.umich.edu/~icenter/index.html.

Readmission

A student who is not enrolled for 12 months or more must apply for readmission through the Office of Recruitment and Admissions, and should do so at least two months before the date of desired enrollment. Readmitted students are subject to the rules in effect at the time of readmission.

A student whose enrollment has been withheld must first be reinstated on probation by the Committee on Scholastic Standing.

An application for readmission should be requested from the Office of Recruitment & Admissions, 1108 Lurie Engineering Center, Ann Arbor, MI 48109-2102 (734) 647-7101 or at enginrta@umich.edu.

Undergraduate Non-Candidate for Degree (NCFD) (Special Student Status, Exchange, Unclassified)

The NCFD status is for those individuals who are approved to take courses in the College of Engineering in a non-degree capacity. Such students are designated as unclassified. NCFD admission is for one term and is granted only if space is available after all degree-seeking students have been accommodated.

NCFD Status for Students from Other Colleges and Universities

A student from another college or university who seeks enrollment as a non-candidate for degree (NCFD) must meet the same academic standards of admission as a degree-seeking applicant for transfer admissions.
NCFD applicants should contact the Office of Recruitment and Admissions to request an application. Official transcripts from current and former colleges or universities should be mailed to the Office of Recruitment and Admissions. Once an applicant has been evaluated, the department from which the applicant desires to take courses will be contacted for approval. The applicant will be notified of their NCFD admission status. Registration for admitted NCFD students cannot occur until written permission of the instructor(s) of the class(es) in which the student will enroll has been provided and the department office has been notified. The applicant should contact the instructor, obtain written permission to register for the course, and provide the documentation to the Office of Recruitment and Admissions. Approval to register can then be granted. Registration for courses can only be done on or after the first day of classes for the term of admission. If more than one term is requested, the student cannot register for the subsequent term until his or her academic record has been reviewed and approved by an admissions counselor and the engineering departmental program advisor.

NCFD Status for Graduates and Graduate Candidates of the College of Engineering

A graduate with a conferred bachelor's degree from the College of Engineering (including those who seek enrollment for the term following completion of the degree) who desires to take courses with NCFD status can request processing for enrollment by obtaining written approval of the program advisor for the department in which they intend to take course(s) and submitting an application for readmission to the Office of Recruitment and Admissions. The instructor(s) of the course(s) in which the student intends to enroll must also grant written permission.

Approval to register is granted for one term only. The enrollment status is designated as unclassified. Course registration for individuals with special student status should not be done prior to the first day of classes. The engineering department from which the degree was conferred will also be notified of the NCFD status.

Exchange Students from CoE Partner Institutions

Undergraduate and graduate students from CoE partner institutions may apply to study at the UM for 1-2 semesters as NCFD students. The CoE also accepts exchange student applications through the Global Engineering Education Exchange (GE3) program. Prospective exchange students must be nominated by their home institutions and all applications are processed by the International Programs in Engineering (IPE) office.

Unclassified Status

When a student is no longer a candidate for a degree from the College of Engineering but is planning to transfer into another field of study, the student will be advised by the Engineering Advising Center to arrange for registration for an additional term in the College of Engineering on an "Unclassified" status.

Residency Classification for Tuition Assessment Purposes

The University of Michigan's tuition structure is two-tiered, reflecting resident and nonresident rates. To be eligible for resident classification, a student must demonstrate compliance with the University's Residency Classification Guidelines, which can be found at http://www.umich.edu/~regoff/resreg.html. These guidelines differ from those of other schools and are independent of guidelines used by state authorities to determine residency for purposes such as tax liability, driving, voting, etc.

Circumstances Under Which You Must File a Residency Application

If you believe you are eligible to be classified as a resident and any of the following circumstances apply, you must file an Application for Resident Classification and be approved in order to qualify for resident tuition:

- You currently live outside the state of Michigan for any purpose, including, but not limited to, education, volunteer activities, military service, travel, employment.
- You have attended or graduated from a college outside the state of Michigan.
- You have been employed or domiciled outside the state of Michigan within the last 3 years.
- You are not a U.S. citizen or Permanent Resident Alien (if you're a Permanent Resident Alien, you must have a Permanent Resident Alien card).
- Your spouse, partner, or parent is in Michigan as a nonresident student, medical resident, fellow, or for military assignment or other temporary employment.
- You are 24 years of age or younger and a parent lives outside the state of Michigan.
- You are 24 years of age or younger and have attended or graduated from a high school outside the state of Michigan.
- You have attended or graduated from an out-of-state high school and have been involved in educational pursuits for the majority of time since high school graduation.
- You previously attended any U-M campus (Ann Arbor, Dearborn, or Flint) as a nonresident.

Other circumstances may also require you to file a residency application.

How To File a Residency Application

Applications for resident classification can be downloaded at http://www.umich.edu/~regoff/resreg.html.

Filing Deadlines

The deadline dates for submitting applications for resident classification apply to the term for which residency is sought and are as follows:

September 30 for Fall Term
January 31 for Winter Term
July 31 for Spring, Spring/Summer, and Summer Terms.

Applications must be received in the Residency Classification Office by 5 p.m. on the deadline date.
For additional information contact the Residency Classification Office, University of Michigan Office of the Registrar, 1210 LSA, 500 S. State St., Ann Arbor, MI 48109-1382, phone (734) 764-1400.

Financial Aid

To determine your eligibility for need-based financial aid, contact the University of Michigan's Office of Financial Aid at the number or address below. Excellent information is also available on the web site of the Office of Financial Aid at http://www.finaid.umich.edu

University of Michigan, Office of Financial Aid
2011 Student Activities Building
515 E. Jefferson Street
Ann Arbor MI, 48109-1316
Phone: (734) 763-6600/Fax: (734) 647-3081
Email: financial.aid@umich.edu
North Campus Office: B430 Pierpont Commons
Ann Arbor, MI 48109-1316
*Please note: The North Campus phone number, fax number, and email address are the same as for the Main Office on Central Campus

Scholarships

In keeping with the University's practice and policy, financial assistance is available to qualified students irrespective of sex, race, color, or creed. Scholarships are established by gifts to the College and by allocations from the University's general fund. The loyal alumni and many friends of the University and the College of Engineering—along with other interested individuals, industry, and many public and private organizations—contribute support through annual gifts and endowment funds that earn income to be used for scholarships. There is no direct obligation to repay a scholarship, but as recipients recognize their moral obligation to return gifts to the College scholarship fund, according to their abilities, other worthy students will benefit. The broad range of undergraduate scholarships available to Engineering students is described below.

Entering Students

Although families (students, parents, spouses) are primarily responsible for meeting college costs, and are expected to contribute according to their ability, Academic or Merit Scholarships are granted by the University of Michigan's Admissions Office, the Office of Financial Aid, and the College of Engineering to incoming students (first-year students and transfer students).

University Admissions Office and Office of Financial Aid Academic Scholarships

The University of Michigan has established a variety of programs to recognize superior academic achievement. Nominees are selected or identified from admissions applications or the roster of admitted students and are formally notified of their eligibility. Financial need is not a factor in the criteria for most merit awards. For more information and a listing of scholarships, see http://www.finaid.umich.edu/types_of_financial_aid/scholarships/scholar.asp.

College of Engineering Merit Scholarships

Incoming first-year students are automatically considered for honorary scholarships. Selection is made from a review of all first-year students admitted to the College of Engineering and is based on SAT and/or ACT scores, class rank, grade point average (GPA), activities, awards, and essays included in your application for admission. An application is not required for consideration. Candidates will receive notification of their selection or the need for additional information, before mid-April. Most honorary awards are renewable. For information pertaining to First-Year Merit Awards, entering students should contact the Engineering Scholarship Office. Merit Scholarships for transfer students are awarded to the top students each Fall & Winter Term.

Transfer students are automatically considered for this award based on the information on their official college or university transcripts. There is no separate scholarship application to be filled out. The Transfer Student Award is renewable. For further information on scholarships, contact the Engineering Scholarship Office in Room 1432, Lurie Engineering Center (LEC) or call (734) 647-7113.

Continuing Students

The College of Engineering offers Michigan Engineering undergraduates financial support through a range of scholarships. These funds are awarded based on criteria such as academic excellence, financial need, or field of study. In addition, some scholarships have preferred (optional) criteria that encourage awarding the funds to a particular geographic area or to someone who participates in certain extracurricular activities. Students interested in scholarship support should be aware that there are limited funds and that all requests, even those based on financial need, may not be met.

Merit Awards

Merit scholarships are restricted to full-time (minimum of 12 credit hours) students who have completed one full term in the College of Engineering, and established a grade point average (GPA) of 3.0 or higher.

Need-Based Awards

Need-based scholarships are restricted to students demonstrating financial need and are citizens or permanent residents of the United States. Students must apply for aid in order to be considered for need-based aid. For more information, see the Office of Financial Aid's website at http://www.finaid.umich.edu.

The College of Engineering's need-based scholarship application is available online at http://www.engin.umich.edu/students/scholarships/Current_Students.html

Industry-Sponsored Scholarships

Several industries offer scholarships to students. Sometimes a summer internship accompanies the monetary award given by corporate sponsors. Recipients are selected based on criteria established by the donor.

Industry-sponsored scholarships are restricted to full-time (12 credit hours) students who have completed one full term in the College of Engineering and have established a grade point average (GPA) of 3.0 or higher.

Where to Apply

Continuing (2nd term freshmen and beyond) students interested in applying or reapplying for an industry-sponsored scholarship can apply online at the URL listed below. **Students need not apply for a particular scholarship,** but should apply online with one general application form.

Engineering Scholarship Office
1432 Robert H. Lurie Engineering Center
1221 Beal Avenue
Ann Arbor, MI 48109-2102
Phone: (734) 647-7113
Fax: (734) 647-7126
http://www.engin.umich.edu/students/scholarships/Current_Students.html

Deadline

Applications for industry-sponsored awards are generally accepted from March 1– June 15 each year. Applications submitted after the deadline will be reviewed based on the availability of funds.

International Students

International students must be prepared to finance their entire undergraduate education while enrolled in the College of Engineering. A guarantee of total financial backing must be provided when making application for admission.

College of Engineering Tuition Fellowship Program

The College of Engineering participates in several institutional agreements to promote student exchange and international research collaboration. The College welcomes students from its partner institutions and believes that exchange students bring valuable experience and cultural diversity to the College community. To support international exchange, the College administers a tuition fellowship program for undergraduate and graduate students from its partner institutions. Incoming students must be nominated by their home institutions and all applications are processed by the International Programs in Engineering (IPE) office. To fulfill the terms of its exchange agreements, the College of Engineering also encourages its own students to participate in study abroad programs.

Study Abroad Merit Scholarships

In order to support students who plan to study abroad, the International Programs in Engineering (IPE) office offers a merit scholarship to students with a cumulative GPA of 3.4 or better (7.0 for graduate students) for overseas study.

Veterans and Social Security Benefits

Educational benefits are available to students who qualify under the Public Laws providing benefits for veterans (or their children) and to orphans or children of a disabled parent who qualify under the Social Security Law. Questions may be referred to the Office of Student Certification, 413 E. Huron.

Fee Regulations, Expenses, Indebtedness

A non-refundable application fee of $40 will be required of each applicant for admission to the University.

The Estimated Tuition and Registration Fees for one full term for the 2005–2006* academic year are:

*Tuition and fees for 2006-2007 will be established by the University of Michigan Board of Regents in July 2006.

Resident Lower Division $ 4,860
Resident Upper Division $ 6,279
Non-Resident Lower Division $ 13,882
Non-Resident Upper Division $ 15,580

Students enrolled as special students or guest students in the College of Engineering will be assessed the upper-division fees. Fees are subject to change at any time by the Regents of the University. Detailed information relating to fees, deposits, payments, and refunds may be obtained in the Engineering Student Records Office and/or may be found on the Registrar's website.

Class Standing
The number of credit hours accumulated toward graduation at the close of a given term is used to determine a student's class standing for statistical purposes. Questions concerning class-level designations should be referred to the Engineering Student Records Office.

Class	Hours
Lower Division	Freshman 0 to 24 Sophomore 25 to 54
Upper Division	Junior 55 to 84 Senior 85 or more

A student admitted to a prescribed program will be a senior when there are 35 hours or fewer to complete.

Withdrawal
A student who withdraws after registration shall pay a disenrollment fee according to the rules in effect at the time of withdrawal as found on the Registrar's website.

Indebtedness to the University
Students shall pay all accounts due the University in accordance with regulations set forth for such payments by the Executive Vice President and Chief Financial Officer.

When a student's account shows indebtedness, no transcript of academic record or diploma will be issued, nor will future registration be permitted.

Academic and Personal Support Services

Students have many places on campus to seek help with personal and academic difficulties. This section briefly describes the University and College offices dedicated to supporting the well being and success of our students.

For **academic problems**, students are encouraged to discuss the matter with their course instructor or GSI as soon as problems arise. If the problem cannot be resolved at that time, the student can speak with their department's program advisor and/or the department chair, or for the case of first year and undeclared students, with the advisors in the Engineering Advising Center. If further assistance is needed, one of the academic deans in the College should be consulted. On some occasions, formal processes for resolving academic problems may be needed, and these are described in the section on <u>Academic Rules and Policies</u>.

For **personal problems,** there are a number of offices on campus where staff are available to help students get the support that is needed. In the College, students may contact staff in the Engineering Advising Center (especially for first year and undeclared students), the Minority Engineering Program Office and the Women in Engineering Office. The offices of the Managing Director for Undergraduate Education, the Associate Dean for Undergraduate Education, and the Associate Dean for Graduate Education, are also available resources.
The sexual harassment intake officers for the College of Engineering are Tony England (*england@umich.edu*, 647-7020), and Debbie Taylor (*dpoet@umich.edu*, 647-7014).

Academic Services
1410 Lurie Engineering Center (LEC)
Phone: (734) 647-7118/Fax: (734) 647-7126

The Office of Academic Services serves students, faculty and staff with a particular focus on four areas: Academic Services, Curriculum, Scholarships and Student Recognition. The staff of Academic Services is dedicated to assisting students navigate through the registration to degree completion processes and to increase the recognition of student leaders and scholars.

Academic Services: These services include the records office, room scheduling, major and minor declarations, diploma application and degree audits. The staff is available to answer questions about the processes and to provide the appropriate forms and procedures for each process.

Curriculum: This area staffs the College Curriculum Committee, continuously improves the quality and usefulness of the Bulletin and seeks input and communicates with students about curricular issues.

Scholarships: The Scholarship Office coordinates the awarding of scholarships to incoming and continuing undergraduate students. Scholarships are available from College general funds, endowed and expendable gifts to the College, and gifts from industry sponsors. The Scholarship Office also strives to be a clearinghouse of information on non-University scholarship opportunities that are available to engineering students.

Student Recognition Events: Three major College events are organized through the Office of Academic Services: Parent's Weekend, the Student Leadership Recognition Dinner and the Student Honors Brunch. In addition to these events, this area also coordinates the Roger M. Jones Poetry Contest and the Roger M. Jones Fellowship Abroad.

The Ameritech Engineering Learning Resource Center
Ameritech Engineering Learning Resource Center
G264 Lurie Engineering Center (LEC)
Phone: (734) 647-7125

The AELRC is a resource for academic support for engineering students. The AELRC offers a study area with CAEN-supported computers and offers a variety of academic support services including free <u>peer tutoring</u>, supplemental Instruction sessions for selected first and second-year courses, academic skill development workshops on topics such as time management and study skills, and practice exam sessions.

Engineering Advising Center
1001 Lurie Engineering Center (LEC)
Phone: (734) 647-7106/Fax: (734) 647-7126
http://www.engin.umich.edu/students/advising

The <u>Engineering Advising Center (EAC)</u> provides academic advising services and support for first-year and undeclared students in their transition from high school to the rigorous academic demands of the College of Engineering. The EAC's programs and services foster success by assisting students in exploring their educational, career and life goals. The EAC plays an integral role in the first year experience. The center provides students with the College and University's resources, that can help them achieve their goals, and support their personal growth and leadership development. The EAC promotes academic success, empowering students to strive for excellence at Michigan and beyond.

Orientation
All first-year students must participate in the University of Michigan and College of Engineering orientation. Summer/Fall and International orientation sessions provide students with important academic information, guidance in the course selection and registration process, and an introduction to the engineering computer environment. During orientation all students meet individually with advisors to begin their exploration of educational opportunities.

All new graduate students are invited to join the CoE's New Graduate Student Welcome event at the start of the Fall semester. This event serves as an introduction to the Office of the Associate Dean for Graduate Education, presents an opportunity to gather information about student societies and student services offices on campus, and provides sessions on computing, funding, and a Q & A period with a panel of current graduate students.

Academic Advising
First-year student advisors, consisting of a group of well-qualified faculty from the engineering departments, professional EAC advisors, and peer advisors, work with students to facilitate their transition and learning process.

During the fall and winter terms, students are encouraged to explore their educational and career goals. As part of their ongoing support for students, the advisors assist students with personal issues and provide guidance in evaluation of attitudes, goals, values and academic priorities. Students also meet with an advisor to select courses and monitor their academic progress and explore engineering options. All first-year students are required to meet with an advisor each term before registration for course advising.

Developing self-reliance and the ability to make choices, as well as the ability to appraise one's own performance and intellectual growth, is an important part of the student's education. It is the role of the EAC advisors to facilitate this process by:

- Making academic policies and procedures clear and meaningful to students.
- Helping students with course selection, and the process of monitoring course progress.
- Encouraging students exploration of educational opportunities.
- Assisting students in setting and attaining academic and career goals.
- Helping students strengthen their academic skills.
- Helping students learn how to make effective decisions.
- Helping students navigate through the University of Michigan and the College of Engineering resources to help them succeed.
- Make referrals to other services when needed.

The Engineering Advising Center also publishes the First-Year Handbook, and the monthly newsletter Advising Matters. Students and parents should visit the EAC web site for additional information. www.engin.umich.edu/students/advising

Academic Advising for Continuing and Transfer Students
Declared and transfer students receive advising from Program Advisors.
At the beginning of each undergraduate degree program description (beginning on page 72) is the name(s) of the faculty member(s) designated as Program Advisor(s). Upon selecting a degree program, the student is referred to the respective Program Advisor, who is responsible for the necessary academic advising through graduation.

Graduate Student Support
245A Chrysler Center, Campus Zip 2092
Phone: (734) 647-7028/7077 Fax: (734) 647-7081
http://www.engin.umich.edu/admin/adge/students/gradliaison

The Office of the Associate Dean for Graduate Education (ADGE) is dedicated to providing quality recruiting and retention programs for our prospective and current graduate students, as defined below:

Current Graduate Students:
http://www.engin.umich.edu/students/current/graduate/
On this website, you will find information pertaining to academics, support, funding, a new student resource guide, student activities, and more. Here are the services that are provided through our office:

- Academic, Personal, Professional, and Social Activities for Graduate Students
  http://www.engin.umich.edu/admin/adge/students/events/calendar/
- Graduate Student Instructor (GSI) Training
  http://www.engin.umich.edu/students/current/graduate/gsi.html
- Professional and Interdisciplinary Programs
  http://www.engin.umich.edu/admin/adge/overview/programs.html#interpro
- Graduate Student Advisory Committee (GSAC)
  http://www.engin.umich.edu/admin/adge/gsac/
  A group that advocates for changes, plans events, and enhances communication between students, faculty, and staff.
- Graduate Student Liaison
  http://www.engin.umich.edu/admin/adge/students/liaison/
  Provides a discreet, neutral environment where students can go for help.

- Just ASK (Alumni Sharing Knowledge) Mentoring Program
  https://www.engin.umich.edu/admin/adge/justask/
  Register to be paired with an alumna/us from CoE graduate program.
- CoE Graduate Student Newsletter
  http://www.engin.umich.edu/admin/adge/students/newsletter.html
  Published each fall and winter term and distributed via email and on the web.
- Graduate Student Resource Library
  http://www.engin.umich.edu/admin/adge/students/resources/library.html
  A collection of books on personal and professional development that you may borrow.

Prospective Graduate Student Recruitment:
http://www.engin.umich.edu/admin/adge/recruiting/

On Campus Recruiting
The Office of the Associate Dean of Graduate Education coordinates various on-campus graduate student recruiting events annually. These events target all prospective graduate masters and doctoral students as well as specific populations. Additionally all graduate engineering departments are involved with the events so that students have opportunities to visit departments and gather information from faculty and staff. These include such programs as Graduate Programs Information Day, PREVIEW, several Graduate School Information Sessions, and IMPACT. On-campus recruitment programs are hosted for College of Engineering undergraduates and external students looking to enroll in graduate studies at the University of Michigan.

Off Campus Recruiting
Off-campus recruiting events constitute a great deal of the College's graduate student recruitment efforts. Annually the office of the Associate Dean of Graduate Education sponsors numerous faculty, staff, and current graduate students to attend these events. National conferences, graduate school fairs, and campus visitations are utilized to promote all of the Colleges advanced degree programs. Collaboration with other University of Michigan units such as Rackham Graduate School/AGEP Alliance, LSA Sciences, Program in Biomedical Sciences, School of Information, and the Ross School of Business assist with these campus wide recruitment efforts.

Minority Engineering Program Office (MEPO)
Minority Engineering Program Office (MEPO)
1463 Lurie Engineering Center (LEC)
Phone: (734) 647-7120/Fax: (734) 647-7126
http://www.engin.umich.edu/students/support/mepo/

The College of Engineering's Minority Engineering Program Office (MEPO) was established to increase the number of underrepresented minority engineering students who graduate with engineering degrees, from the baccalaureate to the doctorate. To accomplish this, MEPO works with students from a diversity of backgrounds, from 7th grade through completion of graduate studies; maintains collaborative relationships with faculty and staff; and networks with engineering employers to secure resources and employment opportunities for engineering students.
At the pre-college level, MEPO offers students in grades 7 through 12 opportunities to actively explore and prepare for engineering and other technical career fields.

MEPO hosts the Summer Engineering Academy and the Ford Summer Engineering Institute (for entering first-year students) each year to address participants' pre-college academic and personal development needs.

MEPO also maintains a formal relationship with the Detroit Area Pre-College Engineering Program (DAPCEP), which sponsors tutorial services, hands-on projects, academic enrichment, and engineering exposure sessions.

MEPO is also actively engaged in the local, regional, and national initiatives of GEM (National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc.), which encourages promising minority students to pursue graduate degrees in engineering.

The MEPO Advisory Council, composed of executives from many of the College's engineering employer partners, provides advice, financial support, and strategic direction for outreach and retention efforts. The Council sponsors the annual ScholarPOWER Academic Awards Banquet to recognize student achievement.

Finally, MEPO consults with College and University administration and faculty to facilitate an environment conducive to diversity.

Women in Engineering Office
1240 Lurie Engineering Center (LEC)
Phone: (734) 647-7011/Fax: (734) 647-7126
http://www.engin.umich.edu/org/wie

The Women in Engineering Office (WIE) division of the Women in Science and Engineering Program (WISE) works with students, faculty and staff to provide an inviting and supportive environment for women at all levels throughout the College of Engineering. The WIE Office provides services and resources to assist women in various stages of academic and professional development and provides leadership in the College concerning women's issues. The goals of the WIE Office include increasing the pool of qualified women who enter engineering, assisting in their retention, assisting women in pursuing undergraduate and graduate degrees and careers, supporting student, staff and faculty groups that focus on women's issues and facilitating a cooperative environment within engineering. To meet these goals, WIE:

- Generates and disseminates data on women in engineering disciplines
- Offers research opportunities for juniors through the Marian Sarah Parker Program, a graduate school awareness program
- Sponsors weekend and summer outreach programs for middle and high school students
- Provides advising and counseling
- Oversees the WISE Residence Program, a living-learning program for undergraduate students
- Maintains a small library of print and video resources
- Sponsors Speaker Series
- Publishes a bi-annual newsletter
- Maintains a website with scholarship, career and academic information
- Provides graduate peer advisors for new graduate students
- Provides administrative support to student organizations
- Offers professional development workshops

The WIE Office also advocates for women students by educating the University community about gender equity, an important contribution to supporting the success of women and providing a more comfortable campus climate for all students. WIE is committed to responding to the needs of our constituents and enhancing the educational experience of all College of Engineering students.

International Programs and Services
With faculty members and students from over eighty countries, the College of Engineering recognizes the global nature of the engineering profession and the value of overseas experience. In response, the College offers numerous international programs and opportunities for cross-cultural interaction among its students.

International Programs in Engineering (IPE)
245 Chrysler Center
2121 Bonisteel Blvd.
Ann Arbor, MI 48109-2092
Phone: (734) 647-7129/Fax: (734) 647-7081
http://www.engin.umich.edu/ipe/

The International Programs in Engineering (IPE) office helps graduate and undergraduate students add an international dimension to their college experience. The IPE office manages study and work abroad opportunities, global academic programs and cross-cultural training sessions. Our staff members assist international students through orientation and social programming and support student organizations such as the Society of Global Engineers. The IPE office also works closely with faculty members to coordinate teaching exchanges and international research initiatives.

Academic Programs
The IPE office oversees two academic programs that promote cross-cultural learning and international experience: the Engineering Global Leadership (EGL) Honors Program and the Program in Global Engineering (PGE). Prospective students should visit the IPE office early in their programs to ensure proper planning.

Study and Work Abroad
The IPE office sponsors full-year, one-semester and summer study abroad programs throughout the world. English language programs are available in Asia, Australia, Europe, Latin America and the Middle East. Foreign language immersion programs are available for students with the requisite skills. For students seeking overseas internships, the IPE office provides information about placement organizations and practical guides to working abroad.

IPE staff members advise students about program options and provide assistance with applications and transfer credit evaluations. Students who are interested in earning degree credit through participation in study abroad should contact the IPE office early in their programs to plan their overseas courses. Applicants for IPE programs should have good academic records.

The IPE office also provides resources for locating financial aid and maintains a searchable scholarship database. Most forms of student financial aid can be applied to College of Engineering programs.

International Student Support
The IPE office supports international students through orientation programs, social activities and oversight of the College of Engineering Tuition Fellowship Program. The International Buddy Program is open to all incoming international students and pairs them with current UM students. The IPE office also advises the Society of Global Engineers, a student organization that promotes professional development and interaction among students from all countries.

Campus Resources for International Students

English Language Institute

The English Language Institute (ELI) offers advanced instruction in the English language to non-native speakers enrolled in the University. Before enrolling in ELI courses, most international students will take the Academic English Evaluation (AEE) as a condition of their admission to the University. Results of the AEE are then used to help the students choose the most suitable ELI courses. The College of Engineering requires students to take the ELI courses they placed into. These courses do not count towards degree credit.

International Center

International Center services are available to international students, faculty, and visiting scholars in addition to all students considering work, travel, or study abroad. The International Center helps international students deal with the Department of Homeland Security regulations, with their sponsors and governments, and with other individuals and organizations. International Student/Scholar Advisors are available to discuss and advise on visa and immigration issues, employment regulations, cross-cultural issues, health insurance, personal and family concerns, cross-cultural adjustment, finances, and other matters.

American and international students may obtain information regarding options for overseas study, internships, work, volunteering, travel and international careers through individual consulting and informational programs. The Center's Overseas Opportunities Office library has one of the largest collections of overseas opportunities in the United States.

International Institute

The University of Michigan International Institute (II) promotes research, education, and service in international and area studies. The II and its constituent units offer programs, services and funding opportunities that contribute to internationalizing undergraduate and graduate-level education and is a particularly valuable resource for graduate students and faculty seeking interdisciplinary relationships with area studies and language faculty.

University of Michigan Student Support Services

The College of Engineering partners with the University of Michigan to provide the tools and services necessary to foster success and promote good health. Engineering students are encouraged to learn about the numerous campus offices, organizations, and services available to them. Refer to the University's Web site at http://www.umich.edu for detailed information. Of particular importance is the University's Counseling and Psychological Services office.

Counseling and Psychological Services

Central Campus
3100 Michigan Union
Phone: (734) 764-8312
North Campus
Lower Level, Pierpont Commons:Phone: (734) 763-9658
http://www.umich.edu/~caps

Counseling and Psychological Services offers a variety of personal counseling, workshops, and consultation services to University of Michigan students and other members of the University community. Services to students include crisis intervention; brief personal counseling and short-term psychotherapy for individuals, couples, and groups; and workshops on various informational and skill-building topics. The staff consists of social workers, psychologists, psychiatrists, and graduate students in psychology and social work.

Services for Students with Disabilities

Central Campus
G-664 Haven Hall
Phone: (734) 763-3000/Fax: (734) 936-3947
http://www.umich.edu/~sswd/ssd

The University of Michigan Office of Services for Students with Disabilities (SSD) provides services to students with visual impairments, learning disabilities, mobility impairments, or hearing impairments. SSD also works with students who have chronic health problems or psychological disabilities, and it offers services that are not provided by other University offices or outside organizations. SSD provides accessible campus transportation, adaptive technology, sign language and oral interpreting, readers and other volunteers, guidance for course accommodations, and requests to modify degree requirements. Services are free of charge.

Before and after a student enrolls at the University, SSD staff are available to answer questions and provide referrals concerning admission, registration, services available, financial aid, etc. In addition, SSD can help assess the need for modified housing, attendants, interpreters, transportation, classroom accommodations, note takers, and adaptive equipment.

University Health Service

Central Campus
207 Fletcher
Phone: (734) 763-1320
http://www.uhs.umich.edu

The University Health Service (UHS) provides comprehensive outpatient medical services to all students, faculty, staff and dependents. As a highly utilized and essential student support unit, UHS is committed to help students stay healthy while accommodating students' demanding schedules.

Most services provided at UHS will be covered by the health service fee, even when they are not covered by a student's private health insurance. This fee is incurred every semester as part of each student's tuition. Thus, students will not be directly charged for most services received at UHS. Those services and products for which additional fees apply include: pharmaceuticals, routine optometric care, eyewear, contact lenses, orthopedic devices and certain immunizations.

For more details on UHS services, pick up a copy of the "Health Care for U-M Students" brochure or call the Health Promotion and Community Relations Department at (734) 763-1320. The Health Service building is accessible to mobility-impaired persons via the South entrance.

Other resources include:
• The residence halls maintain a staff of advisors and student assistants who help students make an effective adjustment to the University community.
• The Office of Financial Aid provides counsel on financial issues.
• The Dental School's patient services (http://www.dent.umich.edu/patients/).

Student Activities and Co-Curricular Opportunities
Students at the University of Michigan have many opportunities to participate in co-curricular activities. Some of these are associated with professional societies, others with social organizations, music and drama groups, sports or service groups. In addition, a great many cultural programs are offered throughout the year. Involvement in student organizations fosters a sense of community and provides opportunities for students to take initiative for their own learning and development.
The following is a list of organizations of particular interest to students in Engineering. If you are interested in any of the following organizations or have questions about student organizations or leadership development opportunities contact the Student Leadership and Activities Coordinator, 1009 LEC; (734) 647-7155. Those interested in exploring other University-wide opportunities may obtain information at the Student Activities and Leadership Office, 2209 Michigan Union, Ann Arbor, Michigan 48109; (734) 763-5900.

Honor Societies
• Alpha Pi Mu, national Industrial Engineering honor society (APM)
• Alpha Sigma Mu, Materials Science and Engineering honor society (ASM)
• Association of Electrical Engineering Graduate Students
• Chi Epsilon, Civil Engineering honor society (XE)
• Engineering Global Leadership honor society (EGL)
• Epeians, Michigan Engineering leadership honor society
• Eta Kappa Nu, national Electrical Engineering honor society (HKN)
• Golden Key, national honor society
• Mortar Board, national senior honor society
• Omega Chi Epsilon, national Chemical Engineering honor society (OXE)
• Phi Beta Kappa, national senior honor society, emphasis on education in the liberal arts
• Phi Kappa Phi, national honor society for seniors of all schools and colleges
• Pi Tau Sigma, national Mechanical Engineering honor society (PTS)
• Quarterdeck Honorary Society, honorary technical society for the Department of Naval Architecture and Marine Engineering (QD)
• Sigma Gamma Tau, national Aerospace honor society (SGT)
• Sigma Xi, national society devoted to the encouragement of research
• Tau Beta Pi, national engineering honor society (TBP)

Student Project Teams
Concrete Canoe
Field Emission Get Away Special Investigation
Formula Car
FutureCar
Human-Powered Helicopter
Human-Powered Submarine
Michigan Mars Rover
Mini-Baja
Solar Car
Steel Bridge

Professional Societies
ACM - Association for Computing Machinery
AEEGS - Association of Electrical Engineering Graduate Students
AIAA - American Institute of Aeronautics and Astronautics
AIChE - American Institute of Chemical Engineers
Alpha Chi Sigma, Chemical Engineering (AXE)
AMES - Aerospace Minority Engineering Society
ANS - American Nuclear Society
ASCE - American Society of Civil Engineers
ASEE - American Society for Engineering Education
ASME - American Society of Mechanical Engineers
BLUElab - Better Living Using Engineering
B-SURE - Biomedical Society for Under-Represented Engineers
BEECS - Black Electrical Engineers and Computer Scientists
BMES - Biomedical Engineering Society
ChEGS - Chemical Engineering Graduates Society
Chi Alpha Christian Fellowship
COS - Congress of Sciences
CSEG - Computer Science and Engineering Graduates
CSSA - Chinese Students and Scholars Association
ECA - Engineering Collaboration for the Arts
EERI - Earthquake Engineering Research Institute
EHC - Engineering Honor Council
FE Club - Financial Engineering Club
GrEENPEAS - Graduate Environmental Network of Professionals, Educators, and Students
HFES - Human Factors and Ergonomics Society
IAESTE - International Association for the Exchange of Students for Technical Experience
IEEE - Institute of Electrical and Electronics Engineers
IIE - Institute of Industrial Engineers
ISPE - International Society for Pharmaceutical Engineering
KEECS - Korean Student Association in Electrical Engineering and Computer Science
ME - Michigan Entrepreneurs
MECC - Michigan Engineering Consulting Club
MEGC - Mechanical Engineering Graduate Council
MESA - Muslim Engineering Student Association
MESH - Michigan Engineering Software and Hardware
METSS -Michigan Engineering Transfer Students Society
MMS - Michigan Materials Society
MUG - Macintosh User Group
MUSES - Movement of Underrepresented Sisters in Engineering and Science
NOBCChE - National Organization of Black Chemists and Chemical Engineers
NSBE - National Society of Black Engineers
OMIE - Outstanding Multicultural Industrial Engineers
Phi Rho - Phi Sigma Rho Engineering Sorority
QED - Queer Engineers Discourse
SAE - Society of Automotive Engineers
SCO - Senior Class Officers
SEngBiz - Society of Engineers in Business
SGE – Society of Global Engineers
SHPE - Society of Hispanic Professional Engineers
Siggraph - Special Interest Group Graphics
SMArT - Science and Math AchieveR Teams
SME - Society of Manufacturing Engineers
SMES - Society of Minority Engineering Students
SMES-G - Society of Minority Engineers and Scientists - Graduate
SSA - Singapore Students' Association

SWE - Society of Women Engineers
TC - Tzu Ching Theta Tau - Professional Engineering Fraternity
TWSA - Taiwan Student Association
UMEC - University of Michigan Engineering Council
UMME - Unified Minority Mechanical Engineers
WIMS - Wireless Integrated Microsystems Students Association
W-SOFT - Wolverine Soft

College Student Government
University of Michigan Engineering Council
1230 EECS Building
Phone: (734) 764-8511/Fax: (734) 615-6047
http://www.engin.umich.edu/soc/umec

The University of Michigan Engineering Council (UMEC) is the student government of the College of Engineering and serves as a representative for engineering student opinions on College and University issues. Membership is open to all engineering students. By participating in UMEC, students can develop leadership skills, contribute to the improvement of the College, meet other student leaders, voice concerns to the College's administration, and learn about the many organizations and events on campus. For more information, visit the UMEC website at http://www.umec.engin.umich.edu/

Honor Council
The Engineering Honor Council, the student judiciary for the College, has the responsibility of investigating alleged Honor Code violations. Following the investigation, the Honor Council conducts a hearing and provides a recommendation to the faculty committee on discipline. For more information, see the Honor Council website at http://www.engin.umich.edu/students/honorcode/.

Honor Society
The criteria for election to an honor society are based on the rules and regulations of the society. In general, the criteria include a scholastic requirement. Student members of a society are responsible for election of new members. On request, the College will provide to each society the names and local addresses of students who are eligible for election according to scholastic criteria specified by the respective society. Membership in honor societies will be posted on the academic record upon receipt of the list of newly elected members from the secretary of the organization.

Undergraduate Student Advisory Board (USAB)
The purpose of the USAB is to provide a stronger voice for undergraduate students regarding academic, social and campus community issues that are of critical importance to the quality of the undergraduate engineering experience and to the quality of North Campus. For more information or to provide feedback on current concerns, visit the USAB website at http://www.engin.umich.edu/students/support/usab/. To contact the USAB directly, email usab@umich.edu.

Graduate Student Advisory Committee (GSAC)
The CoE Graduate Student Advisory Committee (GSAC) was formed in September 2002 by Stella W. Pang, Associate Dean for Graduate Education. Every graduate program and major graduate student society is represented on the committee. The Coordinator of Graduate Student Activities facilitates the bi-monthly meetings of the GSAC group along with Associate Dean Pang, to discuss activities for the graduate students. GSAC also has three focus groups that concentrate on improving particular areas of student need: Personal and Professional Development, Social Functions, and Student and Academic Issues. Any CoE graduate student may join one of these focus groups, which meet as needed to accomplish their goals. GSAC works hard to enhance communication between students, faculty and staff, to provide quality programs, and to advocate for changes to improve the graduate student experience. For more information, please check out the GSAC website: http://www.engin.umich.edu/admin/adge/gsac.

Preparing for a Career
Careers with an Engineering Degree
The main criteria in choosing engineering as a career are usually an interest in, and successful completion of, high school mathematics and science courses; a desire and ability to investigate the "why" as well as the "how" of things; and an interest in the creative development of devices or systems that meet specific needs. The engineer of the future will be increasingly concerned with the preservation of our natural environment, the wise use of our natural resources, and the importance of individual creativity and initiative in the framework of a free democratic society. Certainly not all of these interests will apply to everyone, but they may be used as a rough guide.
Academic advisors of the College are glad to consult with high school or transfer students who are faced with a critical career choice or with the problem of choosing the school that best suits their interests and abilities.

First-year and undeclared students with questions in this regard may benefit from a visit to the Engineering Advising Center, College of Engineering, 1001 Lurie Engineering Center, Ann Arbor, Michigan 48109-2102, http://www.engin.umich.edu/students/advising.

Registration as Professional Engineer
Modern civilization has found it necessary to regulate the practice of persons whose activities deal with the protection of life, health, property, or other rights.

A profession such as engineering is judged by the qualifications and competency of all who use its name; therefore, to provide the public with a clearly recognizable line of demarcation between the engineer and the non-engineer, the state establishes standards and provides the legal processes associated with the registration of individuals and their practices as professional engineers.

In Michigan, the State Board of Registration for Professional Engineers provides an opportunity for students during their senior year to take the first half of a 16-hour, two-part examination as the first step toward registration, provided: (1) the engineering degree is awarded within six months after the examination; and (2) the degree program has been accredited by the Accreditation Board for Engineering and Technology (ABET).

The first half of the exam covers the fundamentals common to all engineering fields of specialization, including mathematics. After a minimum of four years of experience, which may include one year of graduate study, the applicant will take the second half of the examination, which will involve the application of engineering judgment and planning ability.
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. While state laws may differ in some respects, an engineer registered under the laws of one state will find that reciprocal agreements between states generally make possible ready transfer of privileges to other states.

Other Careers
There are numerous career options with an engineering undergraduate degree. While most graduates become engineers or continue with their schooling to receive an advanced engineering degree, an increasing number of Michigan Engineering graduates are pursuing non-engineering careers. Engineering is an excellent start to professional training in medicine, the law, or business.

Many engineering graduates continue their education in medical school, receive their J.D. degrees at a law school, or go after a master's degree in business. Still other graduates find that their engineering knowledge is put to good use in many communications fields, particularly journalism. A person's ability to clearly communicate increasingly technical information to mass and targeted audiences is a skill that is in much demand.

Whatever your career path, the College of Engineering has an excellent resource available to assist you in your search. Learning about careers and job-seeking skills is an education that runs right along with the engineering program. Those undergraduates-from their first year through graduation and beyond-who take advantage of the wealth of services offered through the Engineering Career Resource Center (ECRC) are among the College's most successful alumni. These services range from skill-building to on-the-job experience.

Engineering Career Resource Center
230 Chrysler Center
Phone: (734) 647-7160/Fax: (734) 647-7161
http://career.engin.umich.edu/

The College of Engineering considers the preparation and the transition of its students in successful careers central to its overall mission. The opportunities and environments that require the comprehensive academic preparation received at the College of Engineering are broad and expanding. As a result, students must become much more proactive in thinking about and securing careers that match their needs and goals.

The Engineering Career Resource Center (ECRC) recognizes that defining one's career path can be a challenging goal, and ECRC is here to support students' efforts. Services include the arrangement of employment interviews on campus (October-December and January-March) for graduating students and students seeking co-ops and internships. ECRC provides information about position openings, career guidance and volumes of employer/career information. The center maintains an online system for on campus interview sign-up and job postings specifically geared toward Michigan Engineering students and graduates.

Students receive opportunities to explore careers in many industry sectors and to meet employers through multiple workshops and company days coordinated by the ECRC. Workshops include: Strategies for Effective Interviewing, Negotiating the Job Offer, Job Search Strategies, Résumé Writing, and Online Access-Getting Started.

Internships and cooperative education positions are available and encouraged as a valuable way to identify and pursue potential careers, as well as a great source of additional income. Students may start searching and competing during their first year in anticipation of sophomore status (25-54 hours). The ECRC coordinates and provides support to registered internship and cooperative education students. Go here for more details on cooperative education programs.

International students should be aware that some placement activity may be limited, by employer request, to United States citizens and permanent residents. In the past, employers involved in national defense work have usually interviewed only U.S. citizens.

Other Career Advising
In addition to ECRC career services on North Campus, the Central Campus Career Center office in the Student Activities Building is an excellent resource. The offices work cooperatively to provide a wide range of services for engineering students. The Career Center offers numerous workshops, employer information, a career library, and many additional services for your career development.

Academic Rules, Rights and Responsibilities

General Standards of Conduct for Engineering Students
In establishing a standard of student conduct, the University of Michigan is committed to the basic principles of entrusting each student with a high degree of freedom to govern his or her life and conduct while enrolled at the University.

The College of Engineering encourages its students to protect and use this freedom with wisdom and good judgment, and to accept and discharge the responsibility inherent to such freedom.

Students are expected to respect the rights and property of others and to comply with University regulations and public laws.

The College of Engineering welcomes the participation of students in decision making relevant to their affairs and provides channels of communication, both at the College and department level, for that purpose. To benefit from such activity, each student should recognize his or her responsibility to fellow students and to the faculty and staff, and should discharge all duties with the standards that make such student-college relationships effective and valuable.

The College of Engineering reserves the right to discipline, exclude from participation in relevant activities, or dismiss any student whose conduct or performance it considers in violation of standards. Such a decision will be made only after review by the appropriate student and faculty committees. During this review, the student will have full opportunity to present his or her position. A student also has the right of appeal to the Executive Committee of the College.

The Honor Code of the College of Engineering (below) bears witness to the deep trust that characterizes the student-faculty relationships in one of the most important aspects of student conduct.

Honor Code
The engineering profession has a long-standing record of fostering high standards of integrity in the performance of professional services. Not until the 1930s, however, was the first Canon of Ethics for Engineers developed and adopted by national professional engineering societies. The current version of the Canon of Ethics for Engineers, as approved by the Engineers' Council for Professional Development in 1963, includes the following:

The Engineer
1. Will not compete unfairly with another Engineer.
2. Will be honest and impartial, and will serve with devotion his employer, his clients, and the public.
3. Will strive to increase the competence and prestige of the engineering profession.
4. Will use his knowledge and skill for the advancement of human welfare.
5. Will not injure maliciously the professional reputation, prospects, or practice of another Engineer. However, if he has proof that another Engineer has been unethical, illegal, or unfair in his practice, he should so advise the proper authority.

In 1915, some 15 years before the first Canon of Ethics was published, the students of the College of Engineering proposed an Honor Code. This was approved by the faculty in 1916 and has been in effect since its inception. The Honor Code truly is a distinguishing feature of the College of Engineering.

Applications of the Honor Code
The Honor Code holds that students are honorable, trustworthy people and encourages them to behave with integrity in all phases of university life. By conforming to the Code, students do their work in an environment conducive to establishing high standards of personal integrity, professional ethics, and mutual respect.

As a basic feature of the Code, students are placed upon their honor during all examinations, written quizzes, computer questions, homework, laboratory reports, and any other work turned in for credit, as required by the instructor. During examinations, the instructor is available for questions, but the examination is not proctored. As a reminder of the Honor Code, the student is asked to write and sign the following pledge on the examination paper:
"I have neither given nor received aid on this examination, nor have I concealed a violation of the Honor Code."

The Honor Code remains in force whether or not the student signs the Pledge.
With regard to assignments made in class, each class/professor may have a different policy regarding what constitutes an Honor Code violation and this policy should be clearly outlined in the syllabus for the course. If a student is in doubt, the professor responsible for the course should be asked for clarification. In particular, be aware that some professors allow and/or encourage group work, while others may not even allow discussion regarding homework problems.

In general, the principles of the Honor Code also apply to homework when the instructor requires that the material be turned in for grading. While independent study is recognized as a primary method of effective learning, some students may find that they benefit from studying together and discussing home assignments and laboratory experiments. When any material is turned in for inspection and grading, the students should clearly understand whether, and to what degree, collaboration among students is permitted by the instructor. In some courses, full collaboration is allowed, while in other courses each student must work completely independently. The instructor may require the signing of the Pledge on homework assignments and expect the same high standards of integrity as during examinations.

It is always required that ideas and materials obtained from another student or from any other source be acknowledged in one's work. The latter is particularly important, since material is so freely available on the Internet. According to Webster's II New Collegiate Dictionary [Houghton Mifflin, Boston, MA, 2001], to plagiarize is "To steal and use (the ideas or writings of another) as one's own." To avoid plagiarism, it is necessary to cite all sources of both ideas and direct quotations, including those found on the Internet. The Department of English web site and the University Library hand-out provide thorough discussions of plagiarism:

http://www.lsa.umich.edu/english/undergraduate/plagNote.asp
http://www.lib.umich.edu/handouts/plagiar.pdf

The Honor Code Process

Either a student or the instructor may report a suspected Honor Code violation by contacting the office of the Associate Dean for Undergraduate Education, or by calling 734-647-7117. The accusation is then investigated by the Engineering Honor Council, and if wrongdoing is found, a recommendation is sent to the Faculty Committee on Discipline (FCD). The FCD holds a hearing at which the student is asked to appear and testify on his/her own behalf. After the hearing (whether or not the student attends), the FCD reviews the recommendation made by the Honor Council, decides if an Honor Code violation has occurred, and determines an appropriate sanction, if warranted. The student is then notified of the FCD's decision by the representative of the Associate Dean for Undergraduate Education.

Typical sanctions for a first violation may include a zero on the assignment, a reduction in grade for the course, and community service. For especially serious or repeated violations of the Honor Code, the sanctions may also include suspension or expulsion from the College of Engineering. The student may appeal the FCD's decision to the Executive Committee of the College of Engineering.

The Honor Council has prepared a booklet that explains the principles and operation of the Honor Code. The Honor Code booklet is available in the Office of Student Records, Undergraduate Education, 1401 Lurie Engineering Center (LEC), and on the College of Engineering website: http://www.engin.umich.edu/students/honorcode/.

Statement of Student Rights and Responsibilities

I. Introduction

The University of Michigan-Ann Arbor (the University) is dedicated to supporting and maintaining a scholarly community. As its central purpose, this community promotes intellectual inquiry through vigorous discourse. Values which undergird this purpose include civility, dignity, diversity, education, equality, freedom, honesty, and safety.

When students choose to accept admission to the University, they accept the Rights and Responsibilities of membership in the University's academic and social community. As members of the University community, students are expected to uphold its previously stated values by maintaining a high standard of conduct. Because the University establishes high standards for membership, its standards of conduct, while falling within the limits of the law, may exceed federal, state, or local requirements.

Within the University, entities (such as schools and colleges, campus, professional, and student organizations) have developed policies that outline standards of conduct governing their constituents and that sometimes provide procedures for sanctioning violations of those standards. This Statement of Student Rights and Responsibilities (the Statement) does not replace those standards; nor does it constrain the procedures or sanctions provided by those policies. This Statement describes possible behaviors which are inconsistent with the values of the University community; it outlines procedures to respond to such behaviors; and it suggests possible sanctions which are intended to educate and to safeguard members of the University community.

II. Student Rights

Students at the University have the same rights and protections under the Constitutions of the United States and the State of Michigan as other citizens. These rights include freedom of expression, press, religion, and assembly. The University has a long tradition of student activism and values freedom of expression, which includes voicing unpopular views and dissent. As members of the University community, students have the right to express their own views, but must also take responsibility for according the same right to others.

Students have the right to be treated fairly and with dignity regardless of age, color, creed, disability, gender identity, marital status, national origin or ancestry, race, religion, sex, sexual orientation, or veteran status. The University has a long-standing tradition of commitment to pluralistic education. Accordingly, the University, through this Statement, will not discriminate on the basis of group status.

Students have the right to be protected from capricious decision making by the University and to have access to University policies which affect them. The University has an enduring commitment to provide students with a balanced and fair system of dispute resolution. Accordingly, this Statement will not deprive students of the appropriate due process protections to which they are entitled. This Statement is one of the University's administrative procedures and should not be equated with procedures used in civil or criminal court.

III. Student Responsibilities

Along with rights come certain responsibilities. Students at the University are expected to act consistently with the values of the University community and to obey local, state, and federal laws.

For complete information on Students Rights and Responsibilities see the Office of Student Conflict Resolution, Division of Student Affairs at: http://www.umich.edu/~oscr/index.htm.

Registration, Grading Options and Program Selection

Registration (Official Enrollment)

All students must register to be officially enrolled in classes. This process includes meeting with a departmental advisor (for first-year students, advising is mandatory) so that appropriate classes are selected. This is followed by the actual web registration process.

All students are required to have and use a Student Identification Number for registration and records purposes. More specific information about registration is available in the front of each term's Schedule of Classes.

Completion of both the advising and registration procedures are required before a student attends any classes or uses any University facilities. As of the first day of class, a late registration fee will be assessed. Exceptions to the Late Registration Fee are late admissions, non-degree students, Ph.D. students registering to defend their dissertations, or students who have an official waiver based on a University action. The Late Registration Fee is increased by $25 at the beginning of each subsequent month.

Unless a student is registered, there is no obligation on the part of faculty members to permit attendance in their classes.

A student who completes the registration procedure (including early registration) and fails to attend classes must officially withdraw from the College at the Office of Student Records, 1401 LEC, and pay the usual disenrollment fee as stated in the current Schedule of Classes.

Important Election Dates

Third-Week Deadline:

- Registration portion of Wolverine Access closes.
- Election changes (drop, add, modification) need signature of instructor and program advisor and must be processed by the Office of Student Records (1401 LEC); no documentation needed for changes.
- Dropped classes receive a grade of "W"; for drop without record, students must petition the Scholastic Standing Committee (1420 LEC) and document non-attendance with written verification from instructor.

Ninth-Week Deadline:

- Course additions, course credit modifications, section changes and cross-list changes need signature of instructor and program advisor and must be processed by the Office of Student Records (1401 LEC); no documentation needed for these changes.
- Course drops, pass/fail and visit modifications must be petitioned through the Scholastic Standing Committee (1420 LEC); documentation needed for these changes.

Note: For half term courses during the Fall and Winter, students must petition after the fifth week

Half-Term Courses During Fall or Winter Terms (2 credits)

Begin and End dates:

- All departments will have the same begin and end dates for classes.
- For Fall and Winter Terms the first half-term course will begin on the regular first day of classes.
- For Fall, the second half term will start at the beginning of the 8th week whenever possible.
- For Winter, the start of the second half term will be the Monday immediately following Spring Break.
- Beginning days will be adjusted so that no class will begin on a Friday.

Drop/Modify Schedule: Drop/Modify periods without a "W" will end by the end of the 3rd week for both half terms. Students must petition the SSC to drop or modify a class after the fifth week.

Fee Adjustments: There is a three-week deadline (coinciding with Drop/Modify deadlines) for fee adjustments. Documentation is needed for fee adjustments after the deadline. Fee adjustments are finalized through the Registrar's Office.

Important Note: Students should register for second half-term classes during the normal full-term registration period.

Drop/Modify Policy (Change of Elections)

During the first three weeks of classes (first two weeks in a Spring or Summer half term), students may drop without a "W" or add courses using the web-based registration process.

Third week through ninth week:

From the third week through the ninth week of classes (second week through fifth week in a Spring or Summer half term), students must obtain Drop/Add forms from their program advisor (For first-year and undeclared students, these forms must be signed by an advisor in the Engineering Advising Center) to drop, add or modify courses. These forms must be signed by the program advisor and instructor, and must be submitted to the Office of Student Records, 1401 LEC. A "W" will appear for courses dropped during this time period.

Ninth week through last day of classes:
After the ninth week (fifth week for a Spring or Summer half term), course additions, section changes, credit modifications and cross-list changes are processed using a Drop/Add form obtained from the program advisor (For first-year and undeclared students, these forms must be signed by an advisor in the Engineering Advising Center). Forms must be signed by the program advisor and instructor. Students can submit them to the Office of Student Records, 1401 LEC.

For course drops and pass/fail or visit modifications after the ninth week (fifth week for a Spring or Summer half term), students petition the Scholastic Standing Committee (SSC). Students must be able to document extenuating circumstances such as severe health problems, prolonged family illness, etc. Students may not petition to drop solely because of poor performance. Approved drops will be posted to the official record with a "W."

Petitions are available at 1420 LEC or on the web at http://www.engin.umich.edu/students/support/slas/scholasticstanding/petitions.html.

After the last day of classes, or after the term has ended: Individual course additions, section changes, credit modifications and cross-list changes are processed using a Drop/Add form obtained from the program advisor (For first-year and undeclared students, these forms must be signed by an advisor in the Engineering Advising Center). Forms must be signed by the program advisor and instructor. Students can submit them to the Office of Student Records, 1401 LEC.

For course drops and pass/fail or visit modifications after the last day of classes or the term has ended, students shall petition the Scholastic Standing Committee (SSC). Petitions are available at 1420 LEC or on the web at http://www.engin.umich.edu/students/support/slas/scholasticstanding/petitions.html. Students must be able to document extenuating circumstances such as severe health problems, prolonged family illness, etc. Students may not petition to drop solely because of poor performance. The petition must be signed as indicated. All petitions will be reviewed by the SSC. Approved drops will be posted to the official record with a "W."

The grade for any course dropped without the permission of the program advisor will be recorded as "ED" (unofficial drop) and computed as "E" in grade-point averages.

Junior and senior students enrolled in a Military Officer Education Program must also have approval of the Chair in charge of the unit before they can drop a Military Officer Education Program course or be relieved of the obligation assumed when enrolling in the program.

Pass/Fail Option
Elective courses in Humanities and Social Sciences or courses to be used as Unrestricted Electives can be taken pass/fail. A maximum of fourteen (14) credit hours can be used toward CoE degree(s) requirements. Pass/Fail course elections are limited to two courses per full term (Fall or Winter) or one course in a half term (Spring or Summer). Course elections exceeding the full/half term limits will be reverted to the grade earned. Course/credit limits will be calculated in academic term order of election. Any course that is offered only on a pass/fail basis will not be counted in the above totals.

1. The decision to elect a course on a pass/fail basis or on a graded basis must be made within the first nine weeks of the term (or first five weeks of a Spring or Summer half term). No changes in election as a graded course or as a pass/fail course can be made after the ninth week of a term, or first five weeks of a half term.

2. Instructors are not notified of pass/fail elections; they will report grades as usual, "A+" through "E." The University of Michigan Registrar's Office will then translate grades as follows:
a. A grade of "C-" through "A+" in a course elected on a pass/fail basis is considered satisfactory and will be recorded as "P" (pass—for credit toward the degree and no effect on the grade point average).
b. A grade of "D+" or lower in a course elected on a pass/fail basis is considered unsatisfactory and will be recorded as "F" (fail—no credit and no effect on grade point average).

3. To be eligible for the Dean's Honor List, a minimum of 12 credit hours (6 for a half term) must be elected for grades, with a grade point average of 3.5 or better.

4. To be eligible for Recognition on the Diploma, a minimum of 45 hours of credit with grades must be completed with a grade point average of 3.2 or better.

5. If a student completes a course for pass/fail and subsequently changes the degree program of study to one in which the course comes into conflict with the stated constraints for pass/fail elections in the new program, the course will be accepted in the new program as follows:

a. A record of "P" (pass) is regarded as a satisfactory completion of the program requirement.
b. A record of "F" (fail) is regarded as unsatisfactory completion and the course must be repeated for grades.

Courses Offered on a Pass/Fail Basis Only
A department or instructor may offer an undergraduate pass/fail course on the following basis:

1. The instructor will report the grade as pass/fail for each student enrolled.
2. The grade will be treated the same as when the student chooses to elect a course on a pass/fail basis if the following conditions are satisfied:

a. The course is not required for any program or department.
b. It is the type of course which might be considered appropriate to a pass/fail grading system. Examples of such courses may include: design, survey-type, individual directed research, laboratory, or undergraduate seminars.
c. The pass/fail nature of the course is announced by the instructor at the beginning of the term, and, with the exception of individual instruction courses, in the Registrar's Office schedule of classes website (http://www.umich.edu/~regoff/schedule).

Visit
With permission of the advisor and course instructor, a student may enroll in a course as a visitor. In such a case, the course will be entered on the permanent record with a "VI" instead of a letter grade. The same fee will be charged whether the student enrolls for credit or as a visitor.

A change in elections from credit to visit must be made during the first nine weeks of a term. Signed petitions are required after this point. Required courses may not be elected as a visit.

Election of Studies
Term
A term (semester) extends over approximately four months, including examinations. The University's year-round calendar, by months, is approximately as follows:

Term	Months	Indication
Fall	Sept., Oct., Nov., Dec.	I
Winter	Jan., Feb., Mar., Apr.	II
Spring/Summer	May, June, July, Aug.	III

The Spring-Summer term may be scheduled as two half terms, approximately as follows:

Term	Months	Indication
Spring	May, June	IIIa half term
Summer	July, Aug.	IIIb half term

Course Offerings
The appropriate Bulletin and the Schedule of Classes (http://www.umich.edu/~regoff/schedule/) prepared for each term will serve the student as a guide in planning each term's schedule. Course descriptions can be found in this Bulletin and on the web at: http://www.engin.umich.edu/students/courses
The Faculty reserves the right to withdraw the offering of any elective course not chosen by at least eight students.

Credit Hour
A credit hour (semester hour) generally represents one hour of recitation or lecture per week for a term, or two for a half term; preparation for each credit hour normally requires a minimum of three hours of study per week. Generally, one period of laboratory work is considered to be equal to one hour of credit.

Work Load
The number of credit hours a student is able to carry in any one term depends upon a number of factors - including abilities, health, and the amount of time devoted to extracurricular activities or to outside work. Twelve credit hours are considered a minimum full-time academic schedule for a full term (six for half term). Reduced program fees apply to 11 credit hours or less for undergraduate students.

Unless approved by the program advisor (for first-year students, the Director of the Engineering Advising Center), the student may not elect courses (or change elections) for which the total number of hours for a term is less than 12 or more than 18, and for a half term, less than six or more than nine. A student should have a 3.0 average or more for the previous term to be permitted to carry a term load of more than 18 hours.

Attention is called to the section on Time Requirements for a statement on estimating the time needed for a bachelor's degree.

Attendance and Absences

Regular and punctual attendance in classes is one of a number of expressions of interest and maturity. The reasons for good attendance should be obvious, and students may expect unexcused absences to be reflected in their final grade.

All students should account for their absences to their instructors. A student who has been absent from studies for more than one week because of illness or other emergency should consult the program advisor to determine the advisability of reducing elections. A student with an unresolved problem related to absences may consult the Director of the Engineering Advising Center.

Examinations

Examinations may be given at any time, with or without notice, on any part of the work. An examination at the end of the term is an essential part of the work of the course. The instructor is required to observe the official final examination schedule established by the University.

Any student absent from an examination should report to the instructor as soon thereafter as possible. If a student presents a valid excuse for being absent, a make-up examination may be arranged by the instructor for another time.

Program Selection

Declaration requirements:

A first-year student may declare an Engineering degree program as early as their second term in the College of Engineering. To declare a major the student must be in good academic standing, have a 2.0 GPA in Engineering core courses, and have completed (or be currently enrolled in) the first year level math, chemistry, physics, Engineering 100, and Engineering 101. For EECS degree programs a grade of C or better is required in all the engineering core courses. The Mechanical and Biomedical Engineering departments require that students have completed the first year level math, chemistry, physics, Engineering 100, and Engineering 101 before declaration into the program.

Some Engineering degree programs have a higher minimum degree requirement:

Biomedical Engineering – 3.2 GPA
Engineering Physics – 2.8 GPA

Changing or Adding a Program

When students wish to change from one program to another, or to elect an additional program, they must consult the program advisors of the programs involved.

Transfer students or continuing students who have earned 55 credit hours or more are subject to grade point averages and other requirements approved by the Associate Dean for Undergraduate Education for admission to the various degree programs.

Transferring Out, Withdrawing, and Readmission

Transferring Out

A student who wishes to pursue studies in another unit of the University must apply for admission to that unit and be accepted in order to continue enrollment in the University. In most cases, a student must be in good scholastic standing to be eligible for admission to other colleges/schools.

Term Withdrawals

Students may withdraw from the term until the last day of classes at the Office of Student Records, 1401 LEC. The rules and procedures for term withdrawals vary based on when the withdrawal takes place, as outlined below:

- ***Before the first day of classes:*** Students must withdraw through the Office of the Registrar. This may be done in-person at B430 LL Pierpont Commons or 413 E. Huron (temporary location); via e-mail (ro.registrar.questions@umich.edu); by fax (734-763-9053 or 734-763-7961); or by mail (Office of the Registrar, Room 1513 LSA Building, Ann Arbor, MI 48109-1382). Term fully removed from academic record.
- ***First day of classes to third-week deadline:*** Student must report to the Office of Student Records (1401 LEC); term fully removed from academic record. No documentation needed; exit survey.
- ***Third-week deadline to ninth-week deadline:*** Student must report to the Office of Student Records (1401 LEC); "W" will appear for each course. No documentation needed; exit survey.
- ***Ninth-week deadline to last day of classes:*** Student must report to the Office of Student Records (1401 LEC); 'W' will appear for each course. No documentation needed; exit survey. student not eligible to enroll in next full term. "Not to Register" denoted on record.
- ***After last day of classes (retroactive):*** Student must petition the Scholastic Standing Committee (1420 LEC) and provide documentation of extenuating circumstances.

  Petitions are available at 1420 LEC or on the web at http://www.engin.umich.edu/students/support/slas/scholasticstanding/petitions.html.

Students withdrawing after the ninth-week deadline are not eligible to enroll in the next full term. A "Not to Register" designation will be placed on their academic record. If they are already registered they will be disenrolled. When they are eligible to return, a "Permission to Register" designation will be placed on their academic record. Students with extenuating circumstances may petition the Scholastic Standing Committee to waive this rule.

All students withdrawing from the College of Engineering will be asked to complete an exit survey. Tuition and fee adjustments are in accordance with the Office of the Registrar.

Readmission

A student who is not enrolled for 12 months or more must apply for readmission through the Office of Recruitment and Admissions, and should do so at least two months before the date of desired enrollment. Readmitted students are subject to the rules in effect at the time of readmission.

Students who have graduated from the College and wish to elect courses for an additional term must seek readmission through the Office of Recruitment and Admissions. A student whose enrollment has been withheld must first be reinstated by the Scholastic Standing Committee.

Grades and Scholastic Standing

Unofficial Transcript

Each student's transcript is the cumulative record of courses elected and grades earned while enrolled at the University of Michigan. Unless withheld for infringement of rules, an individual may obtain an official copy of his or her transcript from the Office of the Registrar at no charge. An unofficial copy of the transcript may be obtained through Wolverine Access (http://wolverineaccess.umich.edu).

Students electing Study Abroad classes through the Office of International Programs (OIP) will receive credit hours and the appropriate number of grade points. OIP grades will be averaged into the student's overall grade point average.

Grade Point Averages

The term grade point average (GPA) and the cumulative GPA are computed for each student at the end of each term and become part of the academic record. The grades are valued per hour of credit as follows:

Letter Grades		Honor Points
A+		4.0
A	excellent	4.0
A-		3.7
B+		3.3
B	good	3.0
B-		2.7
C+		2.3
C	satisfactory	2.0
C-		1.7
D+		1.3
D		1.0
D-		0.7
E	not passed	0.0
ED	unofficial drop	0.0

These items do not affect grade point averages:

- **Pass/Fail**
  - P (passed) credit, no honor points
  - F (failed) no credit, no honor points
- **Credit/No Credit**
  - CR (credit) credit, no honor points
  - NC (no credit) no credit, no honor points
- **Satisfactory/Unsatisfactory**
  - S (satisfactory) credit, no honor points
  - U (unsatisfactory) no credit, no honor points
- **Withdrawal/Drop**
  - W (official withdrawal) no credit, no honor points
  - ED (dropped unofficially) no credit, no honor points
    (A notation of ED for a graded election has the same effect on the grade point average as does an E.)
- **Incomplete/Work in Progress**
  - I* (incomplete) no credit, no honor points
  - Y* (work in progress for no credit, no honor points, project approved to extend for two successive terms)
    (Y can only be used with course[s] specially approved by College of Engineering Curriculum Committee as "two-term" sequence course[s].)
- **Official Audit (VI)**
  - VI (Visitor) no credit, no honor points
- **Miscellaneous Notations (NR, ##)**
  - NR* *(no report) no credit, no honor points
  - ## (no grade reported) no credit, no honor points

*A notation of I, or Y, if not replaced by a passing grade, eventually lapses to E and, for graded elections, is computed into the term and cumulative grade point average.

**A notation of NR becomes an ED and has the same effect on the grade point average as does an E.
In the remainder of this section of the Bulletin, the term "a grade" applies to any of the grades A+ through E.

The grade point average is computed by dividing the grade points (Michigan Honor Points or MHP) by the graded hours attempted (Michigan Semester Hours or MSH).

Grades associated with transfer credit are neither recorded nor used in computing the cumulative average. The only exception to this rule is for courses elected on the Ann Arbor campus (effective November 1986).

Honor Point Deficit Calculator*

(Michigan Semester Hours * 2) - Michigan Honor Points = Honor Point Deficit

* Use cumulative totals to calculate cumulative deficit; use term totals to calculate term deficit. Totals reflect number of 'B' credits needed to raise cumulative or semester GPA above 2.0.

The GPA is figured by dividing Michigan Honor Points (MHP) by Michigan Semester Hours (MSH): 25.6 MHP / 16.00 MSH = 1.600 GPA. The term honor point deficit is calculated by multiplying MSH by 2 and subtracting MHP: (16.00 MSH x 2) - 25.60 MHP = 6.4 honor point deficit.

Thus, this student needs 6.4 credits of 'B' grades to raise his/her term GPA above 2.00.

General Scholastic Standing

Scholastic Standing Committee

Scholastic Standing Committee http://www.engin.umich.edu/students/support/slas/scholasticstanding/
1420 Lurie Engineering Center (LEC)
Phone: (734) 647-7115
Fax: (734) 647-7126

The Scholastic Standing Committee (SSC) is comprised of faculty representatives and academic services staff members. Faculty are appointed for a three-year term. The SSC studies problems related to scholastic performance and recommends criteria for defining scholastic deficiencies and for reinstating students whose enrollment is withheld according to the rules of the College.

The SSC reviews the petitions of students seeking reinstatement, determining who is reinstated and the conditions thereof. Students seeking reinstatement may be required to meet with the SSC, where two Committee members hear the student's case and outline the conditions of reinstatement or the reasons for permanent or temporary dismissal. In addition, the SSC reviews all petitions within the College, including the Petition for Late Drop, the Petition for Exception to College Rules and the Petition for Entire Term Action.

Standards Governing Scholastic Standing for Unsatisfactory Performance

All students will be in one of the following classifications:

- ***Good Standing:*** 2.00 GPA or better for both the term and the cumulative average.
- ***Probation:*** a deficiency up to 10 MHP for the term or cumulative.
- ***Enrollment Withheld:*** a deficiency of 10 MHP* or above for the term or cumulative; or the third or greater incidence of probation.
- ***Reinstated on Probation:*** Enrollment Withheld, but reinstated by the Scholastic Standing Committee.
- ***Enrollment Withheld Waived:*** Enrollment Withheld status remains but the petition process is waived because previous reinstatement conditions were met.
- ***Dismissal:*** SSC decision based upon failure to meet agreed upon conditions of reinstatement. Students no longer eligible to enroll in the College of Engineering or petition the Scholastic Standing Committee for reinstatement.
- ***Mandatory Leave:*** SSC decision requiring a leave from the College of Engineering based upon unsatisfactory academic performance.

Scholastic standing action will be determined as follows:

Probation

When a student has a deficiency between 0 and 10 MHPs for either the term or cumulative GPA, the student is placed on probation. The notation "Probation" will be entered on the unofficial transcript.

A student on probation may continue enrollment, but is required to meet with a program advisor (for first-year/undeclared students advising in the Engineering Advising Center) regarding course selection for the following term. Failure to do so may prevent students from enrolling or attending future terms. Probation is a serious warning that there is a need to improve scholastic performance or further enrollment may be jeopardized.

Enrollment Withheld

A student will have the notation "Enrollment Withheld" placed on his/her transcript and will not be allowed to enroll for classes if: a) on Probation for the third time and each time thereafter; or, b) a deficiency of 10 MHP or more for either the term or the cumulative GPA.

When a student is on Enrollment Withheld, the student must submit a petition in writing to the Scholastic Standing Committee (SSC) requesting reinstatement. The student must arrange to meet with his/her program advisor to discuss the petition. The petition should document the reasons for the unsatisfactory performance, and it should offer sufficient and convincing evidence that another opportunity is warranted. If illness has been a factor, students must include supporting information, including a statement (with dates) from their physician. Documentation supporting other contributing factors must also be included.

Reinstatement petitions must be submitted to the SSC Administrator, 1420 LEC, by the date indicated on the student's academic standing notification letter. Failure to petition the SSC in time and failure to follow the prescribed procedure will result in forfeit of the right to petition for reinstatement for that term and disenrollment from the College. Students returning after time away from the College must submit their reinstatement petitions at least four weeks prior to the beginning of term in which they wish to attend, but preferably earlier.

It is the policy of the College and the SSC not to reinstate students with 128 credit hours solely for the purpose of improving their grade point average or removing an honor point deficiency to meet the 2.0 cumulative grade point average requirement for the baccalaureate (B.S.E. or B.S.) degree requirements.

Reinstated students are not permitted to register for future terms unless they can demonstrate they have met their conditions of reinstatement.

Students must wait until grades are posted or complete a progress report, available at 1420 LEC.

Petitions are reviewed by the SSC. Students may be called in for a meeting with the Committee. Questions, appointments and petition forms are handled by the SSC, 1420 LEC, (734) 647-7115. Consultations and advice about the procedure are also available. Petitions are available online at http://www.engin.umich.edu/students/support/slas/scholasticstanding/petitions.html

Mandatory Leaves
Three (3) Enrollment Withheld (EW) notations require a student to take a leave from the College of Engineering for one (1) full term (Fall or Winter)*. A student may also be required to take a mandatory leave with less than three EW notations if they have a very large deficit and/or have issues that need immediate attention.

If a student with three EW's intends to return to the College after the required leave, he/she is expected to contact the office of Academic Services, and in consultation with the student's academic advisor, will assist the student in developing a plan for addressing the factors that are impacting his/her academic performance. If granted reinstatement after a mandatory leave, the student will have one term to meet the reinstatement conditions as determined by the student and the SSC. Failure to do so will result in permanent dismissal from the College.

*Students receiving their third EW at the end of the Winter term will not be eligible to enroll in the Spring, Summer, Spring-Summer or Fall terms at the University of Michigan.

C- and D Grades
Credit is allowed for a course in which a grade of "C-" or "D" is earned while enrolled in the College of Engineering. The "D" level of performance is not considered satisfactory for a course that is a pre-requisite for a later-elected course; in this case, the course must be repeated before electing the next course unless waived by the program advisor. A grade of "C-" is not a satisfactory level of performance in some programs. A grade of "D+" and lower is not acceptable in any program for Engineering 100 and Engineering 101. It is the student's responsibility to review such performance with the advisor as soon as the grade is known in order to make any changes that may be necessary in elections.

Transfer credit will be granted for courses taken outside the University of Michigan, Ann Arbor campus, provided a grade of "C" or better is earned. Transfer credit will be granted for courses taken in any academic unit at the University of Michigan, Ann Arbor campus, provided a grade of "C-" or better is earned.

Students should be aware that some programs limit the number of "C-" grades or require that courses completed with a "C-" or lower grade be repeated. Some programs may have a higher minimum grade requirement for some courses.

E Grades
Neither credit nor Michigan Honor Points are granted for a course in which a student earns the grade of "E." A course required by the student's program must be repeated as soon as possible.

Incompletes
When a student is prevented by illness, or by any other cause beyond the student's control, from taking an examination or from completing any part of a course, or if credit in a course is temporarily withheld for good reason, the mark "I" may be reported to indicate the course has not been completed. This mark should be used only when there is a good probability that the student can complete the course with a grade of "D-" or better. The instructor and student should mutually understand the reasons for the "I" mark and agree on methods and timeline for completing the work.

No qualifying grade will be recorded on the student's academic record. The "I" mark will not be used in computing either the term or cumulative grade point averages. Scholastic standing at the end of any term is determined on the basis of work graded as "A+" through "E," or "ED."
The required work may be completed and the grade submitted by the instructor whether or not the student is enrolled. The student should plan to complete the work as soon as possible. To secure credit, the required work must be completed by the end of the first term (not including Spring or Summer terms) in which the student is enrolled after the term in which the "I" mark was recorded. It is the student's responsibility to remind the instructor to send a supplementary grade report to the Office of the Registrar when the work is completed. If the final grade is not reported by the last day of exams, the Registrar will automatically change the "I" to an "E." Incomplete extensions must be arranged with the instructor. Forms are available at the Office of Student Records, 1401 LEC.

Other Irregularities
Irregularities associated with a failure to submit changes in academic status are identified on the student's transcript by an appropriate designation such as "ED" (unofficial drop), or "NR" (no report). No credit will be granted to a student for work in any course unless the election of that course is entered officially on the proper form. An unofficial drop will be considered the same as an "E" in computing the term and cumulative averages and will affect the scholastic standing.

Repeating Courses
For "C-," "D" and "E" grades, see above. Except as provided for grades "C-" through "D-," a student may not repeat a course he or she has already passed. In exceptional cases, this rule may be waived by the student's program advisor (for first-year students, the Director of the Engineering Advising Center) after consultation with the department of instruction involved. If the rule is waived, the course and grade will appear on the transcript, but no additional credit or Michigan Honor Points (MHPs) will be granted.

A student repeating a course in which a "C-" through "D-" was previously earned will receive MHPs but no additional credit. Both grades are used in computing the grade point average.

Academic Honors and Awards
The Dean's List (College of Engineering)
Students pursuing an undergraduate degree who elect courses and complete a minimum of 12 credit hours with grades (6 for a half Spring or Summer term) and earn a 3.50 GPA term average or better, attain the distinction of the Dean's List for the term.

University Honors
Students who earn a minimum of 14 credits in courses which include 12 credits elected on a graded basis (A thru E), and who earn a 3.5 grade point average are eligible for University Honors. This Honor will be awarded each full term of classes (Fall & Winter terms). This distinction is posted on a student's transcript by the Registrar's Office. Students who receive this honor two consecutive terms will be invited to attend the annual Honors Convocation.

James B. Angell Scholars (The University of Michigan)
James B. Angell Scholars are students who earn all A+, A, or A- grades for two or more consecutive terms based on a minimum of 14 credits earned in courses which include 12 credits earned on a graded (A-E basis elected each term); all other grades must be P, S, or CR. Terms of fewer than 14 credits completed with grades of A+, A, A-, P, S, or CR enable a student to maintain standing as an Angell Scholar. Any other grades earned during a full or half-term make a student ineligible for this honor. Angell Scholar Honors are posted on a student's transcript by the Office of the Registrar, and recipients of this honor are invited to attend the annual Honors Convocation. Angell Scholars are selected and honored annually.

William J. Branstrom Freshman Prize (The University of Michigan)
Students in the top five percent of the freshman class are eligible for this honor, administered by the University Registrar's Office, if they have earned at least 14 graded credits at Michigan. A book with an inscribed nameplate is presented to each student. Recipients of this award are invited to attend the annual Honors Convocation.

Marian Sarah Parker Scholars (College of Engineering)
The Marian Sarah Parker Scholars Program is a joint program of the College of Engineering and the U-M Women in Science and Engineering (WISE) Program. The Marian Sarah Parker Scholars Program invites high-achieving women, by Fall Term of their junior year, to participate in a two-year exploration of graduate school. Participation as a Marian Sarah Parker Scholar leads to a greater understanding of the graduate-school process by means of seminars, panel discussions, and an academic research project.

Special Awards (College of Engineering)
The College gives special recognition to students with high scholastic achievement, with records of service to the College and its student organizations, or with evidence of extraordinary potential for leadership. Information on qualification requirements can be obtained in the Office of Academic Support Services.

Society Recognition (College of Engineering)
Distinguished scholarship and service to the College are also recognized by election to a number of honor societies that are listed under "Student Activities and Co-Curricular Opportunities". A student's election to a recognized society will be posted on the transcript.

Recognition on Diploma (College of Engineering)
A student graduating with at least 45 hours of credit completed, with grades, while enrolled in this College will be recommended for a degree(s) with recognition on the diploma if the student qualifies according to the following:

Grade Point Average Distinction
3.20-3.49......... cum laude
3.50-3.74......... magna cum laude
3.75-4.00......... summa cum laude

Grade Grievances Procedure

If there is justification to question the accuracy of an assigned grade, the student should first pursue the matter with the instructor. The responsibility for the assignment of grades is primarily that of the instructor and should be settled between the student and instructor whenever possible. Further pursuit of a grade grievance should be addressed with the instructor's Department Chair. The final appeal at the College level is by petition to the Associate Dean for Undergraduate Education.

Student Grievances

The College of Engineering has a grievance procedure to address student complaints. Graduate Students should refer to the following website, available online.

Undergraduate Students should follow these steps until a resolution is achieved:

1. Attempt to resolve the grievance directly with the individual involved (faculty member, staff member, or fellow student).
2. If the matter is unresolved, and the grievance is with a faculty member or teaching assistant, discuss the grievance with the appropriate department chair.
3. If the issue is still unresolved, undergraduate students should see the Associate Dean for Undergraduate Education , who is located in the Robert H. Lurie Engineering Center.
4. All students have the right to appeal to the Dean of the College if they feel their grievances have not been resolved satisfactorily by another dean.

Requirements for a Bachelor's Degree

To obtain a bachelor's degree in the College of Engineering, Ann Arbor campus, 128 credit hours must be earned and a student shall meet the following requirements, subject to approval of the program advisor:

1. The student must achieve a satisfactory level in those subjects specified by the program of his or her choice. A grade of "D" in a required course may not be considered satisfactory unless approved by the program advisor. A student may receive credit toward a degree in one or more of the following ways:
   - By passing a course for credit on the Ann Arbor campus ("D" grades may not be acceptable as a proper level of attainment for a required course, as noted above.)
   - By Advanced Placement Program examination for college-level work completed in high school (See "Advanced Placement," under "Admission.")
   - By an examination regularly offered by a department of the University, or by a recognized testing service.
   - By transfer of equivalent credit from another recognized college (See "Adjustment of Advanced Credit" on page 20.)
   - By demonstrating qualification for enrollment in a higher-level course or series (e.g., honors-level).
   - By demonstrating equivalent and parallel knowledge that enables the student to enroll at an advanced level: In this case, the student will not be allowed credit hours on the transcript, but may be excused from enrolling in courses in which the program advisor judges the student proficient. To qualify, the student must petition the program advisor and, as a condition, may be required to demonstrate his or her proficiency by an appropriate examination.
2. The student must accumulate a final grade point average of 2.00 or more for all credit hours not taken under the pass/fail option while enrolled in the College of Engineering. In addition, a student must earn a cumulative grade point average of 2.00 or higher in all courses taken within the student's academic department. Consult your department for additional information.
3. The student must complete at least 50 credit hours of course work offered by the University of Michigan-Ann Arbor campus (excludes prescribed programs).
4. The student must complete a minimum of 30 credit hours of advanced level (300 or higher) technical courses, as required by the degree program while enrolled in the College of Engineering, Ann Arbor campus.
5. The student must file formal application for the diploma. (See "Diploma and Commencement" below.)

Requirements for a Bachelor's Degree Time Requirement

The time required to complete a degree program depends on the background, abilities, and interests of the individual student. Note: A full-time schedule averaging 16 hours of required subjects will allow a student to complete the degree requirements (128 credit hours) in eight terms as noted in the sample schedules appearing with the program descriptions.

A student who is admitted with advanced preparation, with demonstrated levels of attainment, or with ability to achieve at high levels may accelerate his or her progress. A student who is partially self-supporting while at the campus may find it desirable to plan a schedule longer than eight terms.

A student who plans to continue studies beyond the bachelor's degree may (after attaining senior standing) elect a limited number of graduate-level courses concurrently with the courses required for the bachelor's degree. A course required for the bachelor's degree generally cannot be used for graduate credit also. For details, refer to the regulations published by the University of Michigan Horace H. Rackham School of Graduate Studies.

Requirements for an Additional Bachelor's Degree

Additional bachelor's degrees can be conferred in the College of Engineering, Ann Arbor campus.

1. To obtain additional bachelor's degrees (including prescribed) in the College of Engineering, a student must complete the requirements of each of the degree programs. Furthermore, for each additional degree, the student must complete at least a minimum of 14 additional credit hours in pertinent technical subjects. Approval by involved departments is required.
2. To obtain an additional bachelor's degree in the College of Literature, Science, and the Arts (LS&A) or the School of Music, refer to program requirements under "Combined Programs" with LS&A.

Substitution
Substitution of a course for one which is a requirement for graduation must be approved by the program advisor of the student's degree program.

Diploma and Commencement
For the College of Engineering to recommend the granting of a degree, a student who satisfies all other requirements must also file formal application for the diploma. A student completing the requirements for more than one degree in the College of Engineering or a second degree in LS&A must file an application for each.

The student must Apply for Graduation through Student Business on Wolverine Access. The application must be submitted to the student's department office at the beginning of the term in which the student is reasonably certain of completing the work for the degree.

When a student does not meet the requirements as planned, the student must re-submit an application at the appropriate time. Degrees are awarded at the end of the fall, winter, and spring-summer terms.

All students who are entitled to receive diplomas are expected to be present at the Commencement exercises appropriate to the date of graduation.

Undergraduate Education Mission

The Mission of the undergraduate degree programs of the University of Michigan College of Engineering is to prepare our graduates to begin a lifetime of technical and professional creativity and leadership in their chosen fields.

Undergraduate Educational Objectives

Prepare students for professional creativity and leadership in their chosen fields by:

- Providing students with a comprehensive education that includes in-depth instruction in their chosen fields of study.
- Emphasizing analysis and problem-solving, exposure to open-ended problems, and design studies.
- Fostering teamwork, communication skills, and individual professionalism including ethics and environmental awareness.
- Providing adequate co-curricular opportunities that cultivate lifelong learning skills.

Undergraduate Educational Outcomes

Graduates of the College's undergraduate programs will have:

1. An ability to apply knowledge of mathematics, science, and engineering within their chosen field.
2. An ability to formulate engineering problems and develop practical solutions.
3. An initial ability to design products and processes applicable to their chosen field.
4. An ability to design, conduct, and interpret the results of engineering experiments.
5. An ability to work effectively in diverse teams and provide leadership to teams and organizations.
6. An ability for effective oral, graphic, and written communication.
7. A broad education necessary to understand the impact of engineering decisions in a global/social/economic/environmental context.
8. An understanding of professional and ethical responsibility.
9. A recognition of the need for and an ability to engage in life-long learning.
10. A broad education necessary to contribute effectively beyond their professional careers.
11. A sense of responsibility to make a contribution to society.

In this edition of the College of Engineering *Bulletin*, our traditional "Sample Schedule for Required Programs" has been updated to reflect the current plans in each department and program for undergraduate engineering curriculum revision. It is important to note that the curriculum revision process is an ongoing one; therefore, the program requirements and specific course requirements, especially upper-division courses, listed here should be viewed as works-in-progress.

Important Note: Each department's Program Advising Office and Web site information has been provided for your assistance in obtaining specific program changes.

Undergraduate Degree Options

Undergraduate Engineering Degrees

Each of the undergraduate degree programs has base core requirements that are common to all Programs. The remaining hours identify the majors or fields of specialization in which students will obtain a bachelor's degree as indicated for each program. In most cases, these may be classified as: Advanced Mathematics and Science; Related Technical Subjects; Program Subjects; Technical and Unrestricted Electives. Many of the courses required for one program may be transferred to meet the requirements of another. This opportunity to obtain additional undergraduate engineering degrees must be discussed with the pertinent program advisor. See "Requirements for an Additional Bachelor's Degree."

The 15 undergraduate programs of study are:

Bachelor of Science in Engineering (B.S.E.) Degree Programs

Aerospace Engineering
Biomedical Engineering
Chemical Engineering
Civil Engineering
Computer Engineering
Computer Science
Earth System Science and Engineering
Electrical Engineering
Engineering Physics
Industrial and Operations Engineering
Materials Science and Engineering
Mechanical Engineering
Naval Architecture and Marine Engineering
Nuclear Engineering and Radiological Sciences

Bachelor of Science (B.S.) Degree Programs

Interdisciplinary Program—Engineering

Declaring One of the Degree Programs
Declaration requirements:
A first-year student may declare an Engineering degree program as early as their second term in the College of Engineering. To declare a major the student must be in good academic standing, have a 2.0 GPA in Engineering core courses, and have completed (or be currently enrolled in) the first year level math, chemistry, physics, Engineering 100, and Engineering 101. For EECS degree programs a grade of C or better is required in all the engineering core courses. The Mechanical and Biomedical Engineering departments require that students have completed the first year level math, chemistry, physics, Engineering 100, and Engineering 101 before declaration into the program.
Some Engineering degree programs have a higher minimum degree requirement:
Biomedical Engineering – 3.2 GPA
Engineering Physics – 2.8 GPA

Dual Baccalaureate Degree Opportunities
Students with interest in more than one program offered by the College may work for additional bachelor's degrees concurrently if they plan the course elections carefully. Students will find that it is possible to satisfy the subject requirements of both programs in a minimum amount of time by conferring early with the respective program advisors. Approval by involved departments is required. Opportunities to obtain an additional bachelor's degree in the College of Literature, Science, and the Arts, the School of Business Administration, the School of Music, and other academic units are also available.

Combined Degree Programs
Simultaneous Bachelor's Degrees from the College of Engineering and the College of Literature, Science, and the Arts
Students enrolled for a bachelor's degree in the College of Engineering or the College of Literature, Science, and the Arts (LS&A) may obtain the degrees in both colleges simultaneously by enrolling in the Combined Degree Program that has been established by the two colleges, and by fulfilling the requirements as outlined below. This program has been developed to make it convenient for students to obtain a broader education than would normally be possible by enrolling in only one college.
It is particularly advantageous for students who wish to develop some depth of understanding in both the technically oriented studies offered in the College of Engineering and the physical, natural, or social sciences and humanities available in LS&A. Such a combination can provide a truly liberal education in the contemporary sense and should be excellent preparation for meeting the challenges of modern society, which involve, to an ever-increasing extent, both technical and sociological issues.

Program Requirements
Candidates for a Bachelor of Science in Engineering (B.S.E.) or Bachelor of Science (B.S.) in the College of Engineering combined with a Bachelor of Arts (B.A.) in LS&A must:

- satisfy the requirements of one of the degree programs in the College of Engineering;
- take a minimum of 90 credit hours of work in LS&A, satisfy the distribution requirements of LS&A, and fulfill the concentration requirements for one of the LS&A programs; and
- have a cumulative grade point average of 2.00 or higher.

Candidates for a Bachelor of Science in Engineering (B.S.E.) or Bachelor of Science (B.S.) in the College of Engineering, combined with a Bachelor of General Studies (B.G.S.) in LS&A must:

- satisfy the requirements of one of the degree programs in the College of Engineering;
- take a minimum of 90 credit hours of work in LS&A of which 40 credit hours must be for courses numbered 300 or higher and are passed with a grade of "C" or higher, with no more than 15 of these 40 credit hours to consist of courses in any one department; and
- have a cumulative grade point average of 2.00 or higher.

Students transferring to the University of Michigan with advanced standing and entering a Combined Degree Program must complete a minimum of 60 credit hours of work in LS&A in residence.

All students should consult the program advisors in their field of specialization in each college each term to develop an optimum set of courses for the particular combination of fields of specialization of interest to them.

In general, advisors working with students in this Combined Degree Program will attempt to minimize the total number of courses required by recommending those that will contribute toward fulfilling requirements in both colleges whenever possible. Thus, many of the courses needed to fulfill the requirements in mathematics, chemistry, and physics in the College of Engineering will contribute toward fulfilling natural science distribution requirements and prerequisites for concentration in fields such as astronomy, chemistry, geology-mineralogy, mathematics, and physics in LS&A.

Likewise, requirements in humanities and social sciences for the College of Engineering can be selected from courses taken to fulfill distribution requirements in LS&A. In this way, it is usually possible for students carrying average loads of 16 credit hours per term to complete the requirements of this Combined Degree Program in 10 or 11 terms.

In order to ensure that the courses selected apply effectively and efficiently to both degrees, students must assume responsibility for maintaining contact between their two advisors. They should become thoroughly familiar with the general regulations and procedures of both colleges and with the academic requirements and course offerings in both fields of specialization as set forth in the *Bulletin* of each college. If unusual difficulties or special problems arise, students should consult the Combined Degree Program advisors who will work with the students and their faculty advisors in attempting to find a solution.

Regulations

The following regulations for enrollment will apply:

1. Students initially enrolled in either the College of Engineering or LS&A may enter this Combined Degree Program.
2. To be qualified for admission, students normally should have completed 30 credit hours of the appropriate course work. LS&A students must have an overall grade point average equal to, or higher than, the current minimum grade point average for cross-campus transfer for the particular engineering degree sought. Engineering students must have an overall grade point average of at least 2.7.
3. Students considering this program must obtain the signature of the College of Engineering Associate Dean for Undergraduate Education to apply for admission and to establish advising procedures as soon as their interests are firmly established, preferably by the end of the first year.
4. Upon applying for admission, students must choose a field of specialization in each college. Application for admission must then be approved by the Associate Dean of each college and by the academic advisor in each of these fields of specialization.
5. After being admitted to this program, students will continue to register in the college in which they first enrolled, and that college will be responsible for maintenance of their primary academic records.
6. Students participating in this program should consult with the program advisor for their field of specialization in each college prior to classification each term, to obtain approval of course elections.
7. To be permitted to continue in this Combined Degree Program, students must satisfy the requirements of both colleges with regard to good scholastic standing.
8. Students in good scholastic standing who wish to withdraw from this Combined Degree Program may continue to enroll for a single degree in their original college. If they wish to transfer, they may do so provided their record is acceptable to the other college. For instructions regarding transfers, students should consult the assistant dean of the college in which they are registered. Students not in good scholastic standing will normally remain in the college in which they initially enrolled and be subject to the rules of that college.
9. Upon satisfying the program requirements of both colleges, students will receive both degrees on the same date. At the beginning of the term in which they expect to graduate, they must file a diploma application in each college.

Simultaneous Bachelor's Degrees from the College of Engineering and the Ross School of Business Administration

Students originally enrolled in an undergraduate degree program in the College of Engineering who are admitted to the Ross School of Business Administration may obtain degrees in both simultaneously by enrolling in the Multiple Dependent Degree Program (MDDP) that has been established between the two. This program is designed to allow students to develop a course of study that offers broader academic opportunities than would normally be possible by enrolling in only one college. These combined degrees are open to students initially enrolled in Engineering who are accepted into the School of Business Administration's BBA program. Contact the Student Records Office in the College or School to obtain the application form.

In order to ensure that the courses selected apply efficiently to both degrees, students must maintain coordination between their College of Engineering and Business School advisors. The students must consult the program advisors in their degree disciplines for specific requirements for the appropriate degrees.

Degree requirements must be met for both colleges simultaneously to be eligible to receive the appropriate undergraduate degrees. Upon satisfying the program requirements of both colleges, students will receive both degrees on the same date. At the beginning of the term in which they expect to graduate, students must file a diploma application in each college/school and must ask their program advisor in each unit to submit an appropriate notification of their eligibility for graduation to the appropriate office in the College or School.

Combined Degree in Music and Engineering

This program is designed to allow students to develop a course of study that offers broader academic opportunities than those offered by either the College of Engineering or the School of Music. The program is intended for students who seek the technical studies associated with the College of Engineering in combination with the professional training in applied or academic musical studies associated with the School of Music. These dual degrees are open to students enrolled in either the College of Engineering or the School of Music. They lead to concurrent bachelor's degrees from both units, and are intended primarily for students who were admitted as first-year students to both units.

Each student should consult faculty advisors in both engineering and music to develop the best plan of study. Primary responsibility for planning the academic program and continued contact with academic advisors in the two fields rests with the student, who is also responsible for becoming familiar with the academic policies and procedures of both units and the academic requirements in both fields as described in the *Bulletin* of the College of Engineering and of the School of Music. The student is responsible for maintaining contact with the appropriate engineering department (Engineering Advising Center, if undeclared) in order to receive proper advising for course selection, etc.

Candidates for the combined Bachelor of Science in Engineering (B.S.E.) and music degree (B. Mus., B.M.A., or B.F.A.) must: (a) complete one of the degree programs in the College of Engineering; (b) complete one of the degree programs in the School of Music (usually 90 credits); and (c) maintain a minimum cumulative grade point average of 2.00 and good scholastic standing in both the College of Engineering and the School of Music. It is usually possible for students electing 16-17 credits per term to meet all requirements in 11 or 12 terms.

Students interested in this program will be admitted as first-year students into both the College of Engineering and the School of Music. Students who are dually enrolled and decide not to pursue a degree from the School of Music do not have to reapply for admission to the College of Engineering.

Five-Year Combined BSE/Masters Programs
In many fields, the Master's degree is rapidly becoming the entry level requirement for engineering graduates seeking employment. The College of Engineering, therefore, offers two different options for those students who wish to obtain a combined Bachelor's and Master's degree. Both of these options are academically demanding and require recommendation from the student's undergraduate program advisor. Five-year combined programs in CoE include the Engineering Global Leadership Honors Program (EGL) and the five-year Sequential Graduate/Undergraduate Study Programs (SGUS).

Engineering Global Leadership (EGL) Honors Program

The Engineering Global Leadership Honors Program (EGL) combines a traditional engineering undergraduate curriculum with a core of courses in the Ross School of Business and a cultural core in the College of Literature, Science and Arts. The EGL Honors Program leads to a Bachelor's and Master's degree in engineering.

Employers tell us that the inability of many professionals to communicate across cultures and across the engineering and business boundary is one of the greatest barriers to global competitiveness. The EGL Honors program is designed to prepare students to bridge these gaps. The business core covers the rudiments of marketing, accounting, and finance, and the cultural core exposes students to the language, history and customs of a student-selected region of the world. The success of EGL graduates confirms that this training is in high demand.

Program Requirements
The program requirements include:

- Completion of a Bachelor's and Master's degree in the College of Engineering.
- 12 credits of humanities/social science courses associated with the culture core region
- 2 semesters of the same 2nd year language, associated with the cultural core region
- 12 credits of coursework in the UM Ross School of Business
- a synthesis project that combines student learning with practical experience

EGL students are strongly encouraged to consider study or work abroad, which can be used to satisfy some of the cultural core requirements.

Eligibility
Students should apply to the EGL Honors Program after completing at least 2 semesters in the College of Engineering and after declaring an engineering major.

The EGL honors program is extremely rigorous. Therefore, students must have a minimum 3.60 cumulative GPA prior to admission.

Sequential Graduate/Undergraduate Study (SGUS)
The five-year Sequential Graduate/Undergraduate Study (SGUS) program permits students who enter the program in the first term of their senior year, to receive the B.S.E. and M.S.E. degrees (or the B.S.E. and M.Eng. degrees) upon completion of a minimum of 149 credit hours. The baccalaureate may be awarded upon completion of the undergraduate requirements or concurrently with the Master's degree. Students apply to the SGUS program at the end of their junior year or early in the first semester of their senior year. Consult with the appropriate graduate departmental coordinator for specific deadlines. Recommendation from the appropriate Undergraduate Program Advisor is required, and the standard department graduate admission process is used. SGUS admissions requirements will vary; interested students should contact the department in which they would like to pursue graduate study. For a list of SGUS programs by department, please refer to the degree program listings under the B.S.E. home department.

LS&A Academic Minors
Students in the College of Engineering have been given the option of electing one or more academic minors offered by departments within the College of Literature, Science and Arts. Minors are intended to recognize the completion of a coherent sequence of courses in a particular academic area and can guide you in a more careful selection of your non-engineering courses. They also serve as recognition, via a transcript notation, of the completion of a more in-depth course sequence.

In practice, a student will meet with the LS&A advisor in the minor discipline and together map out the minor courses. The certification that the appropriate courses have been completed will be communicated from the LS&A department offering the minor to a student's undergraduate program advisor in CoE, as well as the Student Records Office. The student will be responsible for making sure this paperwork arrives at the appropriate offices.

Below is a list of approved minors covering a diverse range of academic interests. This is followed by a statement of policies and procedures that should help a student through the process.

LS&A Minors Approved by the College of Engineering

- Afro-American Theatre
- Afro-American Theatre and Drama
- Afro-American and African Studies
- Anthropology
- Applied Statistics
- Asian Languages and Cultures
- Asian Studies
- Asian/Pacific American Studies
- Asian/Pacific Islander American Studies
- Astronomy and Astrophysics
- Biological Anthropology
- Biology
- Classical Archaeology
- Crime and Justice
- Czech Language, Literature and Culture
- Early Christian Studies
- Earth Sciences - General
- East European Studies
- Ecology and Evolutionary Biology
- Economics
- Environment
- Environment Studies
- Environmental Geology
- French and Francophone Studies
- Geochemistry
- Gender and Health
- Gender, Race and Ethnicity
- German Studies
- Global Change
- Global Media Studies
- Global Transformation
- History
- History of Art
- International Studies
- Italian
- Judaic Studies
- Language, Literature and Culture of Ancient Greece
- Language, Literature and Culture of Ancient Rome
- Latin American and Caribbean Studies
- Latina/o Studies
- Lesbian, Gay, Bisexual and Transgender, Queer (LBGTQ) and Sexuality Studies
- Linguistics
- Mathematics
- Medical Anthropology
- Medieval and Early Modern Studies
- Modern Greek Studies
- Modern Western European Studies
- Music
- Native American Studies
- Near Eastern Languages and Culture
- Oceanography
- Paleontology
- Philosophy
- Physics
- Polish Language, Literature and Culture
- Political Science
- Russian Language, Literature and Culture
- Russian Studies
- Scandinavian Studies
- Science, Technology and Society
- Statistics
- Text-to-Performance
- Urban and Community Studies
- Women, Race and Ethnicity

LSA minors with their requirements and other pertinent information are listed on the Student Affairs Web site at http://www.lsa.umich.edu/lsa/students/resources/academics/conc/.

Policies and Procedures for Declaring and Completing LS&A Academic Minors

As part of the College of Engineering's curriculum reform, engineering students now have greater flexibility in electing courses from other colleges. In the interest of helping students make informed decisions in selecting these courses, we allow and encourage our students to pursue minors offered in LS&A.

Students in the College of Engineering are given the option of electing one or more academic minors offered by units within the College of Literature, Science and the Arts. Electing to earn an academic minor is optional and there is no limit on the number of academic minors a student may elect.

The following is a statement of the policies and procedures to be followed for declaring and completing minors:

1. Each B.S.E. and B.S. student who wishes to complete an approved academic minor must develop a plan for the minor in consultation with the designated LS&A advisor, who must also approve it. The faculty and staff advisors in the LS&A units will advise Engineering students on course selection, and complete the minor declaration form and confirm completion of the minor. There will be no prior approval required from an Engineering advisor.
2. Students may not elect two academic minors offered by the same department or program.
3. The minor declaration form must be received by the College of Engineering Records Office. Upon receipt of the declaration form, the staff member will enter the minor in the M-Pathways database. The form will be available through all Engineering academic departments, the Engineering Advising Center and all relevant LS&A departments.
4. Student Transcripts:
   - The unofficial transcript for an Engineering student who has declared a minor will show the minor in the program action history section.
   - The Official Transcript issued by the Registrar's Office will show the minor at the beginning of the transcript when the student has completed the degree.
5. Minors cannot be completed and added to the transcript, once a student is graduated.

International Academic Programs

The International Programs in Engineering Office (IPE) oversees two academic programs that promote cross-cultural learning and international experience: the Engineering Global Leadership (EGL) Honors Programs and the Program in Global Engineering (PGE). Prospective students should visit the IPE office early in their program to ensure proper planning.

Engineering Global Leadership Honors (EGL) Program

The EGL Honors Program combines a traditional engineering undergraduate curriculum with a core of courses in the Ross School of Business and in the School of Literature, Science, and Arts. Through participation in the program, students earn two degrees: a Bachelor's and a Master's in Engineering.

Program in Global Engineering (PGE)

The Program in Global Engineering is designed to help students focus their humanities, social science and free elective requirements to gain expertise about a region of the world. PGE integrates regional courses, cross-cultural training, and a required study/work abroad experience to help students learn firsthand what it means to be a global engineer.

Eligibility

- completion of one term at the College of Engineering
- cumulative GPA of 3.0

Program Requirements

- Language Study (8 credit hours)
- Regional Focus (8 credit hours, 300-level or higher)
- International Free Electives (6 credit hours)
- Cross-Cultural training
- Overseas experience

Undergraduate Programs

Undergraduate Research Opportunity Program (UROP)

The UROP program enables students to work one-on-one or as part of a small group of students with faculty members conducting research. Students will choose research projects by looking through a catalog of faculty research projects, and will then interview for the positions with the faculty researcher. Students spend on an average nine to ten hours per week working on their research projects. Students can participate in the program for academic credit through ENGR 280. Students receive one credit per three hours of work per week. Most students register for three credits, which is a nine-hour commitment per week. Students participating in the program are also required to attend a biweekly research peer group meeting, meet monthly with a peer advisor, read research-related articles (e.g., research ethics, research in specific disciplines, research methods) and keep a research journal.

All first- and second-year Engineering students are eligible to apply to UROP. Applications for first-year students will be sent out in May and accepted throughout the summer. Students are encouraged, however, to apply early. The deadline for sophomore applications is March 1. Applications can be picked up from the UROP office. Also, applications are mailed to students in February prior to the sophomore year. Selection is done on a rolling basis and determined by a student's level of interest in research, academic background, area of research interest, and availability of positions.

For more information, please visit the following website at http://www.umich.edu/~urop/.

Military Officer Education Program

Opportunities are offered through Reserve Officers' Training (ROTC) for officer training in military, naval, and air science leading to a commission on graduation. Enrollment is voluntary (see conditions of enrollment under the respective program on page 240). If elected, the grades earned will be recorded and used in the computation of grade point averages, and credit hours for the 300- and 400-level courses will be included with the hours completed toward the degree. A maximum of 12 credit hours of 300- and 400-level ROTC courses may be used as unrestricted electives at the discretion of the program advisors.

Cooperative Education

The Cooperative Education Program (Co-op) assists students in pursuing an optional program of work and study within the College of Engineering. Corporations, government agencies, and industry interview students who are interested in having a work-related learning experience that enhances their academic studies. Cooperative Education positions offer work experience relevant to the student's degree interests and enhance the student's opportunities for future permanent hire.

Full-time students are eligible to participate in co-op and may tailor their work assignments for consecutive terms, for example May to December or January to August.

They may also stagger them and alternate work school semesters. Opportunities to co-op are available in manufacturing, design, production, software and hardware development, communications, and other technological fields.

How the Cooperative Education Program Works

Employers provide the Engineering Career Resource Center (ECRC) with a job description and requirements for the co-op position. Students should submit their résumés through the online system. The employer will review the résumé and select students to interview on campus, at the employer location, or by telephone. The co-op representative screens qualified applicants for Cooperative Education.

Final selection of a student for co-op work assignment is a mutual agreement entered into by the employer and the students, and the student becomes an employee of that company. Note that the Engineering Career Resource Center does not guarantee co-op job placement for every applicant; however, every effort is made to help students find appropriate positions.

Work assignment

While on work-term assignment, students are subject to the rules and regulations of the employer. The employer will evaluate the student's performance at the end of the work term and forward the evaluation to the Engineering Career Resource Center. Co-op students are also required to complete and return an evaluation report of their learning experience to ECRC.

Engineering Career Resource Center
http://career.engin.umich.edu
230 Chrysler Center
Ann Arbor, Michigan 48109-2192
Phone: (734) 647-7140

How to sign up

Students interested in Co-op should contact the Engineering Career Resource Center, pick up a Degree Plan, and discuss the rules and regulations of the Cooperative Education Program with the co-op coordinator. The co-op student is registered while on co-op job assignment; registration is by permission only and must be done through the ECRC.

Core CoE Requirements

Planning the Student's Program

Students vary in their goals and objectives, in their level of achievement, and in their high school or pre-engineering preparation. Considerable variety and flexibility are provided to plan each student's schedule so that the individual may reach graduation as efficiently as possible. The objective is to place each new student in courses commensurate with his or her academic profile, previous experience, and potential for academic success.

Most courses have prerequisites. The completion of courses on schedule and with satisfactory grades is essential to the student's progress. The appropriate schedule for each student in each term will depend on a number of factors: past scholastic record, placement tests, extracurricular activities, election of Military Office Education Program, health, and need for partial self-support. A schedule of 12 to 18 hours is considered full-time.

First- and Second-Year Programs

At the time of the first advising session, all of the high school and advance placement records may not yet be in the student's file. It is the entering student responsibility to make certain that all pertinent information is brought to the attention of an EAC Advisor. Any changes in test scores or transfer credits will affect final course selection and need to be discussed with an advisor.

With complete information available, the advisor and the student will be able to make carefully considered adjustments in course elections for the first-term course schedule.

First Year

Assuming that a student has the necessary academic preparation and no advanced placement credit, he/she will be expected to complete some combination of the following courses:

1. Mathematics 115 and 116 or one of the honors Math sequences.
2. Chemistry 130 and 125/126, or, for some, 130, 210, and 211.
3. Engineering 100
4. Physics 140 and 141
5. Engineering 101
6. Additional course information will be available during the advising session.

Second Year

All students will continue with the mathematics, physics, humanities, and social sciences courses common to all programs. A second-term student who has selected a degree program should be meeting with that program advisor for third-term elections.

Students who have not selected a degree program should consult the Engineering Advising Center for their course selections.

Honors-Level Courses

A student whose record indicates qualifications to perform at an advanced level may discuss this option with an advisor in the Engineering Advising Center.

Minimum Common Requirements

Each of the degree programs offered by the College includes credit hours that are common to all programs, subject to appropriate adjustment for equivalent alternatives. See individual sample schedules for required programs in each program section of this Bulletin. Some programs may have a higher minimum grade requirement for some courses.

Mathematics

The mathematics courses of 115 (4), 116 (4), 215 (4), and 216 (4) provide an integrated 16-hour sequence in college mathematics that includes analytic geometry, calculus, elementary linear algebra, and elementary differential equations. Some students taking mathematics courses preparing them for the election of the first calculus course (currently Math 105 and Math 110) may not use these courses as credit toward an Engineering degree; however, grades from these courses will be used in computing students' grade point averages.

All students with strong preparation and interest in mathematics are encouraged to consider the honors-level math sequence. Qualified and interested students should consult their engineering advisor about these options. It is not necessary to be in an honors program to enroll in these courses.

Engineering 100: Introduction to Engineering

Engineering 100 introduces students to the professional skills required of engineers and provides them with an overview of engineering at the beginning of their program. An important component of the course is the real-world engineering project. Important engineering skills developed in Engineering 100 include:

- Qualitative project-based work in an engineering discipline
- Written, oral and visual communication skills
- Team building and teamwork
- Ethical concerns in the engineering profession
- The role of engineers in society
- Environmental and quality concerns in the engineering profession.

Important Note: *You must receive a grade of C- or better in Engineering 100 to fulfill the requirement. Note: A grade of "C" is required for EECS. Transfer students must complete English composition as a prerequisite for transfer admission. Be sure to consult with the Office of Recruitment and Admissions if you have questions.*

Advanced Placement English Credit

Advanced Placement (AP) English Literature credit is assessed as English departmental credit and can be used toward your Humanities requirement. AP English composition credit is used as unrestricted electives and will not fulfill the Engineering 100 requirement. You will not receive credit for Sweetland Writing Center courses.

Engineering 101: Introduction to Computers and Programming

The objective of Engineering 101: Introduction to Computers and Programming is to introduce students in Engineering to the algorithmic method that drives the information age. Algorithms are an organized means to construct the solution of a problem, structured as a well-defined set of steps that can be carried out by a mechanism such as a computer.

Engineering 101 focuses on the development of algorithms to solve problems of relevance in engineering practice and on the implementation of these algorithms using high-level computer languages. Because it is a first-year course, it does not focus on the analysis of complex, realistic systems requiring significant background knowledge. Instead, it is centered on quantitative and numerical problems that are suited to computational solutions, which often arise as part of larger, more complex problems in engineering practice.

Engineering 101 ties itself to the introductory physics and math courses, and provides concrete examples of some of the concepts being covered. Sample problem types might include:

- Finding area and volume
- Simulating statistical processes
- Data analysis
- Physical simulation
- Simulating complex systems with simple rules
- Minimization and optimization

In addition to the problem-solving component, students who take Engineering 101 will learn aspects of the C++ programming languages and be exposed to the MATLAB programming language. C++ is used today in many fields of engineering. MATLAB is also popular and has powerful capabilities for handling computation involving matrices and for visualizing data using 2-D and 3-D graphics. Important note: You must receive a grade of "C-" or better in Engineering 101 to fulfill the requirement. Note: A grade of "C" or better is required for EECS.

Chemistry

Chem 130 (3) with laboratory Chem 125/126 (2) is required by most degree programs. Students will normally elect these courses during the freshman year. The following degree programs require additional chemistry: Biomedical Engineering, Chemical Engineering, and Materials Science and Engineering. Students expecting to enter one of these degree programs would normally elect Chem 130 (3), Chem 210 (4) with laboratory, Chem 211 (1) during the freshman year depending on U-M placement exam.

***Important Note:** (1) If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution you will have met the Chemistry CORE Requirement for CoE. (2) Students who place into Chem 210/211 will **not** be given credit for Chem 130.*

Physics
The usual first year schedule includes Physics 140 (4) with laboratory, Physics 141 (1). This course requires completion of Calculus I. A second course, Physics 240 (4) with laboratory, 241 (1), is required by all programs and is normally scheduled in the third term.

***Important Note:** (1) If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution you will have met the Physics Core Requirement for CoE. (2) All students with strong preparation and interest in physics are encouraged to consider the honors-level physics sequence.*

Foreign Languages
A student may take an examination in a foreign language regardless of how the language skills were developed; however, credit by examination for foreign languages, either at the University of Michigan or Advanced Placement, IB and A-levels will be granted up to a maximum of eight credit hours. If the language credit earned is at the first-year level, then the credit hours may be used only as unrestricted electives. If the language credit earned is at the second-year level, then the credit hours may be used as humanities or unrestricted elective credits. Students earning language credit by completing qualifying courses at the University of Michigan, designated by LR or HU, or by transfer credit of equivalent courses from any other institution of higher learning, may apply all credits earned towards humanities.

Humanities and Social Sciences
The Humanities and Social Sciences Requirements offer a variety of academic choices for all students working toward an undergraduate Engineering degree. It is designed to provide the students with social, cultural, political and economic background crucial to fulfilling the College of Engineering's purpose of "preparing our graduates to begin a lifetime of technical and professional creativity and leadership in their chosen field".

To provide a breadth of education, each program in the College identifies a certain number of credit hours of elective courses (a minimum of 16) concerned with cultures and relationships--generally identified as humanities and social sciences. Students are encouraged to select a cluster theme for their humanities/social science electives. This is a unifying theme (such as psychology, economics, or history) that focuses the student's HU/SS electives.

Requirements:
The specific requirements for all students are listed below:

I. Humanities (6 credit hours):
At least two courses totaling at least six credit hours.

II. Sequence of humanities or social sciences courses (six credit hours):
A sequence of at least two courses in either the humanities or social sciences (or both) totaling six or more credit hours, must be taken from the same department or division (e.g., History), at least one of which must be an upper level (numbered 300 or above). This requirement may, of course, overlap requirement 1.

III. The remaining credit hours may be satisfied with elective courses in either humanities or social sciences.

Definitions and Exceptions:
These requirements can often be satisfied by a number of courses from the College of Literature, Science and the Arts (LSA), or in part by Advanced Placement, A levels or IB credit or by courses taken at another university. For purposes of this College of Engineering requirement a course is defined as being a humanities or social science as follows:

1. Any course that is designated as "HU" or "SS" by the College of Literature, Science and Arts meets this requirement as humanities or a social science, respectively.
2. Language courses, those designated as "LR" are counted as humanities. However, advanced placement credit, A levels, IB or University of Michigan placement credit for language courses at the 100-level and below are not to be used to satisfy this requirement. These may be counted instead as Unrestricted Electives.
3. Courses that are designated as "BS", "CE", "MSA", "NS", "QR", "experiential", "directed reading or independent study", or course titles that include the terms or partial phrases "composition", "conversations:", "intro composition", "math", "outreach", "performance", "physics", "practice", "practicum", "statistics", "studio", "tutor" may not be used to satisfy this requirement.
4. For the purposes of this requirement, courses not covered by items 1, 2 & 3 above will be defined as *humanities* courses if they are offered by the following departments or divisions:
    - American Culture
    - Architecture (non-studio)
    - Art (non-studio)
    - Classical Archaeology
    - Classical Studies
    - Comparative Literature
    - Dance (non-performance)
    - Film and Video Studies
    - Great Books

- History of Art
- Asian, English, Germanic, Romance (French, Italian, Portuguese, Spanish) and Slavic Languages and Literatures
- Music (non-performance)
- Music History and Musicology
- Philosophy
- Religion
- Theatre and Drama (non-performance)

Similarly, courses not covered by items 1, 2 & 3 above will be defined as *social sciences* if they are offered by the following departments:

- Afro-American and African Studies
- Cultural Anthropology
- Communication Studies
- Armenian, Judaic, Latin American and Caribbean, Latina/Latino, Middle Eastern and North African, Native American, Near Eastern, Russian and East European Studies
- Economics
- History
- Linguistics
- Political Science
- Psychology
- Sociology
- Women's Studies

Unrestricted Electives

Unrestricted electives may be selected from the offerings of any regular academic unit of the University and from the Pilot Program. All undergraduate degree programs will accept a maximum of 3 credit hours in the following areas:

1. Performance courses in the schools of music or art, including marching band;
2. Courses which require tutoring of other students enrolled in courses;

- All undergraduate degree programs in the College of Engineering will accept up to 12 credit hours toward unrestricted electives from credits earned by a student in 300- and 400-level courses in military, naval, or air science.
- Tutorial courses are not acceptable for credit or grade points but will be included on the student's official record.

Course Titles and Descriptions

Courses and course descriptions are listed under each degree program. Course titles and numbers, prerequisites, other notes, credit hours, and descriptions approved by the Curriculum Committee are included. Course descriptions also are available on the College's Web site at: http://courses.engin.umich.edu/. They may be downloaded or printed.

The courses offered by the College of Engineering, and by certain closely associated departments of other units of the University, are listed. Schedules of classes are issued separately, giving hours and room assignments for the courses and sections offered each term.

Designations

- Each listing begins with the course number and title set in bold-face type. "([Course number])" indicates cross-listed courses.
- Prerequisites, if any, are set in italics. They are followed by roman numerals, also set in italics, that indicate the times at which the department plans to offer the course:
  See under "Term" for definitions relating to the several terms.

I	fall
II	winter
III	spring-summer
IIIa	spring-half
IIIb	summer-half

- The italics in parentheses indicate the hours of credit for the course; for example, "(3 credits)" denotes three credit hours.

What the Course Number Indicates

The number of each course is designated to indicate the general level of maturity and prior training expected.

100	Freshman-level courses
200	Sophomore-level courses
300	Junior-level courses
400*	Senior-level courses
500	Predominantly Graduate-level courses
600	Graduate-level courses and above

Unless a phrase such as "junior standing," "senior standing," or "graduate standing" is part of the list of prerequisites for a course, a student may elect an advanced-level course relative to his/her current status if the other prerequisites are satisfied. If the difference in standing level is greater than one academic year, it is usually not wise to elect an advanced-level course without first consulting the department or the instructor offering the course.

In general, the prerequisites listed for a course designate specific subject materials and/or skills the student is expected to have mastered before electing the course (or, in some cases, concurrently with it).

**A 400-level course listed in the Bulletin of the Horace H. Rackham School of Graduate Studies may be elected for graduate credit when this is approved by the student's graduate program advisor.*

Course Equivalence

Unless otherwise stated, the phrase "or equivalent" may be considered an implicit part of the prerequisite for any course. When a student has satisfactorily completed a course that is not listed but is believed to be substantially equivalent to one specified as a prerequisite for a course that the student wants to elect, the individual may consult the program advisor and upon determining if equivalency has been satisfied, election may be approved.

Permission of Instructor

The phrase "or permission of instructor (or department)" may be considered an implicit part of the statement of prerequisites for any course. When permission is a stated requirement, or when a student does not have the stated prerequisite for a course but can give evidence of background, training, maturity, or high academic record, the student should present to the program advisor a note of approval from the instructor or department concerned.

Representative Sample Schedules

The information in this Bulletin for a number of the degree programs includes a schedule that is an example of one leading to graduation in eight terms. This sample schedule is for informational purposes only and should not be construed to mean that students are required to follow the schedule exactly.

A transfer student attending a community or liberal arts college and pursuing a pre-engineering degree program may not be able to follow a similar schedule because of a lack of certain offerings. Departmental program advisors should always be consulted when planning course selections.

Graduate Admissions

Mission Statement:

- Provide support, improve communication, and start new initiatives for graduate students, departments, and interdisciplinary programs.
- Provide a positive graduate student experience and increase retention of graduate students through various programs and activities.
- Utilize a variety of recruitment programs to attract high quality and diverse graduate students.
- Create excellent international programs for faculty, students, international visitors, and exchange students.
- Provide training, mentoring, and support of Graduate Student Instructors (GSI), with the assistance of the Center for Research on Learning and Teaching, to ensure high quality teaching.

Students who are candidates for the M.S. and M.S.E. degrees, the post-Master's Professional Engineering degree, or the Ph.D. degree are enrolled in the Horace H. Rackham School of Graduate Studies; its Bulletin should be consulted for complete information.

The Master of Engineering degree and the Doctor of Engineering in Manufacturing degree are offered through the College of Engineering.

Anyone contemplating graduate work should consult with the program advisor for the desired program. Information on graduate programs by department is in this Bulletin.

Application Information
Depending on which degree you seek, your application will be made either to the Horace H. Rackham School of Graduate Studies, or to the College of Engineering. Electronic and printable copies of the official admission applications can be found through the College of Engineering's website.

Application Status
Some departments or programs review applications on a rolling basis as applications are received; others review applications on a scheduled basis. Before contacting the department or program please allow at least six weeks for processing.

Admissions Criteria
Contact individual departments or programs for specific admissions criteria:
http://www.engin.umich.edu/admin/adge/contacts/gradprogcontacts.pdf. Admission is usually determined by an evaluation of the following:

- Transcript of your academic record
- Recommendations from three faculty members who have supervised your course work or research
- Graduate Record Examination (GRE); test scores must be taken within five years of application (NOTE: required for Ph.D. candidates, check with individual departments for specific requirements for Master's students).
- Written description of your graduate study objectives
- Test of English as a Foreign Language (TOEFL), or the Michigan English Language Assessment Battery (MELAB), for applicants who studied at an institution that did not teach English as a second language, or for whom English is not their native language

Graduate Degree Options
The University of Michigan College of Engineering offers the following graduate degree programs throughout eleven departments and three interdisciplinary programs:

- Master of Science (M.S.)
- Master of Science in Engineering (M.S.E.)
- Master of Engineering (M.Eng.)
- Professional Engineer
- Doctor of Philosophy (Ph.D.)
- Doctor of Engineering (D.Eng.)

Departments

- Aerospace Engineering
- Atmospheric, Oceanic and Space Sciences
- Biomedical Engineering
- Chemical Engineering
- Civil and Environmental Engineering
- Electrical Engineering and Computer Science
- Industrial and Operations Engineering
- Materials Science and Engineering
- Mechanical Engineering
- Naval Architecture and Marine Engineering
- Nuclear Engineering and Radiological Sciences

Programs

- InterPro: Interdisciplinary Professional Programs:
  - Automotive Engineering
  - Financial Engineering
  - Global Automotive and Manufacturing Engineering
  - Integrated MicroSystems
  - Manufacturing
  - Pharmaceutical Engineering
- Applied Physics
- Macromolecular Science and Engineering

Dual Master's

Graduate students in the College of Engineering can pursue dual master's degrees within the College or across units of the University of Michigan campus. See the website for more information on the list of Rackham dual degrees, student initiated dual degrees, and the double counting of credits. www.engin.umich.edu/students/current/graduate/academics/programs/dualdegrees.pdf

Horace H. Rackham School of Graduate Studies

Office of Graduate Admissions
Rackham Graduate School
915 East Washington, Room 106
Ann Arbor, Michigan 48109-1070

The Horace H. Rackham School of Graduate Studies administers the following graduate programs:

- Master of Science (M.S.)
- Master of Science in Engineering (M.S.E.)
- Professional Engineer
- Doctor of Philosophy (Ph.D.)

Application materials should be sent to the individual department to which you are applying and to:

Office of Graduate Admissions
Rackham Graduate School
915 East Washington, Room 106
Ann Arbor, Michigan 48109-1070

For questions regarding the application process or to obtain an application packet, please contact Rackham at 734-764-8129.
To obtain detailed information on the Rackham admissions process for both domestic and international students go to: http://www.rackham.umich.edu/Admis/.
To obtain an online application go to http://www.rackham.umich.edu/Admis/rackhamalt.html

Master of Science/Master of Science in Engineering

The Master of Science and Master of Science in Engineering degrees represent mastery of a particular discipline in the College of Engineering. They require 30 credits of course work, taken predominantly from the area of study. Some programs involve theses or internships. Others require only coursework.

Professional Engineering Degrees

The professional engineering degree programs require a minimum of 30 credit hours of work beyond the Master of Science in Engineering level or its equivalent, taken at this University with a grade of "B" or better. Successful completion of a qualifying examination for admission to candidacy is required.

Doctor of Philosophy - Ph.D.

The doctoral degree is conferred in recognition of marked ability and scholarship in a chosen field of knowledge. There is no general course or credit requirement for the doctorate. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in related subject areas outside the department, called cognate subjects. In most areas, a student must pass a comprehensive examination in a major field of specialization and be recommended for candidacy for the doctorate. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the results of the investigation in the form of a dissertation. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in the field of specialization. Candidacy is achieved when the student demonstrates competence in his/her broad field of knowledge through completion of a prescribed set of courses and passing a comprehensive exam.

Requirements regarding foreign language and non-technical courses are left to individual departments or programs, and to the Graduate School. A prospective doctoral student should consult the program advisor for specific details. Admissions Officer
Center for Professional Development
2121 Bonisteel Boulevard
Room 273
Ann Arbor, Michigan 48109-2092

College of Engineering Degrees

The College of Engineering administers the following graduate programs:

- Master of Engineering (M.Eng.)
- Doctorate of Engineering in Manufacturing (D.Eng.)

Master of Engineering - M.Eng.

The College of Engineering offers the master of engineering degree as a professional, practice-oriented degree, designed to further the education of engineers who have practical experience in industry, and plan to return to industry after completion of their selected program. This degree can be completed in one calendar year (12 months). Programs are organized around a team-project experience with industry.

Information on these programs can be requested by sending an e-mail to: engin.pro.prgms@umich.edu. Applications may also be obtained by contacting the individual departments or by calling 734-647-7024.

Application materials should be sent to:
Admissions Officer
Center for Professional Development
2121 Bonisteel Boulevard, Room 273
Ann Arbor, Michigan 48109-2092

Doctor of Engineering in Manufacturing (D.Eng.)

The Doctor of Engineering in Manufacturing is a graduate professional degree in engineering for students who have already earned a B.S.E. degree and an M.S.E. degree in any engineering discipline; or a Master of Business Administration.

To obtain detailed information on the Doctor of Engineering admissions process for both domestic and international students, go on-line to http://interpro.engin.umich.edu/mfgeng_prog/academic/doc_of_eng.htm

Applicants may also call 734-647-7024.
Application materials should be sent to:
Admissions Officer
Center for Professional Development
2121 Bonisteel Boulevard, Room 273
Ann Arbor, Michigan 48109-2092

Aerospace Engineering

Undergraduate Student Services Coordinator
Ms. Deborah Laird
3054 François-Xavier Bagnoud Building
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Undergraduate Advisor
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Aerospace Engineering

Aerospace technology has grown out of the problems of design, construction, and operation of vehicles that move above the Earth's surface, vehicles ranging from airplanes and helicopters to rockets and spacecraft. Design of such vehicles has always been challenging, not only because of the high premium placed on lightweight vehicles performing efficiently and with high reliability, but also because they must sometimes operate in hostile environments. These same requirements exist not only for future spacecraft and high-performance transport aircraft, but also to the next generation of ground transportation, such as high-speed trains, over-water transportation, and automated motor vehicles. In addition to working on vehicle-oriented design problems, aerospace engineering graduates are often involved in systems management in the broadest sense. Because of the anticipated life mission of the aerospace student, the undergraduate curriculum at the University of Michigan is designed to convey a clear understanding of the fundamental aspects of the fields most pertinent to aerospace engineering. Real-life problems in aerospace and related areas are emphasized in the applications of theory. In their senior year, students select a design course in which they are given an appreciation of the interrelation of the various areas of study in the design of a whole system.

Facilities

The Aerospace Engineering Department is primarily housed in the Francois-Xavier Bagnoud (FXB) building. The Aerospace Engineering program office and all the faculty and staff offices are located in this building. The FXB building also houses instructional and research laboratories, a CAEN computing lab, the Aerospace Engineering Library and Learning Center, several lecture rooms, the Boeing Auditorium and the Lockheed Design Room. Other department facilities including the Plasma and Electric Propulsion Laboratory (PEPL), the 5'x7' and 2'x2' Wind Tunnels and the Student Fabrication Laboratory are housed in nearby buildings.

Department Laboratories

Engineering knowledge is gained in part through experience with engineering problems and the experimental approach to their solution. In required laboratory courses, the student is introduced to the basic principles of operation and use of modern laboratory instrumentation. These courses, taken in the junior and senior year, may be followed by additional experimental work either in formal elective courses or in projects of the student's choosing. The department's laboratories include subsonic and supersonic wind tunnels; shock and detonation tubes; laser diagnostic equipment; fabrication laboratory; structural test equipment; flight controls test equipment; and a wide range of optical, electronic, and computer diagnostic equipment. Students also gain experience in the use of computers for computation, system design and fabrication, and simulation. Undergraduate students at Michigan profit by their contact with graduate students and faculty members, who carry out research work parallel to the areas of undergraduate instruction and student projects.

Accreditation

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Mission

To provide internationally recognized leadership in aerospace engineering education, through a continuously improving educational program that graduates students with strong engineering science fundamentals while incorporating applied engineering aspects.

Goals

- Educate students who are widely known for exceptional strength in technical fundamentals across all aerospace disciplines, who are cognizant of modern aerospace technologies, and who are sought after by top graduate schools and by aerospace and related industries worldwide.
- Support vibrant and highly recognized research programs that serve the educational goals of the undergraduate and graduate degree programs, that make major contributions to the knowledge base in aerospace sciences and technology, and that are turned to by industry and government for solutions.
- Create an environment of intellectual challenge and excitement that at the same time is collegial and conducive to higher learning.
- Take full advantage of knowledge, technology, facilities and resources at the University of Michigan.

Objectives

- Educate students in the following fundamental disciplines of aerospace engineering and how to apply them: aerodynamics, aerospace materials, structures, aircraft and rocket propulsion, flight mechanics, orbital mechanics, and aircraft stability and control.
- Educate students in the methodology and tools of design, and the synthesis of fundamental aerospace disciplines necessary to carry out the design of an aerospace vehicle or system.
- Educate students in the basics of instrumentation and measurement, laboratory techniques, and how to design and conduct experiments.
- Help students learn to function on multi-disciplinary teams, and provide them with teamwork experiences throughout their curriculum.
- Help students learn to communicate effectively.
- Expose students to environmental, ethical and contemporary issues in aerospace engineering.
- Expose students to other disciplines of engineering beyond the aerospace field.

Outcomes

The outcomes we desire are that graduates of the University of Michigan Aerospace Program demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering;
- An ability to design and conduct experiments, as well as to analyze and interpret data;
- An ability to design a system, component or process to meet desired needs;
- An ability to function on multi-disciplinary teams;
- An ability to identify, formulate, and solve engineering problems;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively;
- The broad education necessary to understand the impact of engineering solutions in a global and societal context;
- A recognition of the need for, and an ability to engage in life-long learning;
- A knowledge of contemporary issues;
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice;
- A knowledge of aerodynamics, aerospace materials, structures, aircraft and rocket propulsion, flight mechanics, orbital mechanics, and aircraft stability and control;
- Competence in the integration of aerospace science and engineering topics and their application in aerospace vehicle design.

Aerospace Engineering Undergraduate Education

Undergraduate Student Services Coordinator
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Degree Program

The degree program gives the student a broad education in engineering by requiring basic courses in aerodynamics and propulsion (collectively referred to as "gas dynamics"), structural mechanics, and flight dynamics and control systems. These courses cover fundamentals and their application to the analysis, design and construction of aircraft, spacecraft and other vehicular systems and subsystems. Courses in gas dynamics treat fluid and gas flow around bodies and through turbojet engines and rocket nozzles. In courses on structural mechanics, lightweight structures are studied from their strength, elastic, stiffness, stability, and dynamic behavior. Flight dynamics and control systems courses deal with the dynamical behavior of vehicles and systems as a whole, their stability and controllability both by human and automatic pilots. Integration of all these subjects takes place in the capstone aircraft design course or space system design course that is chosen by the student. The aerospace engineering program offers considerable flexibility through technical and unrestricted electives, in which the students have an opportunity to study in greater depth any of the areas mentioned above. In addition, other technical elective areas are available to aerospace engineering students, including aerophysical sciences, environmental studies, computers, person-machine systems, and transportation. Elective courses in each technical elective area include courses taught both inside and outside the aerospace engineering department.

Combined Degrees Program

For students with special interests, combined degree programs leading to two bachelor's degrees are available. The flexibility of the aerospace curriculum makes it feasible to obtain a second bachelor's degree. Popular second-degree areas of concentration among aerospace engineers are Naval Architecture and Marine Engineering, and Mechanical Engineering, but combined degrees with other departments can be arranged.

Sequential Graduate/Undergraduate Study (SGUS)

Department of Aerospace Engineering SGUS

Undergraduate Student Services Coordinator
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SGUS Advisor
Professor Bram van Leer
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B.S.E. in Aerospace Engineering/M.S.E. in Aerospace Engineering

Students enrolled in the College of Engineering who complete 90 credit hours toward the B.S.E. degree in Aerospace Engineering with GPA 3.5 or higher and who meet all other conditions required for admission as determined by the Department Graduate Committee, may apply for, and be granted admission to, the combined bachelor's/ master's program. Please contact the Aerospace Engineering department for more information.

B.S.E. in Aerospace Engineering/M.Eng. in Space Engineering

Undergraduate Student Services Coordinator
Ms. Deborah Laird
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Phone: (734) 764-3310/dcak@engin.umich.edu

Professor Harris McClamroch
SGUS Advisor
nhm@umich.edu

Students enrolled in the College of Engineering who complete 90 credit hours toward the B.S.E. degree in Aerospace Engineering, and who meet all other conditions required for admission as determined by the M.Eng. in Space Engineering program committee, may apply for, and be granted admission to, the combined bachelor's/ master's program. Please contact the Aerospace Engineering department for more information.

Sample Schedule
B.S.E. (Aerospace Engineering)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engr 100, Intro to Engr	4	4	-	-	-	-	-	-	-
Engr 101, Intro to Computers	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130, or 210 and 211[1]	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 241[2]	10	-	5	5	-	-	-	-	-
Humanities and Social Sciences	16	4	4	-	-	-	4	4	-
Advanced Mathematics/Science (3hrs.)									
Advanced Math/Science Elective[3]	3	-	-	-	-	3	-	-	-
Related Technical Core Subjects (12 hrs.)									
ME 240, Intro to Dynamics and Vibrations	4	-	-	-	4	-	-	-	-
MSE 220, Intro to Materials and Manufacturing or MSE 250, Principles of Engineering Materials	4	-	-	4	-	-	-	-	-
EECS 206, Signals and Systems I or EECS 314, Cct Analy and Electronics	4	-	-	-	-	4	-	-	-
Aerospace Science Subjects (24 hrs.)									
Aero 215, Intro to Solid Mechanics and Aerospace Structures	4	-	-	-	4	-	-	-	-
Aero 225, Intro to Gas Dynamics	4	-	-	-	4	-	-	-	-
Aero 315, Aircraft and Spacecraft Structures	4	-	-	-	-	4	-	-	-
Aero 325, Aerodynamics	4	-	-	-	-	-	4	-	-
Aero 335, Aircraft and Spacecraft Propulsion	4	-	-	-	-	4	-	-	-
Aero 345, Flight Dynamics and Control	4	-	-	-	-	-	4	-	-
Aerospace Engineering Subjects (16 hrs.)									
Aero 245, Performance of Aircraft and Spacecraft	4	-	-	4	-	-	-	-	-
Aero 305, Aerospace Engr Lab I	4	-	-	-	-	-	4	-	-
Aero 405, Aerospace Engr Lab II	4	-	-	-	-	-	-	4	-
Aero 481, Aircraft Design or Aero 483, Space System Design	4	-	-	-	-	-	-	-	4
Electives (18 hrs.)									
Technical Electives[4]	9	-	-	-	-	1	-	4	4
Unrestricted Electives (9-12)	9-12	-	-	-	-	-	-	3	6
Total	128	17	17	17	16	16	16	15	14

Candidates for the Bachelor of Science degree in Engineering (Aerospace Engineering) - B.S.E (Aerospace E.) - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]Math 371, 419, 450 or 454 are recommended to fulfill this requirement. Math 354, 404, 425, 471; Stat 412, 425; Engr 371 may also be used.[4]Upper-level math, science or engineering courses approved by faculty advisor. If advanced math class taken is 4 credit hours, this requirement is for 8 rather than 9 credit hours. Must include 1 credit hour aerospace seminar course.

Aerospace Engineering Concentrations

Propulsion, Aerodynamics and Combustion

Air-Breathing Propulsion and Combustion Science

Fundamental and advanced courses are offered in fluid mechanics, combustion, and turbulent mixing. A graduate laboratory class is offered in optical measurement techniques in gas dynamics. Applied propulsion classes include Rocket Propulsion and Turbojet Propulsion. Research covers the areas of laser-based flow visualization, velocity field imaging, spray combustion, supersonic mixing, hydrogen combustion in a scramjet-like device, and soot formation.

Space Propulsion

Classes are offered in the areas of electric propulsion, space plasma physics, kinetic theory of rarefied gases, and the space environment. Ion thruster experiments employ spectroscopic methods in one of the most advanced university facilities.

Aerodynamics and Turbulence

Courses cover basic and advanced wing theory, boundary layers and aerodynamic drag, compressible high-speed flows, effects of turbulence on drag and mixing, and a graduate-level laboratory. Research projects utilize advanced flow field measurement techniques to study the fundamental nature of turbulent mixing and employ MEMS devices to control turbulence and aerodynamics.

Computational Fluid Dynamics of Transonic and Hypersonic Vehicles

Classes provide in-depth development of numerical algorithms. Research projects use these algorithms to model hypersonic re-entry, delta wings, solar wind on space vehicles, shock buffeting of transonic vehicles, and aeroacoustics.

Structural Mechanics

Advanced Materials for Airframe Applications

Courses are offered in structural and solid mechanics that emphasize the basic knowledge required to address several contemporary topics in the design and analysis of aircraft and spacecraft structures. Areas of research include composite materials, composite structures, fracture mechanics, design of composite microstructures and novel instrumentation for probing materials.

Adaptive Materials and Constitutive Modeling for Aerospace Structures

Advanced courses are offered that address structural and material instabilities found in aerospace structures and in advanced materials. Research includes theoretical and experimental studies of adaptive materials, such as shape memory alloys, and their application to smart structures.

Aeroelasticity, Structural Dynamics, Optimal Design of Structures

Courses focus on structural dynamics and aeroelasticity of fixed wing and rotary wing vehicles including finite element computations for optimal structural design. Research includes aeroelasticity and aeroservoelasticity of rotary- and fixed-wing vehicles. Optimal structural design of aerospace vehicles with multi-disciplinary constraints is pursued.

Flight Dynamics and Control

Dynamics and Control of Aircraft

Performance, dynamics, and automatic control of atmospheric flight vehicles are core subjects. Performance measures for steady level flight, steady climbing flight, and steady turning flight are developed in several courses. Mathematical models are developed for aircraft and used to study longitudinal and lateral flight dynamics. Automatic control methods are applied to achieve improved flight stability and maneuverability.

Dynamics and Control of Spacecraft

Mathematical models form the basis for analysis of spacecraft orbital dynamics and spacecraft attitude dynamics. Orbit models are based on two-body and restricted three-body assumptions. Attitude models are based on rigid body assumptions, including gravity gradient effects. Automatic control methods are applied to achieve orbital corrections and attitude stabilization.

Astrodynamics

Astrodynamics, guidance, and navigation treat problems related to orbits of natural and human-made bodies. Astrodynamics covers the mathematical foundations of orbital mechanics, including orbital characteristics and orbit transfers. Navigation is concerned with the use of sensors and avionics to estimate orbital position and orbital velocity.

Aerospace Vehicles

This area focuses on courses that deal with the behavior of the entire vehicle, such as aircraft, helicopters and spacecraft. Several courses emphasize large-scale system integration and multidisciplinary design aspects that play a key role in the development of modern rotary- and fixed-wing aircraft as well as spacecraft.

Aerospace Engineering Graduate Education

Graduate Advisor
Professor Bram van Leer
3057 François-Xavier Bagnoud Building
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Graduate Degrees

- Master of Science in Engineering (M.S.E.) in Aerospace Engineering
- Master of Science (M.S.) in Aerospace Science
- Master of Engineering (M.Eng.) in Space Engineering
- Doctor of Philosophy (Ph.D.) in Aerospace Engineering
- Doctor of Philosophy (Ph.D.) in Aerospace Science

M.S.E. in Aerospace Engineering

This degree is designed for students who desire a curriculum that is focused on the scientific aspects of Aerospace Engineering. A total of 30 credit hours is required (typically 10 classes). Of these, 15 credit hours must be 500-level classes in Aerospace Engineering, and 6 credits must be from approved courses in mathematics. A thesis is optional. Consult the official university publications for specific degree requirements.

Admission requirements include a strong performance in an undergraduate program in engineering or science and submission of acceptable Graduate Record Exam (GRE) scores. Students have substantial flexibility in selecting courses, but courses must be approved by a Graduate Advisor.

Students are strongly encouraged to consult with faculty in their intended areas of specialization to discuss the composition of their program.

M.Eng. in Space Engineering (MEngSE)

The MEngSE provides a comprehensive set of courses and training in space-related science and engineering, and the systems approach to design and manage complex space systems. The M.Eng. in Space Engineering requires 30 credits of course work, of which 18 must be at the 500-level or higher and 24 must be graded (not P/F).

Course elections must include:

- Depth in a main area (9 credits). For example, a student could select dynamics and control, structures or propulsion.
- Breadth by crossing engineering/science boundaries (9 credits)
- Systems engineering (6 credits)
- Team design experience (6 credits)

Ph.D. in Aerospace Engineering

Study towards the Ph.D. degree requires a strong background in an area of specialization and an ability to carry out independent research. Students must complete, in order:

Precandidacy Status

A student must apply for and be admitted to precandidacy status before taking the Preliminary Exam. There are two ways to enroll as precandidate:

1. By requesting a change of program from Master to Precandidate after at least one term of enrollment in the MSE/MS program.
2. By applying for admission into the doctoral program with a BSE/BS degree or a MSE/MS degree or equivalent.

To be admitted as a precandidate, the student's GPA must be above 6.5 out of 9.0 (equivalent to 3.5/4.0) in relevant courses. Admission is determined by the Graduate Committee.

Students admitted directly to the doctoral program may also earn a Master degree, by fulfilling the Master degree requirements concurrently with the Doctoral degree.

Preliminary Exam

To become a Ph.D. candidate, a student must demonstrate a high level of competency by passing a Preliminary Exam. To take the exam the student must: (i) be accepted as a Precandidate, and (ii) have had research experience as a Research Assistant or have completed successfully three credits of directed study (AE 590) supervised by a faculty member in the department. Precandidates must be registered in the department during the term in which the exam is taken.

Candidacy

Candidacy status is achieved upon successful completion of the Preliminary Exam. Students must also meet other academic credit requirements as described in the Rackham Student Handbook.

The Dissertation

The student must perform original research, present a written dissertation, and defend the dissertation at a final oral presentation. The research is done under the supervision of a faculty adviser in the Aerospace Engineering department and a dissertation committee. Students are encouraged to begin research in their first year of graduate study.

Ph.D. Degree

The Ph.D. degree is awarded upon successful completion of a Ph.D. dissertation, a Ph.D. defense, and other academic credit requirements. See the *Rackham Student Handbook* for details. Students should have taken a minimum of 16 graduate courses beyond the bachelor's degree. There is no foreign language requirement, and there are no specific course requirements.

Aerospace Engineering Fields of Study
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Aerospace Engineering Courses

Aero 215. Introduction to Solid Mechanics and Aerospace Structures

Prerequisite: Preceded or accompanied by Math 216 and Aero 245. I, II (4 credits)

An introduction to the fundamental phenomena of solid and structural mechanics in Aerospace systems. Includes analysis and numerical methods of solutions used for design of thin-walled Aerospace structures. Emphasis is placed on understanding behavior particular to thin-walled structures.

Aero 225. Introduction to Gas Dynamics

Prerequisite: Math 215, Chem 125/130, Physics 140/141. I, II (4 credits)

An introduction to gas dynamics, covering fundamental concepts in thermodynamics and fluid dynamics. Topics include molecular and continuum concepts for fluids, first and second laws of thermodynamics, conservation laws for moving fluids, one-dimensional compressible flows, shocks and expansion waves, flows in nozzles, and two- and three-dimensional compressible flows.

Aero 245. Performance of Aircraft and Spacecraft

Prerequisite: preceded by Engr 100, Engr 101, Physics 140/141, and Math 116. I, II (4 credits)

An introduction to the aerospace field. Introduces students to steady motion of aircraft and spacecraft and to methods for evaluating performance of aircraft and spacecraft systems. Students learn basic aerodynamics, propulsion, and orbital mechanics. Involves team projects that include written reports.

Aero 305. Aerospace Engineering Laboratory I

Prerequisite: preceded or accompanied by EECS 206 or 215 or EECS 314. Preceded by Aero 225 and Aero 215. I, II (4 credits)

First course of a two-semester sequence covering fundamentals of instrumentation and measurement and their application in engineering testing and experimentation. Includes principles of analog and digital data acquisition, analysis of discrete measurement data, statistical assessment of hypotheses, design of experiments, and similarity scaling of data. Emphasized development of skills for written communication and for working effectively in a team environment.

Aero 315. Aircraft and Spacecraft Structures

Prerequisite: preceded by Aero 215 and Math 216. I, II (4 credits)

Concepts of displacement, strain, stress, compatibility, equilibrium, and constitutive equations as used in solid mechanics. Emphasis is on boundary-value problem formulation via simple examples, followed by the use of the finite-element method for solving problems in vehicle design.

Aero 325. Aerodynamics

Prerequisite: preceded by Math 216 and Aero 225. I, II (4 credits)

Fundamental concepts in aerodynamics. Students learn how airfoils produce lift and how the pressure distribution about an airfoil can be calculated. Introduces the boundary-layer concept, how boundary layers lead to drag, and what makes them prone to instability and turbulence or separation. Effects of the wing planform shape on lift and drag. Introduction to airfoil design, high-lift devices and high-speed aerodynamics.

Aero 335. Aircraft and Spacecraft Propulsion

Prerequisite: preceded by Aero 225 and Math 216. I, II (4 credits)

Airbreathing propulsion, rocket propulsion, and an introduction to modern advanced propulsion concepts. Includes thermodynamic cycles as related to propulsion and the chemistry and thermodynamics of combustion. Students analyze turbojets, turbofans and other air-breathing propulsion systems. Introduces liquid- and solid-propellant rockets and advanced propulsion concepts such as Hall thrusters and pulsed plasma thrusters. Students also learn about the environmental impact of propulsion systems and work in teams to design a jet engine.

Aero 345. Flight Dynamics and Control

Prerequisite: preceded by Math 216, Aero 245, and ME 240. I, II (4 credits)

An introduction to dynamics and control of aircraft. Introduces concepts from linear systems theory (state equations, transfer functions, stability, time and frequency response). Aircraft longitudinal and lateral flight dynamics and control systems.

Aero 351. Computational Methods in Aerospace Vehicle Analysis and Design

Prerequisite: Aero 245, Math 216. I (3 credits)

Students learn to use computational methods for solving problems in aerospace engineering, in the areas of aerodynamics, structures, flight mechanics, and propulsion. Lectures cover the engineering analysis and design methods, basic numerical methods, and programming techniques necessary to solve these problems.

Aero 384. Introduction to Solid Modeling and CAD

Prerequisite: preceded or accompanied by Aero 245, 215. I (3 credits)

Design process including specifications, configurations, trades, and design drivers. Introduction to solid visualization and modeling through an integrated CAD/CAE/CAM/PDM software package in the context of the design process. The role of CAD in analysis, manufacturing, and product management. Flight vehicle related projects.

Aero 385. Contemporary Aerospace Issues

Prerequisite: preceded or accompanied by Aero 245. I (1 credit)

A series of seminars by noted speakers, designed to acquaint undergraduates with contemporary technology and the aerospace industry. Involves a short term project or paper pertinent to one of the seminar topics.

Aero 390. Directed Study (to be arranged)

Individual study of specialized aspects of aerospace engineering.

Aero 405. Aerospace Laboratory II

Prerequisite: preceded by Aero 305. Preceded or accompanied by Aero 315 and Aero 325. I, II (4 credits)

Second course of a two-semester sequence covering fundamentals of instrumentation and measurement and their application in engineering testing and experimentation. Focuses primarily on application of the fundamental principles learned in Aero 305 to more advanced test and measurement applications. Involves instructor-designed experiments and one major project conceived, designed, conducted, analyzed, and reported by student teams. Emphasizes development of skills for written communication and for working effectively in a team environment.

Aero 416 (NA 416). Theory of Plates and Shells
Prerequisite: Aero 315. II alternate years (3 credits)
Linear elastic plates. Membrane and bending theory of axisymmetric and non-axisymmetric shells.
Variational formulation of governing equations boundary conditions. Finite element techniques for plate and shell problems.
Aero 421. Engineering Aerodynamics
Prerequisite: Aero 325. II alternate years (3 credits)
This course teaches contemporary aerodynamic analysis and design of aerospace vehicles and other systems. Topics include: review of theoretical concepts and methods, computer-based CFD tools, experimental methods and wind tunnel testing. Case studies are discussed to illustrate the combined use of advanced aerodynamic design methods. A team project is required.
Aero 445. Flight Dynamics of Aerospace Vehicles
Prerequisite: Aero 345. II (3 credits)
Flight-oriented models of aerospace vehicles. Analytical modeling principles, parameter identification methods. Open- and closed-loop control for command following and stabilization. Computer-based simulation, performance evaluation, and model validation. Flight properties of representative aerospace vehicles, including fixed-wing aircraft, rotorcraft, launch and reentry vehicles, orbiters, and interplanetary vehicles.
Aero 447. Flight Testing
Prerequisite: Aero 305 and Aero 345. II (3 credits)
Theory and practice of obtaining flight-test data on performance and stability of airplanes from actual flight tests. Modern electronic flight test instrumentation, collection of flight test data, calibration procedures for air data sensors, estimation of stability derivatives from flight test data. Lectures and laboratory.
Aero 464 (AOSS 464) (ENSCEN 464). The Space Environment
Prerequisite: senior or graduate standing in a physical science or engineering. I (3 credits)
An introduction to physical and aeronomical processes in the space environment. Discussion of theoretical tools, the Sun, solar spectrum, solar wind, interplanetary magnetic field, planetary magnetosphere, ionospheres and upper atmospheres. Atmospheric processes, densities, temperatures, and wind.
Aero 481. Aircraft Design
Prerequisite: Aero 315, Aero 325, required, Aero 335 and Aero 345 can be concurrent. I (4 credits)
Multidisciplinary integration of aerodynamics, performance, stability and control, propulsion, structures and aeroelasticity in a system approach aimed at designing an aircraft for a set of specifications. Includes weight estimates, configuration and power plant selection, tail-sizing, maneuver and gust diagrams, wing loading, structural and aeroelastic analysis. Students work in teams on the design project.
Aero 483. Space System Design
Prerequisite: preceded by Aero 345. Preceded or accompanied by Aero 315, 325, and 335. II (4 credits)
Introduction to the engineering design process for space systems. Includes a lecture phase that covers mission planning, launch vehicle integration, propulsion, power systems, communications, budgeting, and reliability. Subsequently, students experience the latest practices in space-systems engineering by forming into mission-component teams and collectively designing a space mission. Effective team and communication skills are emphasized. Report writing and presentations are required throughout, culminating in the final report and public presentation.
Aero 484. Computer Aided Design
Prerequisite: preceded by Aero 315, Aero 325, Aero 335, and Aero 345. I (4 credits)
Advanced computer-aided design. Students learn about computer generation of geometric models, calculation of design parameters, trade-off diagrams, and finite-element modeling and analysis. Each student carries out a structural component design using industry-standard software. The course includes individual and team assignments.
Aero 490. Directed Study (to be arranged)
Individual study of specialized aspects of aerospace engineering. Primarily for undergraduates.
Aero 495. Special Topics in Aerospace Engineering
Prerequisite: permission of instructor. Term offered depends on special topic (to be arranged).
Aero 495. Special Topics in Aerospace Engineering
Prerequisite: permission of instructor. Term offered depends on special topic (to be arranged).
Aero 510. Finite Elements in Mechanical and Structural Analysis I
Prerequisite: Aero 315. I (3 credits)
Introductory level. Finite element solutions for structural dynamics and nonlinear problems. Normal modes, forced vibrations, Euler buckling (bifurcations), large deflections, nonlinear elasticity, transient heat conduction. Computer laboratory based on a general purpose finite element code.
Aero 511. Finite Elements in Mechanical and Structural Analysis II
Prerequisite: Aero 510 or ME 505. II (3 credits)
Intermediate level. Finite element solutions for structural dynamics and nonlinear problems. Normal modes, forced vibration, Euler buckling (bifurcation), large deflections, nonlinear elasticity, transient heat conduction. Computer laboratory based on a general purpose finite element code.
Aero 512. Experimental Solid Mechanics
Prerequisite: Aero 305, Aero 315 or equivalents. II (3 credits)
Lectures and experiments that demonstrate historical and contemporary methods of measurement in solid mechanics. A review of classical experiments that substantiate many typical assumptions (e.g., material linearity or Hooke's Law) concerning the response of solids. An introduction to contemporary techniques of process measurement involving piezoresistivity.

Aero 513. Foundations of Solid and Structural Mechanics I
Prerequisite: Aero 315, ME 311 or equivalent. I (3 credits)
Introduction to linear continuum and structural mechanics. Three-dimensional analysis of stress and infinitesimal strain, including transformation of tensors, equations of motion, and kinematic compatibility. Boundary value problem formation. Constitutive relations for isotropic and anisotropic linear elastic materials. Introduction to variational calculus and energy methods. Applications to thin-walled and slender aerospace structures.

Aero 514. Foundations of Solid and Structural Mechanics II
Prerequisite: Aero 315 or equivalent. II (3 credits)
Introduction to nonlinear continuum and structural mechanics. Elements of tensor calculus, basic kinematics, conservation laws (mass, linear and angular momentum, energy, etc.), constitutive equations in continual applications in hyperelastic solids, numerical (f.e.m.) methods for the corresponding nonlinear boundary value problems, derivation of nonlinear shell theories from 3-D considerations.

Aero 515. Mechanics of Composite and Microstructured Media
Prerequisite: Aero 514 or equivalent. I (3 credits)
An introduction to the mechanics of composite (more than one phase) solids with an emphasis on the derivation of macroscopical constitutive laws based on the microstructure. Eshelby transformation theory, self consistent methods, homogenization theory for periodic media, bounding properties for effective moduli of composites. Applications of aerospace interest.

Aero 516. Mechanics of Fibrous Composites
Prerequisite: Aero 315 or ME 412. I (3 credits)
Effective stiffness properties of composites. Constitutive description of laminated plates. Laminated plate theory. Edge effects in laminates. Nonlinear theory of generally laminated plates. Governing equations in the Von Karman sense. Laminated plates with moderately large deflections. Postbuckling and nonlinear vibration of laminated plates. Failure theories and experimental results for laminates.

Aero 518. Theory of Elastic Stability I
Prerequisite: Aero 315 or ME 412 or the equivalent. II (3 credits)
Concepts of stability and bifurcation. Simple examples to illustrate buckling and instability mechanisms in structures. Both equilibrium and time dependent problems discussed. General theory for stability in continuum, conservative elastic solids. Applications to bars, rings, plates and shells.

Aero 520. Compressible Flow I
Prerequisite: Aero 325. I (3 credits)
Elements of inviscid compressible-flow theory: review of thermodynamics; equations of frictionless flow; analysis of unsteady one-dimensional and steady supersonic two-dimensional flows; including the method of characteristics; small-disturbance theory with applications to supersonic thin-airfoil theory.

Aero 521. Experimental Methods in Fluid Mechanics
Prerequisite: Aero 405 or Grad standing. II (3 credits)
Fundamental principles and practice of non-intrusive measurement techniques for compressible and incompressible flows. Review of geometric and Gaussian beam optics; Laser Doppler Velocimentry; quantitative flow field measurement techniques including interferometry, Laser induced Fluorescence and Particle Image Velocimetry. Advanced data processing techniques for turbulent flow. Error estimation. Lecture and laboratory.

Aero 522. Viscous Flow
Prerequisite: Aero 325. I (3 credits)
The Navier-Stokes equations, including elementary discussion of tensors; exact solutions. Laminar boundary-layer theory; three-dimensional and compressible boundary layers. Laminar-flow instability theory; transition. Introduction to the mechanics of turbulence; turbulent free shear flows and boundary layers.

Aero 523 (ME 523). Computational Fluid Dynamics I
Prerequisite: Aero 325 or preceded or accompanied by ME 520. I (3 credits)
Physical and mathematical foundations of computational fluid mechanics with emphasis on applications. Solution methods for model equations and the Euler and the Navier-Stokes equations. The finite volume formulation of the equations. Classification of partial differential equations and solution techniques. Truncation errors, stability, conservation, and monotonicity. Computer projects and homework.

Aero 524. Aerodynamics II
Prerequisite: Aero 325. II (3 credits)
Two- and three-dimensional potential flow about wings and bodies; complex-variable methods; singularity distributions; numerical solution using panel methods. Unsteady aerodynamics; slender-body theory. Viscous effects: airfoil stall, high-lift systems, boundary-layer control. Wings and bodies at transonic and supersonic speeds; numerical methods.

Aero 525. Introduction to Turbulent Flows
Prerequisite: Aero 522. II (3 credits)
Mathematical description of turbulent flow phenomena. Flow equations, vorticity dynamics, Reynolds-averaged equations, engineering turbulence models. Theory of homogeneous turbulence, spectral dynamics. Shear flow turbulence, mean and fluctuating structure of free and wall-bounded turbulent flows.

Aero 526. Hypersonic Aerothermodynamics
Prerequisite: Graduate standing or Aero 225 and Aero 325. I (3 credits)
Hypersonic vehicles offer rapid air transportation and access to space. This course provides an introduction to the aerothermodynamics of hypersonic vehicles. Topics covered include: vehicle types (missiles, space planes, air-breathers); flight dynamics (trajectory, range, stability); aerothermodynamics (fluid dynamics, thermodynamics, aerodynamics, heating); and propulsion systems (scramjets, combined cycles).

Aero 530. Gas-Turbine Propulsion
Prerequisite: Aero 335 II (3 credits)
Advanced analysis of turbojet engines: effect of altitude parameters on engine performance; off-design equilibrium running of a turbojet engine; dynamics of engine considered as a quasi-static system; fluid mechanics of a rotating axial blade row; centrifugal compressors; transonic flow problems.
Aero 532. Molecular Gas Dynamics
Prerequisite: permission of instructor. II (3 credits)
Analysis of basic gas properties at the molecular level. Kinetic theory: molecular collisions, the Boltzmann equation. Maxwellian distribution function. Quantum mechanics: the Schrodinger equation, quantum energy states for translation, rotation, vibration, and electronic models of atoms and molecules. Statistical mechanics: the Boltzmann relation, the Boltzmann energy distribution, partition functions. These ideas are combined for the analysis of a chemically reacting gas at the molecular level.
Aero 533 (ENSCEN 533). Combustion Processes
Prerequisite: Aero 225. (3 credits)
This course covers the fundamentals of combustion systems, and fire and explosion phenomena. Topics covered include thermochemistry, chemical kinetics, laminar flame propagation, detonations and explosions, flammability and ignition, spray combustion, and the use of computer techniques in combustion problems.
Aero 535. Rocket Propulsion
Prerequisite: Aero 335. I (3 credits)
Analysis of liquid and solid propellant rocket powerplants; propellant thermochemistry, heat transfer, system considerations. Low-thrust rockets, multi-stage rockets, trajectories in powered flight, electric propulsion.
Aero 536. Electric Propulsion
Prerequisite: Aero 335, senior standing. I (3 credits)
Introduction to electric propulsion with an overview of electricity and magnetism, atomic physics, non-equilibrium flows and electrothermal, electromagnetic, and electrostatic electric propulsion systems.
Aero 540 (ME 540). Intermediate Dynamics
Prerequisite: ME 240. I (3 credits)
Newton/Euler and Lagrangian formulations for three dimensional motion of particles and rigid bodies. Principles of dynamics applied to various rigid-body and multi-body dynamics problems that arise in aerospace and mechanical engineering.
Aero 543. Structural Dynamics
Prerequisite: Aero 315 or Aero 540. (3 credits)
Natural frequencies and mode shapes of elastic bodies. Nonconservative elastic systems. Structural and viscous damping. Influence coefficient methods for typical flight structures. Response of structures to random and shock loads. Lab demonstration.
Aero 544. Aeroelasticity
Prerequisite: Aero 315 or Aero 540. (3 credits)
Introduction to aeroelasticity. Vibration and flutter of elastic bodies exposed to fluid flow. Static divergence and flutter of airplane wings. Flutter of flat plates and thin walled cylinders at supersonic speeds. Oscillations of structures due to vortex shedding.
Aero 545. Principles of Helicopter and V/STOL Flight
Prerequisite: preceded or accompanied by Aero 325. I (3 credits)
Introduction to helicopter performance, aerodynamics, stability and control, vibration and flutter. Other V/STOL concepts of current interest.
Aero 548. Astrodynamics
Prerequisite: Aero 345. II (3 credits)
Review of two-body problem for spacecraft: orbital trajectories, transfers, targeting, and time of flight. Orbit perturbation formulations and analysis. Restricted 3-body problem and applications.
Aero 550 (EECS 560) (ME 564). Linear Systems Theory
Prerequisite: graduate standing. I (4 credits)
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability.
Aero 551 (EECS 562). Nonlinear Systems and Control
Prerequisite: graduate standing. II (3 credits)
Introduction to the analysis and design of nonlinear systems and nonlinear control systems. Stability analysis using Liapunov, input-output and asymptotic methods. Design of stabilizing controllers using a variety of methods: linearization, absolute stability theory, vibrational control, sliding modes and feedback linearization.
Aero 565. Optimal Structural Design
Prerequisite: Aero 315, a course in advanced calculus. II (3 credits)
Optimal design of structural elements (bars, trusses, frames, plates, sheets) and systems; variational formulation for discrete and distributed parameter structures; sensitivity analysis; optimal material distribution and layout; design for criteria of stiffness, strength, buckling, and dynamic response.
Aero 573. Dynamics and Control of Spacecraft
Prerequisite: Aero 345. I (3 credits)
Introduction to spacecraft dynamics and control. Spacecraft orbit and attitude representations, kinematics, dynamics. Perturbation equations for near circular orbits. Spacecraft maneuvers formulated and solved as control problems.

Aero 575. Flight and Trajectory Optimization
Prerequisite: Aero 345. I (3 credits)
Formulation and solution of optimization problems for atmospheric flight vehicles and space flight vehicles. Optimality criteria, constraints, vehicle dynamics. Flight and trajectory optimization as problems of nonlinear programming, calculus of variations, and optimal control. Algorithms and software for solution of flight and trajectory optimization problems.
Aero 579. Control of Structures and Fluids
Prerequisite: Aero 345. II (3 credits)
Stabilization and vibration suppression for structures and fluids. Control-oriented modeling of structural and acoustic dynamics. Fixed-gain and adaptive control methods. Control-oriented fluid dynamics for compressible and incompressible fluids. Feedback stabilization of laminar flow, rotating surge and stall.
Aero 580 (EECS 565). Linear Feedback Control Systems
Prerequisite: EECS 460 or Aero 345 or ME 461 and Aero 550 (EECS 560). II (3 credits)
Control design concepts for linear multivariable systems. Review of single variable systems and extensions to multivariable systems. Purpose of feedback. Sensitivity, robustness, and design trade-offs. Design formulations using both frequency domain and state space descriptions. Pole placement/observer design. Linear quadratic Gaussian based design methods. Design problems unique to multivariable systems.
Aero 581 (AOSS 581). Space System Management
Prerequisite: graduate standing. I (3 credits)
The first part of the course will offer a comprehensive introduction to modern management methods used in large projects. The second part will concentrate on successful management examples of complex space projects. This course will usually be taught by adjunct faculty with extensive experience in successful management of large space projects.
Aero 582 (AOSS 582). Spacecraft Technology
Prerequisite: Graduate standing. I (4 credits)
Systematic and comprehensive review of spacecraft and space mission design and key technologies for space missions. Discussions on project management and the economic and political factors that affect space missions. Specific space mission designs are developed in teams. Students of AERO 483/583 choose their projects based on these designs.
Aero 583. Management of Space Systems Design
Prerequisite: graduate standing. II (4 credits)
Meets with Aero 483 (Space System Design), or other senior design course when appropriate topic is chosen. Students in this course lead teams in high level project design of a space system. Modern methods of concurrent engineering manufacturing, marketing and finance, etc., are incorporated.
Aero 584. Avionics, Navigation and Guidance of Aerospace Vehicles
Prerequisite: Aero 345. II (3 credits)
Principles of avionics, navigation and guidance. Deterministic and stochastic linear perturbation theory. Position fixing and celestial navigation with redundant measurements. Recursive navigation and Kalman filtering. Pursuit guidance, proportional navigation, ballistic guidance and velocity-to-be-gained guidance. Hardware mechanization.
Aero 585. Aerospace Engineering Seminar I (1 credit)
A series of seminars by noted speakers designed to acquaint graduate and undergraduate students with contemporary research and technological issues in the aerospace industry. Involves a short term paper pertinent to one of the seminar topics.
Aero 590. Directed Study
(to be arranged)
Individual study of specialized aspects of aerospace engineering. Primarily for graduates.
Aero 592. Space Systems Projects
Prerequisite: senior or graduate standing. (3-5 credits)
Industry related team project for students enrolled in Master of Engineering in Space Systems degree program. Student teams will conduct aerospace related projects in conjunction with an industry or government partner.
Aero 595. Seminar
Prerequisite: senior or graduate standing. (1-3 credits)
Speakers will emphasize systems engineering, manufacturing, team building practices, business and management, and other topics which broaden the student's perspective. Mandatory for all Master of Engineering in Aerospace Engineering students; open to all seniors and graduate students.
Aero 596. Projects
Prerequisite: graduate standing in Master of Engineering program. (3-5 credits)
Industrial related team project for students enrolling in Master of Engineering degree program. Student teams will conduct design projects for and in conjunction with industrial or government customer.
Aero 597 (AOSS 597). Fundamentals of Space Plasma Physics
Prerequisite: senior-level statistical physics course. II (3 credits)
Basic plasma concepts, Boltzmann equation, higher order moments equations, MHD equations, double adiabatic theory. Plasma expansion to vacuum, transonic flows, solar wind, polar wind. Collisionless shocks, propagating and planetary shocks. Fokker-Planck equation, quasilinear theory, velocity diffusion, cosmic ray transport, shock acceleration. Spacecraft charging, mass loading.

Aero 611. Advanced Topics in Finite Element Structural Analysis
Prerequisite: Aero 511 or ME 605. I (3 credits)
Cyclic symmetry, design sensitivities and optimization. Applications to stress analysis, vibration, heat conduction, centrifugal effects, buckling. Introduction to high-level matrix-oriented programming languages (e.g., Direct Matrix Abstraction Program). Use of a large, general purpose finite element code as a research tool.
Aero 614. Advanced Theory of Plates and Shells
Prerequisite: Aero 416. II alternate years (3 credits)
Differential geometry of surfaces. Linear and nonlinear plate and shell theories in curvilinear coordinates. Anisotropic and laminated shells. Stability and post-buckling behavior. Finite element techniques, including special considerations for collapse analysis.
Aero 615 (CEE 617) (ME 649). Random Vibrations
Prerequisite: Math 425 or equivalent, CEE 513 or ME 541 or Aero 543 or equivalent. II alternate years (3 credits)
Introduction to concepts of random vibration with applications in civil, mechanical, and aerospace engineering. Topics include: characterization of random processes and random fields, calculus of random processes, applications of random vibrations to linear dynamical systems, brief discussion on applications to nonlinear dynamical systems.
Aero 618. Theory of Elastic Stability II
Prerequisite: Aero 518 or equivalent and graduate standing. II (3 credits)
Koiter's theory for buckling, post-buckling, mode interaction and imperfection sensitivity behavior in nonlinear solids. Applications to thin-walled beams, cylindrical and spherical shells as well as to 3-D hyperelastic solids. Loss of ellipticity in finitely strained solids. Hill's theory on bifurcation, uniqueness and post-bifurcation analysis in elastic-plastic solids with applications.
Aero 623. Computational Fluid Dynamics II
Prerequisite: Aero 523 or equivalent, substantial computer programming experience, and Aero 520. II (3 credits)
Advanced mathematical and physical concepts in computational fluid dynamics, with applications to one- and two-dimensional compressible flow. Euler and Navier-Stokes equations, numerical flux functions, boundary conditions, monotonicity, marching in time, marching to a steady state, grid generation.
Aero 625. Advanced Topics in Turbulent Flow
Prerequisite: Aero 525. II (3 credits)
Fundamentals of turbulent shear flows, with emphasis on dimensional reasoning and similarity scaling. Development of laminar shear flows, instability and transition to turbulent flow, kinetic and scalar energy transport mechanisms in turbulent shear flows, critical examination of numerical methods for turbulent flows, comparisons with experiments.
Aero 627. Advanced Gas Dynamics
Prerequisite: Aero 520, Aero 522. I (3 credits)
Linear and nonlinear surface waves. Flow instabilities; nonlinear stability analysis. Vorticity dynamics: vortex motions, instabilities, and breakdown. Boundary layers: steady and unsteady interactions; nonlinear instability.
Aero 633. Advanced Combustion
Prerequisite: Aero 533. II (3 credits)
Thermodynamics of gas mixtures, chemical kinetics, conservation equations for multi-component reacting gas mixtures, deflagration and detonation waves. Nozzle flows and boundary layers with reaction and diffusion.
Aero 714. Special Topics in Structural Mechanics
Prerequisite: permission of instructor. Term offered depends on special topic (to be arranged)
Aero 729. Special Topics in Gas Dynamics
Prerequisite: permission of instructor (to be arranged)
Advanced topics of current interest.
Aero 740. Special Topics in Flight Dynamics and Control Systems
(to be arranged)
Aero 800. Seminar
(to be arranged)
Aero 810. Seminar in Structures
(to be arranged)
Aero 820. Seminar in Aerodynamics
(to be arranged)
Aero 830. Seminar in Propulsion
(to be arranged)
Aero 840. Dynamics and Control Systems
(to be arranged)
Aero 850. Space Systems Seminar, Mandatory
Satisfactory/unsatisfactory. I (1-3 credits)
Participating students, faculty, and invited speakers give seminars about selected space engineering related topics. The speakers will emphasize systems engineering, management, and operations of complex space systems.
Aero 990. Dissertation/Pre-Candidate
I, II (2-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
Aero 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Aerospace Engineering Faculty

Department Office
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Wei Shyy, Ph.D., *Clarence L. "Kelly" Johnson Collegiate Professor of Aerospace Engineering and Chair*

Professors

Dennis S. Bernstein, Ph.D.
Iain D. Boyd, Ph.D.
Werner J.A. Dahm, Ph.D.
James F. Driscoll, Ph.D
Peretz P. Friedmann, Sc.D., *François-Xavier Bagnoud Professor of Engineering*
Alec D. Gallimore, Ph.D.; *also Associate Dean for Academic Programs and Initiatives; Rackham School of Graduate Studies, Arthur F. Thurnau Professor*
Tamas I. Gombosi, Ph.D.; *also Atmospheric, Oceanic and Space Sciences Professor and Chair*
Pierre T. Kabamba, Ph.D.; *also Electrical Engineering and Computer Science*
C. William Kauffman, Ph.D.
N. Harris McClamroch, Ph.D.; *also Electrical Engineering and Computer Science*
Kenneth G. Powell, Sc.D., *Arthur F. Thurnau Professor*
Philip L. Roe, B.A.
Nicolas Triantafyllidis, Ph.D.
Bram van Leer, Ph.D.
Anthony M. Waas, Ph.D.
Margaret S. Wooldridge, Ph.D., *also Mechanical Engineering*
Thomas H. Zurbuchen, Ph.D., *also Atmospheric, Oceanic and Space Sciences*

Adjunct Professor

Jack R. Lousma, B.S.E., Hon. Ph.D.
Elaine S. Oran, Ph.D.

Professors Emeritus

Thomas C. Adamson, Jr., Ph.D.
William J. Anderson, Ph.D.
Frederick L. Bartman, Ph.D.; *also Atmospheric, Oceanic and Space Sciences*
Frederick J. Beutler, Ph.D.; *also Electrical Engineering and Computer Science*
Harm Buning, M.S.E.
Joe G. Eisley, Ph.D.
Elmer G. Gilbert, Ph.D.
Donald T. Greenwood, Ph.D.
Paul B. Hays, Ph.D., *Dwight F. Benton Professor of Advanced Technology; also Atmospheric, Oceanic and Space Sciences*
Robert M. Howe, Ph.D.
Vi-Cheng Liu, Ph.D.
Arthur F. Messiter, Jr., Ph.D.
James A. Nicholls, Ph.D.
Richard L. Phillips, Ph.D.
Lawrence L. Rauch, Ph.D.
William L. Root, Ph.D.; *also Electrical Engineering and Computer Science*
Pauline M. Sherman, M.S.
Martin Sichel, Ph.D.
Nguyen X. Vinh, Ph.D., Sc.D.

Associate Professors

Ella M. Atkins, Ph.D.
Luis P. Bernal, Ph.D.
Carlos E. Cesnik, Ph.D.
Daniel J. Scheeres, Ph.D.
John A. Shaw, Ph.D.
Peter D. Washabaugh, Ph.D

Assistant Professor

Anouk R. Girard, Ph.D.

Lecturer

Donald M. Geister, M.S.E.; *also Mechanical Engineering*

Atmospheric, Oceanic and Space Sciences Undergraduate Education

Undergraduate Program Advisor
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Degree Program
Earth System Science Engineering (ESSE) is a joint program between AOSS and the LSA Department of Geological Sciences. ESSE students begin to understand the interactions among all of the Earth system components while gaining in-depth knowledge in one of three concentrations: Meteorology, Climate Physics or Space Weather.

The B.S.E. degree in AOSS prepares graduates for employment in the National Weather Service, private weather forecasting companies, air- and water-quality management firms, and NASA. As importantly, ESSE students who complete Space Weather, Meteorology or Climate Physics concentrations will be exceptionally well prepared for graduate studies in atmospheric science, space science or space engineering.

In addition to the College of Engineering core courses, all AOSS undergraduate students take four ESSE core courses (17 credit hours) plus five AOSS-ESSE core courses (20 credit hours) that introduce the various aspects of atmospheric, oceanic and space sciences, emphasizing the common elements of, and the interactions between, the various disciplines and the scientific basis of the phenomena that are observed. An additional three courses (12 credit hours) are specific to the concentration area and 24 credit hours are split between technical and unrestricted electives. The electives must be at the 300 level or above. Completion of a concentration will be noted on the student's transcript.

Sequential Graduate/Undergraduate Study (SGUS)
In our increasingly technical world, master's degrees are becoming the minimum accepted level of education in the industry. AOSS SGUS programs are designed to provide a comprehensive knowledge of atmospheric/space sciences or space engineering and to increase your depth of knowledge beyond the baccalaureate degree level. The SGUS program offers breadth, depth and hands-on experience in both areas of concentration. Students interested in completing their undergraduate and master's level education in five years may select either the SGUS in Atmospheric/Space Science or the SGUS in Space Engineering.

Each of the degrees (BSE and MS or MEng) is awarded upon completion of the requirements. Students will typically enter the SGUS program by provisional enrollment in the junior year. Once SGUS students are within six credit hours of completing the required undergraduate degree, they must officially enroll in the AOSS M.S. program for a minimum of two full terms, normally the last two semesters, and pay full graduate tuition for these two terms. Students are allowed to "double count" a certain number of credit hours for the two degrees.

SGUS in Atmospheric/Space Science
Students interested in studying the phenomena that occur in the Earth's atmosphere or deeper into space may select either the Atmospheric Science concentration or the Space Science concentration. The program is designed to provide a comprehensive knowledge of atmospheric or space science and the various components of each system. Students enjoy extensive computational facilities as well as laboratories for measurement of the chemical and physical properties of the atmosphere and space weather.

SGUS in Space Engineering
For students interested in studying the scientific, engineering and management aspects of space engineering, this program, developed with Aerospace Engineering and Electrical Engineering and Computer Science, allows them to structure the program to a specific area of interest. The program is designed to provide a comprehensive knowledge of space science and engineering and their interrelationship; to teach the systems approach to conceiving, designing, manufacturing, managing and operating complex space systems; and to provide practical experience in space system design, project development and management. Eight program concentrations are currently available: Space Science; Propulsion; Plasma Electrodynamics and Sensors; Instrumentation and Sensor Payloads; Launch Vehicles; Telemetry and Spacecraft Communication; Astrodynamics; and Computer Control and Data Handling.
The most up-to-date information on the AOSS SGUS programs, including example concentration course schedules is available at http://aoss.engin.umich.edu/go/index.php?id1=11&id2=2&id3=2. Or, for more information, contact Margaret Reid at aoss.um@umich.edu.

Sample ScheduleB.S.E. Earth System Science and Engineering

Credit Hours		Terms							
		1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 11+, 116, 215, and 216	16	4	4	4	4	–	–	–	–
Engr 100, Intro to Engr	4	4	–	–	–	–	–	–	–
Engr 101, Intro to Computers	4	–	4	–	–	–	–	–	–
Chemistry 125/126 and 130 or Chemistry 210/2111	5	5	–	–	–	–	–	–	–
Physics 140/141; 240/241 2	10	–	5	5	–	–	–	–	–
Humanities and Social Sciences	16	4	4	4	4	–	–	–	–
Required Subjects (36 hrs.)									
AOSS 320, Earth System Evolution	4	–	–	4	–	–	–	–	–
AOSS 321, Earth System Dynamics	4	–	–	–	4	–	–	–	–
EECS 206, Signals and Systems I	4	–	–	–	4	–	–	–	–
AOSS 350, Atmospheric Physics I	4	–	–	–	–	4	–	–	–
AOSS 401, Geophysical Fluid Dynamics	4	–	–	–	–	4	–	–	–
AOSS 380, Atmospheric Physics II	4	–	–	–	–	–	4	–	–
Meteorology and Climate Physics Concentrations: 3StatsSpace Weather Concentration:Math 450, Advanced Mathematics for Engineers I	4	–	–	–	–	–	4	–	–
AOSS 410, Earth System Modeling	4	–	–	–	–	–	–	4	–
AOSS 475, Earth-Ocean-Atmosphere Interactions	4	–	–	–	–	–	–	–	4
Concentrations: (select one)									
Climate Physics: (37 hrs.)									
AOSS 450, Geophysical ElectroMagnetics	4	–	–	–	–	–	–	4	–
AOSS 470, Solar Terrestrial Interactions	4	–	–	–	–	–	–	–	4
Technical Electives	20	–	–	–	–	4	4	4	8
Unrestricted Electives	9-12	–	–	–	–	3	3	3	–
Meteorology: (37 hrs.)									
AOSS 414, Weather Systems	3	–	–	–	–	–	–	3	–
AOSS 462, Instrumentation for Atmos & Space Sciences	4	–	–	–	–	–	–	–	4
AOSS 440, Meteorological Analysis Laboratory	4	–	–	–	–	–	–	–	4
Technical Electives	16	–	–	–	–	4	4	4	4
Unrestricted Electives	10-13	–	–	–	–	3	3	4	–
Space Weather: (37 hrs.)									
AOSS 450, Geophysical ElectroMagnetics	4	–	–	–	–	–	–	4	–
AOSS 470, Solar Terrestrial Interactions	4	–	–	–	–	–	–	–	4
AOSS 495, Thermosphere & Ionosphere	4	–	–	–	–	–	–	–	4
ENG 450, Multidisciplinary Design	4	–	–	–	–	–	–	–	4
Technical Electives	12	–	–	–	–	4	4	4	–
Unrestricted Electives	9-12	–	–	–	–	3	3	3	–
Total\	128	17	17	17	16	15	15	15	16

Candidates for the Bachelor of Science degree in Engineering (Earth System Science and Engineering) — B.S.E (E.E.S.E.)— must complete the classes listed above. The schedule above is an example of one leading to graduation in eight terms.

Notes:

1If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

2If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.3

Stats 412, Introduction to Probability and Statistics (3 credits) or IOE 265, Probability and Statistics for Engineers (4 credits).

Atmospheric, Oceanic, and Space Sciences

Meteorology Concentration
Graduates with a concentration in Meteorology will be prepared for careers in weather forecasting, industries that are increasingly the source of weather analyses and predictions modeling, and for graduate studies in meteorology and the technologies that enable weather and climate prediction.
Required (12 credit hours):
- Mid Latitude Cyclones (4)
- Meteorological Instrumentation (4)
- Meteorological Analysis Laboratory (4)

Students electing this concentration are encouraged to complete an internship in a weather forecasting office.

Climate Physics Concentration
Graduates with a Climate Physics concentration will be prepared for careers in engineering that increasingly provide the water resource, agricultural, seasonal recreation and transportation industries with near-term climate analyses and predictions, and for graduate studies involving the technologies that enable weather and climate prediction.
Required (12 credit hours):
- EM Waves and Radiation (4)
- Earth-Ocean-Atmosphere Interactions (4)
- Solar-Terrestrial Interaction (4)

Space Weather Concentration
Graduates with a Space Weather concentration will be prepared to join the space industry, which is facing a severe workforce shortage. They can also join government agencies and federal laboratories that deal with space related disciplines.
Required (12 credit hours):
- EM Waves and Radiation (4)
- Solar-Terrestrial Interaction (4)
- Upper Atmosphere and Ionosphere (4)

Atmospheric, Oceanic and Space Sciences Graduate Education

Graduate Program Advisor
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Graduate Degrees
- Master of Engineering (M.Eng.) in Space Engineering
- Master of Science (M.S.) in Atmospheric and Space Sciences
- Doctor of Philosophy (Ph.D.) in Atmospheric and Space Sciences
- Doctor of Philosophy (Ph.D.) in Geoscience and Remote Sensing
- Doctor of Philosophy (Ph.D.) in Space and Planetary Physics

M.Eng. in Space Engineering
The AOSS M.Eng. program in Space Engineering combines strong emphasis on both theoretical and applied aspects with extensive hands-on experience at all levels. The program is designed to develop students into a new type of interdisciplinary engineer prepared for future managerial and systems engineering roles in space related industries and government agencies.

If you are interested in studying the scientific, engineering and management aspects of space engineering, this program, developed with the Aerospace Engineering and Electrical Engineering and Computer Science Departments, allows you to structure the program to your specific area of interest.

Program Objectives
- To provide a comprehensive knowledge of space science and engineering and their interrelationship.
- To increase depth beyond the baccalaureate level in a space-related discipline.
- To teach the systems approach to conceiving, designing, manufacturing, managing, and operating complex space systems.
- To provide practical experience in space system design, project development and management.

Program Concentrations

While your specific concentration curriculum will be decided through discussions with your program advisors, suggested programs have been developed in the following areas:

- Space Science Program
- Propulsion Program
- Plasma Electrodynamics and Sensors Program
- Instrumentation and Sensor Payloads Program
- Launch Vehicles Program
- Telemetry and Spacecraft Communications Program
- Astrodynamics Program
- Computer Control and Data Handling Program

M.S. in Atmospheric and Space Sciences

Applicants to the master's program may have a bachelor's degree in any field of study, but they are expected to have completed minimum requirements in mathematics, physics and chemistry. Normally this would include five semesters of mathematics; eight credit hours of physics including two laboratories; and five credit hours of chemistry. Thirty semester hours are required for the master's degree, fifteen of which must be from the Department's offerings. A minimum of four additional hours must be in mathematics and/or natural science. A student will select a research topic if required in conjunction with an appropriate faculty member, who will guide the student in the preparation of both the research and the thesis or research essay. Satisfactory completion of the thesis or research essay will normally count for six credit hours of the total thirty hours required for the Master of Science degree.

Ph.D. in Atmospheric and Space Sciences
Ph.D. in Geoscience and Remote Sensing
Ph.D. in Space and Planetary Physics

Applicants for a doctorate are expected to have the ability and scholarship of a high order in one of the following areas: atmospheric science, space and planetary physics, or geoscience and remote sensing. Doctoral students are expected to carry a course load of nine to twelve semester hours (three to four courses) each semester until the dissertation work is begun. There are no foreign language requirements. During the first year, students must select courses from among the core courses for their particular program. After the second year, students must pass a qualifying examination before they can be advanced to candidacy. After reaching candidate status, students will concentrate on a dissertation topic under the guidance of an advisor.

Professor Thomas Zurbuchen (AOSS)
thomasz@umich.edu
Advisor, Ph.D. in AOSS

Ph.D. in Atmospheric and Space Sciences

This program gives students the basic courses to allow them to specialize later in a broad range of subdisciplines. Students are expected to learn the basic morphology of the atmosphere and the space environment, as well as the necessary physics, chemistry, and mathematics.

Ph.D. in Geoscience and Remote Sensing

Advisors, Ph.D. in Geoscience and Remote Sensing
Professor Christopher Ruf (AOSS)
cruf@umich.eduProfessor Anthony England (AOSS & EECS)
england@umich.eduProfessor Steven Wright (CEE)
sjwright@umich.edu

The AOSS/EECS/CEE Interdisciplinary Graduate Program in Geoscience and Remote Sensing leads to a degree with designated combined specialties in Atmospheric Science and electrical engineering, space science and electrical engineering or environmental science and electrical engineering.

Ph.D. in Space and Planetary Physics

Professor Tamas I. Gombosi (AOSS)
tamas@umich.edu
Professor Fred C. Adams (Physics)
fca@umich.edu
Advisors, Ph.D. in Space and Planetary Physics

The emphasis of this joint graduate degree program is on the physics of the heliosphere, planetary magnetospheres, ionospheres and upper atmospheres (including those of the Earth). The SPP program offers both Ph.D. and M.S. degrees.

The most up-to-date information on the AOSS graduate programs is available online at http://aoss.engin.umich.edu/grad/.

Research in AOSS

Atmospheric Research

AOSS provides an educational and research environment in which students examine a wide range of issues in the atmospheric sciences. Research interests of the faculty include: global climate change (emphasizing modeling of atmospheric and aerosol chemistry), regional and urban air pollution, chemical kinetics, radiative transfer, remote sensing, aerosol-cloud-climate interactions, and atmospheric dynamics. In addition, faculty are now developing a high-resolution computational framework for advanced climate simulation. Students enjoy extensive computational facilities as well as laboratories for measurement of the chemical and physical properties of the atmosphere. AOSS has an active seminar series that includes a series of Distinguished Lectures by experts from outside of the University of Michigan as well as a series of lectures by staff and students.

In addition, faculty members are extensively involved in observations of the Earth from space. They are involved in optical measurements from the Upper Atmosphere Research Satellite and the TIMED satellite, in microwave measurements from the TRMM satellite, and in ozone studies from the Total Ozone Mapping Spectrometer. AOSS faculty also participate in field campaigns, designing and integrating instruments on balloons, aircraft and sounding rockets to study the dynamics and composition of the atmosphere and the near-space environment of the Earth.

Planetary and Space Research

AOSS is known as a leading center for the study of the Earth, the planets, other objects, and plasma regions within and beyond the solar system. Faculty members are active in space instrumentation, data analysis, computer simulation, laboratory simulation, and theory. The associated Space Physics Research Laboratory (SPRL) has developed a strong reputation as one of the select few university centers able to design, construct, test and operate space flight instruments. AOSS faculty members emphasizing planetary science seek to understand the origin and evolution of the atmospheres of the planets, of their satellites, and of comets. Those faculty emphasizing plasma phenomena in space seek to understand the space environment, including the environment near the Earth where most satellites exist, the heliospheric environment produced by the sun, and some more distant space plasma systems.

SPRL has played a significant role in the U.S. Space Program since its founding in 1946, making it one of the first university-owned facilities in the world to participate in space research, beginning with work involving captured World War II V-2 rockets. Over the past five decades, SPRL faculty and engineers have designed and built more than 35 spaceborne instruments as well as numerous sounding rocket, balloon, aircraft, and ground-based instruments.

Recent research by AOSS faculty members has involved building instruments for and/or interpreting data from the Galileo Jupiter mission, the Hubble Space Telescope, the Cassini mission to Saturn and Titan and the Voyager missions. Projects involve the use of ever more advanced technologies. These include the Mercury Messenger mission, the development of advanced particle detectors and mass spectrometers, microwave detector systems, the TIMED Doppler Interferometer (TIDI), Space Tethers, and remote sensing research. AOSS provides a rich intellectual environment and a tremendous opportunity for students to learn through frequent interaction with a wide range of expert colleagues.

Atmospheric, Oceanic and Space Sciences Courses

AOSS 102 (Geol Sci 122) Extreme Weather
Prerequisite: none. I, II (3 credits)
This course provides an introduction to the physics of extreme weather events. The course uses examples of thunderstorms, jet stream, floods, lake-effect snowstorms, lightning, thunder, hail, hurricanes, and tornados to illustrate the physical laws governing the atmosphere. Participants apply these principles in hands-on storm forecasting and weather analysis assignments.

AOSS 105 (Chem 105) (ENSEN 105). Our Changing Atmosphere
Prerequisite: none. I, II (3 credits)
The science of the greenhouse effect, stratospheric ozone depletion, polar ozone holes, and urban smog. These phenomena and their possible consequences are discussed, along with the properties and behavior of the atmosphere and its interactions with other components of the environment.

AOSS 171 (Biol 110) (Univ Course 110)(ENSCEN 171)(ENVIRON 110) (Geol Sci 171). Introduction to Global Change-Part I
Prerequisite: none. I (4 credits)
The course will consider the evolution of the universe, the Earth and its environments, and the evolution of living organisms. Consideration will be given to fundamental processes by which organisms grow and reproduce, how they interact with their environments, and the distribution of major groups of organisms on earth.

AOSS 172 (Univ Course 111) (GEOSCI 172) (ENSCEN 172)(ENVIRON 111) (Soc 111). Introduction to Global Change-Part II
Prerequisite: none. II (4 credits)
An introduction to the evolution of life and the human species on earth, with focus on problems of global change produced by recent human advances in technology and institutions.

AOSS 202. The Atmosphere
Prerequisite: none. I, II (3 credits)
Elementary description of the atmosphere: characteristics and behavior, changes over generations and hours, destructive capability, and response to human activity.

AOSS 204 (Astron 204) (Geol Sci 204). The Planets: Their Geology and Climates
Prerequisite: none. I (3 credits)
Structure, composition, and evolutionary history of the surfaces and atmospheres of the planets and their satellites, with special emphasis given to comparative aspects of geology and climatology. Intended for non-science majors with a background in high school math and science.

AOSS 280. Undergraduate Research Experience
Prerequisites: none. I, II, IIIa, IIIb. (1-4 credits)
Individual or group research experience in atmospheric and space sciences. The Individual or group research experience in atmospheric and space sciences. The program of work is arranged at the beginning of the semester by mutual agreement between the student and a faculty member . Written and/or oral reports will be required.

AOSS 300. Global Environmental Impact of Technological Change
Prerequisite: Chem 130, Math 116. I (3 credits)
This course provides a scientific exploration of the unexpected global environmental side effects of technological innovation. Case studies are presented and discussed illustrating how technological advances can sometimes produce unexpected and undesirable environmental results. Lessons learned from previous environmental crises including new tools for assessing risk are discussed and applied.

AOSS 320. (GEOSCI 320) Earth System Evolution
Prerequisite: Math 116. I (4 credits)
Introduction to the physics and chemistry of Earth. Gravitational energy, radiative energy, Earth's energy budget, and Earth tectonics are discussed along with chemical evolution and biogeochemical cycles. The connections among the carbon cycle, silicate weathering, and the natural greenhouse effect are discussed. Required for AOSS/GS-321, which introduces Earth system dynamics.

AOSS 321 (Geo/Sci 321). Earth System Dynamics
Prerequisite: Preceded or accompanied by Math 215 and Math 216. II (4 credits)
This course will describe the major wind systems and ocean currents that are important to climate studies. The primary equations will be developed and simple solutions derived that will explain many of these motions. The relations among the dynamics and other parameters in the climate system will be illustrated by examples from both paleo and present day systems.

AOSS 323 (Geo/Sci 321). Earth System Analysis
II (2 credits)
Laboratory introduction to the analysis of Earth and Atmospheric Science Systems in a computer programming environment. Topics include turbulent air motion in the planetary boundary layer, cloud and precipitation microphysical composition, tsunami wave propagation, stratospheric ozone depletion, satellite remote sensing and the prediction of El Nino events.

AOSS 350. Atmospheric Physics I
Prerequisite: Math 216. I (4 credits)
Fundamentals of radiative transfer, thermodynamics, and cloud physics of the atmosphere, including absorption, emission, and scattering of radiation, energy balance, adiabatic processes, entropy, water-air systems, and the cloud condensation, microphysics and precipitation processes.

AOSS 380. Atmospheric Physics II
Prerequisite: AOSS 350. II (4 credits)
A continuation of Atmospheric Physics I; will include topics from kinetic theory, radiative transfer for non-grey atmospheres, and cloud microphysics and dynamics.

AOSS 381. Undergraduate Research Experience II
Prerequisites: AOSS 280 or junior/senior standing. I II (1-4 credits)
Individual or group research experience in atmospheric, space science, or space technology. The program of work is arranged at the beginning of the semester by mutual agreement between the student and a faculty member. Written and/or oral reports will be required.

AOSS 401. Geophysical Fluid Dynamics

Prerequisite: Prerequisite: Physics 240, Math 215, Math 216, AOSS 323 I (4 credits)

Dynamics of the oceans and atmosphere. Equations of motion in spherical coordinates, beta-plane approximation, wave properties in the oceans and atmosphere.

AOSS 407. Mathematical Methods in Geophysics

Prerequisite: Math 216. I (4 credits)

Vector calculus and Cartesian tensors; Sturm-Liouville systems, Green's Functions, and solution of boundary value problems; Fourier series, Fourier and Laplace transforms, discrete Fourier transform, fast Fourier transforms, and energy spectra, and singular perturbation theory.

AOSS 410. Earth System Modeling

Prerequisite: none, I (4 credits)

Introduction to Earth System Modeling; discussion of energy balance models, carbon cycle models, and atmospheric chemistry models with multiple time scales; methods for numerical solution and practice building and analyzing results from models.

AOSS 411. Cloud and Precipitation Processes

Prerequisite: AOSS 350, Math 216. I (3 credits)

The special nature of water substance; nucleation of phase changes in the free atmosphere; the structure and content of clouds; the development of physical characteristics of precipitation; and the dynamics of rain systems.

AOSS 414. Weather Systems

Prerequisite: AOSS 350, AOSS 401 or AOSS 551. I (3 credits)

Introduction to the basic characteristics, thermodynamics, and dynamics of atmospheric weather systems on Earth and other planets. The students are exposed to observations of weather systems while reviewing non-dimensional analysis, dynamics and thermodynamics. Weather systems on earth are compared to that of other planets and analytical tools are used to gain insights into their basic physics.

AOSS 420 (NA 420) (ENSCEN 420). Environmental Ocean Dynamics

Prerequisite: NA 320 or AOSS 305 or CEE 325. I (4 credits)

Physical conditions and physical processes of the oceans; integration of observations into comprehensive descriptions and explanations of oceanic phenomena. Emphasis on wave and current prediction, optical and acoustical properties of sea water, currents, tides, waves and pollutant transport.

AOSS 431 (EEC 430). Radiowave Propagation and Link Design

Prerequisite: Phys 405 or EECS 330. II (4 credits)

Fundamentals of electromagnetic wave propagation in the ionosphere, the troposphere, and near the Earth. Student teams will develop practical radio link designs and demonstrate critical technologies. Simple antennas, noise, diffraction, refraction, absorption, multi-path interference, and scattering are studied.

AOSS 440. Meteorological Analysis Laboratory

Prerequisite: AOSS 350, AOSS 401. II (4 credits)

This course provides an introduction into the analysis of both surface-based and remotely-sensed meteorological data. The development and application of operational numerical forecast models will be discussed. Techniques for the prediction of both synoptic and mesoscale meteorological phenomena will also be presented.

AOSS 442(ENSCEN 442). Oceanic Dynamics I

Prerequisite: AOSS 401. II (3 credits)

Wave motions; group velocity and dispersion. Gravity waves, wave statistics and prediction methods; long period waves; the tides. Steady state circulation, including theories of boundary currents and the thermocline.

AOSS 450. Geophysical Electromagnetics

Prerequisite: Math 216. I (4 credits)

The fundamentals of electricity, magnetism, and electrodynamics in the context of the Earth. The first segment will cover electrostatics, the electric structure and circuit of the Earth, electricity in clouds, and lightning. The second segment will cover magnetostatics, currents, the magnetic field and magnetic dynamo of the Earth, and the Earth's magnetosphere. The third segment will cover electrodynamics, electromagnetic waves, radiation in the Earth environment, waveguides, and radiation from sources.

AOSS 451 (ENSCEN 451). Atmospheric Dynamics I

Prerequisites: AOSS 401 or Math 450. II (4 credits)

Quasi-geostrophic energetics; fronts; the mean circulation; planetary and equatorial waves: overview of the dynamics of the middle atmosphere; wave-mean flow interaction; spectral methods; and tropical meteorology.

AOSS 462. Instrumentation for Atmospheric and Space Sciences

Prerequisite: AOSS 350. II (4 Credits)

Introduction to fundamentals of atmospheric, space-based, and meteorological instrumentation. Includes basics of electronic sensors, optics, lasers, radar, data acquisition/management, error analysis, and data presentation. Consists of two lectures and one lab each week, and a team-based term project.

AOSS 463 (ENSCEN 463). Air Pollution Meteorology

Prerequisite: Math 215. I (3 credits)

Weather and motion systems of the atmosphere; topographic influences on winds, atmospheric stability and inversions; atmospheric diffusion; natural cleansing processes; meteorological factors in plant location, design, and operation.

AOSS 464 (Aero 464). Introduction to the Space and Spacecraft Environment

Prerequisite: senior or graduate standing. I (4 credits)

An introduction to physical and aeronomical processes in the space environment. Discussion of theoretical tools, the Sun, solar spectrum, solar wind, interplanetary magnetic field, planetary magnetosphere, ionospheres and upper atmospheres. Atmospheric processes, densities, temperatures, and wind. Spacecraft interaction with radiation, spacecraft aerodynamics, spacecraft-plasma interactions.

AOSS 467 (Chem 467) (Geol Sci 465) (ENSCEN 467) (Environ 467). Biochemical Cycles

Prerequisite: Math 116, Chem 210, Physics 240. II (3 credits)

The biogeochemical cycles of water, carbon, nitrogen, and sulfur; the atmosphere and oceans as reservoirs and reaction media; the fate of natural and man-made sources of carbon, nitrogen, and sulfur compounds; the interactions among the major biogeochemical cycles and resultant global change; greenhouse gases, acid rain and ozone depletion.

AOSS 470. Solar Terrestrial Relations
Prerequisite: none. II (4 credits)
Introduction to solar terrestrial relations with an overview of solar radiation and its variability on all time-scales. We then discuss effects of this variability on the middle and upper atmosphere, and the Earth near space environment, particularly focusing on energetic particle radiation.
AOSS 475. (ENSCEN 475). Earth-Ocean-Atmosphere Interactions
Prerequisite: senior standing in science or engineering. II (4 Credits)
To develop students' abilities to integrate processes important to global change; surface characteristics, hydrology, vegetation, biogeochemical cycles, human dimensions. Analysis of current research advances. Interdisciplinary team projects with oral and poster presentations.
AOSS 479 (ENSCEN 479). Atmospheric Chemistry
Prerequisite: Chem 130, Math 216. I (4 credits)
Thermochemistry, photochemistry, and chemical kinetics of the atmosphere; geochemical cycles, generation of atmospheric layers and effects of pollutants are discussed.
AOSS 495 (ENSCEN 495). Upper Atmosphere and Ionosphere
Prerequisite: AOSS 464. I (4 credits)
Basic physical and chemical processes important in controlling the upper/middle atmosphere and ionosphere: photochemistry, convection, diffusion, wave activity, ionization, heating and cooling. The terrestrial, as well as planetary atmospheres and ionospheres are to be considered.
AOSS 498. Practicum in Atmospheric, Oceanic and Space Sciences
Prerequisite: permission of instructor. I, II, III, IIIa, IIIb (1 or 2 credits)
Course may be repeated to a maximum of 8 credit hours. Students taking this course will participate in research and/or engineering tasks. Supervision will be undertaken by faculty and engineers of the AOSS department. Reporting requirements include a final written summary. Diverse tasks include aircraft spacecraft and rocket payload design field campaign support calibration simulation test. Students will join an active research program of AOSS for a given semester.
AOSS 499. Directed Study for Undergraduate Students
Prerequisite: permission of instructor. I, II, III, IIIa, IIIb (to be arranged)
Directed reading, research, or special study for advanced undergraduate students.
AOSS 501. Seminars in Limnology and Oceanography
Prerequisite: graduate standing. I, II (1 credit)
Current research efforts will be presented by graduate students and faculty dealing with all phases of limnology and oceanography.
AOSS 524. General Circulation
Prerequisite: previous or concurrent with AOSS 401. I alternate years (3 credits)
Processes that maintain the general circulation of the Earth's atmosphere; the observed general circulation; energetics; balance requirements; comparison of observations with simple theories and results from general circulation model simulations.
AOSS 528 (NA 528) (ENSCEN 529). Remote Sensing of Ocean Dynamics
Prerequisite: AOSS 425 (NA 425) or permission of instructor. II (3 credits)
The dynamics of ocean wave motion, both surface and internal waves, and ocean circulation are explored utilizing active and passive remote sensing techniques. Emphasis is placed upon the synoptic perspective of ocean dynamics provided by remote sensing which is not obtainable by conventional means.
AOSS 532. Radiative Transfer
Prerequisite: graduate standing. I (3 credits)
Radiative transfer (thermal and scattering) applicable to planetary atmospheres. Macro and microscopic form of transfer equation. Line broadening mechanisms, band models, Rayleigh and Mie scattering. Discrete ordinate, successive order of scattering and adding and doubling methods of solution. Non LTE formulation. Applications to, and results from, climate studies.
AOSS 550 (NA 550). Offshore Engineering Analysis II
Prerequisite: NA 420 (AOSS 420). II (3 credits)
Design and analysis requirements of offshore facilities. Derivation of hydrodynamic loads on rigid bodies. Loads on long rigid and flexible cylinders. Viscous forces on cylinders, experimental data, Morison's equation, Stokes wave theories. Shallow water waves. Selection of appropriate wave theory. Diffraction of waves by currents. Hydrodynamic loads on risers, cables, pipelines and TLPs.
AOSS 551. Advanced Geophysical Fluid Dynamics
Prerequisite: AOSS 451. II alternate years (3 credits)
Advanced topics in dynamic meteorology and oceanography including frontogenesis, stability and instability, dynamics of the equatorial ocean, CISK and hurricanes, modons and Gulf Stream rings, strange attractors.
AOSS 555. Spectral Methods
Prerequisite: Math 216. Knowledge of FORTRAN. II alternate odd years (4 credits)
An introduction to numerical methods based on Fourier Series, Chebyshev polynomials, and other orthogonal expansions. Although the necessary theory is developed, the emphasis is on algorithms and practical applications in geophysics and engineering, especially fluid mechanics. Many homework assignments will be actual problem-solving on the computer.
AOSS 563 (ENSCEN 563). Air Pollution Dispersion Modeling
Prerequisite: AOSS 463. II (3 credits)
Principles of modeling air pollution transport and dispersion. Discussion of models for line sources, area sources and point sources. Analysis of individual model data requirements, founding assumptions, and inherent limitations. Practical experience using currently operational models.
AOSS 564 (ENSCEN 564). The Stratosphere and Mesosphere
Prerequisite: AOSS 464. II odd years (3 credits)
The physical, chemical, and dynamical properties of the atmosphere between the tropopause and the turbopause. Among the topics covered are the heat and radiation budgets, atmospheric ozone, stratospheric warmings, the biennial stratospheric oscillation, airglow.
AOSS 565. Planetary Atmospheres
Prerequisite: graduate standing. II (4 credits)
Radiative, photochemical, thermodynamic, and aeronomical processes in the atmospheres of the planets and satellites, with the objective of understanding the composition, structure, origin, and evolution of the atmospheres; theoretical and empirical results, including planetary observations by space probes.

AOSS 567 (Chem 567). Chemical Kinetics
Prerequisite: Chem 461 or AOSS 479. I (3 credits)
A general course in chemical kinetics, useful for any branch of chemistry where reaction rates and mechanisms are important. Scope of subject matter: practical analysis of chemical reaction rates and mechanisms, theoretical concepts relating to gas and solution phase reactions.

AOSS 575 (ENSCEN 575). Air Pollution Modeling
Prerequisite: AOSS 463, AOSS 578, NRE 538 (previously or concurrently). II (3 credits)
A practical introduction to the fundamentals of gas and aerosol measurements with a focus on ozone and acidic gases, their precursors, and aerosols; operation of the suite of instruments, detection and sampling techniques, and calibration practices. An important feature will be team-oriented tasks involving air quality monitoring.

AOSS 576 (ENSCEN 576). Air Quality Field Project
Prerequisite: AOSS 578, NRE 538, AOSS 575, or AOSS 563. IIIa (4 credits)
Practical experience in all aspects of air quality field measurements from the design and planning stage through implementation and data analysis and interpretation. Emphasis on research design, sampling, data management systems, sample tracking, computerized data acquisition and processing, error analysis and reporting; team-oriented practicum for modelers and experimenters.

AOSS 578 (EIH 666). Air Pollution Chemistry
Prerequisite: AOSS 479 or Chem 365. II (3 credits)
Tropospheric and stratospheric air pollution are discussed following a review of thermo-chemistry, photo-chemistry, and chemical kinetics. Gaseous and particulate air pollutants are considered in terms of their origins and transformations.

AOSS 580. Remote Sensing and Geographic Information System Project Laboratory
Prerequisite: Math 216, Physics 140. II (2 credits)
Lectures and hands-on demonstrations train students in acquiring and processing remote sensing and field data using computer based image processing and geographic information systems. Students apply this knowledge in individual and small team projects oriented toward student interests. Research project results are communicated in formal presentations and written reports.

AOSS 581 (Aero 581). Space Policy and Management
Prerequisite: Graduate Standing. I (3 credits)
The first part of the course will provide detailed information on how space policy is developed in the United States and the international space community, and how these policies result in specific missions. The second part will provide detailed information on modern management techniques and processes. Project managers from NASA centers and industry will lecture on the detailed management techniques and processes.

AOSS 582(Aero 582). Spacecraft Technology
Prerequisite: graduate standing. I (4 credits)
Systematic and comprehensive review of spacecraft and space mission design and key technologies for space missions. Discussions on project management and the economic and political factors that affect space missions. Specific space mission designs are developed in teams. Students of AERO 483/583 choose their projects based on these designs.

AOSS 583 (Aero 583). Management of Space Systems Design
Prerequisite: Aero/AOSS 582. I (4 credits)
Meets with Aero. Eng. 483 (Space System Design), or other senior design course when appropriate topic is chosen. Students in this course lead teams in high level project design of a space system. Modern methods of concurrent engineering manufacturing, marketing and finance, etc., are incorporated.

AOSS 584. Space Instrumentation
Prerequisite: graduate standing. II (3 credits)
A survey of the physical principles and engineering of instrumentation used throughout the many related fields of space science. Upon completion of the course, students will have a firm grasp of the principles and techniques used to sense and measure photons, neutral gases, charged particles, and cosmic dust.

AOSS 585. Introduction to Remote Sensing and Inversity Theory
Prerequisite: graduate standing. II (3 credits)
Introduction to active (radar and lidar) and passive (thermal emission) visible, infrared and microwave remote sensing. Fundamentals of electromagnetic emission, absorption and scattering. Sensor performance characteristics. Mathematical methods for inversion of integral transforms and ill-conditioned systems of equations commonly encountered in remote sensing applications.

AOSS 590. Space Systems Projects
Prerequisite: graduate standing. IIIa (4 credits)
Space science and application mission related team project. Student teams will participate in ongoing projects in the Space Physics Research Laboratory in conjunction with industry and government sponsors.

AOSS 595 (EECS 518). Magnetosphere and Solar Wind
Prerequisite: graduate standing. I even years (3 credits)
General principles of magnetohydrodynamics; theory of the expanding atmosphere; properties of solar wind, interaction of solar wind with the magnetosphere of the Earth and other planets; bow shock and magnetotail, trapped particles, auroras.

AOSS 596. Gaskinetic Theory
Prerequisite: graduate standing. II (3 credits)
Maxwell-Boltzmann distribution, kinetic determination of equation of state, specific heats of gases. Dynamics of two-particle collisions. Elementary transport theory, molecular effusion, hydrodynamic transport coefficients, mean free path method. Advanced transport theory, the Boltzmann equation, collision terms, Champman-Enskog transport theory. Aerodynamics of free-molecular flow. Shock waves.

AOSS 597 (Aero 597). Fundamentals of Space Plasma Physics
Prerequisite: senior-level statistical physics course. II (3 credits)
Basic plasma concepts, Boltzmann equation, higher order moments equations, MHD equations, double adiabatic theory. Plasma expansion to vacuum, transonic flows, solar wind, polar wind. Collisionless shocks, propagating and planetary shocks. Fokker-Planck equation, quasilinear theory, velocity diffusion, cosmic ray transport, shock acceleration. Spacecraft charging, mass loading.

AOSS 598. The Sun and the Heliosphere
Prerequisites: AOSS 464 & Physics 505 or equivalent. II odd years (3 credits)
A complete description of the physical processes that govern the behavior of the Sun and the heliosphere with emphasis on recent theoretical and observational results.

AOSS 605. (PHYS 600) Current Topics in Atmospheric, Oceanic and Space Sciences
Prerequisite: permission of instructor. I, II (1-4 credits)
Advances in specific fields of atmospheric and oceanic sciences, as revealed by recent research. Lectures, discussion, and assigned reading.

AOSS 606. Computer Applications to Geo-Fluid Problems
Prerequisite: AOSS 442 or AOSS 451, Math 450. II (3-4 credits)
Solution of geo-fluid problems by numerical techniques using a digital computer. Lectures, laboratory, exercises using the digital computer.

AOSS 651. Dynamics of Planetary Atmospheres and the Upper Atmosphere
Prerequisite: AOSS 451. I alternate years (3 credits)
Dynamic meteorology of other planets (Mars, Venus, Jupiter, and Titan), the Earth's middle atmosphere, and thermosphere. Tides, solitary waves, quasi-geostrophic turbulence, and dynamics and chemistry are among the phenomena discussed.

AOSS 701. Special Problems in Meteorology and Oceanography
Prerequisite: permission of instructor. I, II (to be arranged)
Supervised analysis of selected problems in various areas of meteorology and oceanography.

AOSS 747. AOSS Student Seminar
Prerequisite: none. I, II (1 credit)
Students take turns presenting short research seminars (20 minutes) and/or short talks introducing upcoming speakers in AOSS 749. Some class time will also be devoted to discussions of effective oral and poster presentations and professional ethics.

AOSS 749. Atmospheric and Space Science Seminar
Prerequisite: none. I, II (1 credit)
Presentations from UM researchers and outside speakers about current research results, covering a broad range of topics in atmospheric and space science. In this class students take turns serving as seminar chair. Questions from students will be handled before those from faculty. Conditions for credit are participation in this seminar, and the completion of a short paper in which each student follows up on one talk given as part of this seminar series.

AOSS 990. Dissertation/Pre-Candidate
I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

AOSS 995. Dissertation/Candidate Graduate School
Prerequisite: authorization for admission as a doctoral candidate. I, II, III (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Atmospheric, Oceanic and Space Sciences Faculty

Tamas Gombosi, Ph.D., *Department Chair, Professor; also Aerospace Engineering and Director, SPRL*
Perry Samson, Ph.D., *Associate Chair and Professor*
Professors
Sushil Atreya, Ph.D.
John Barker, Ph.D.
John Boyd, Ph.D.; *also Civil & Environmental Engineering*
Mary Anne Carroll, Ph.D.
R. Paul Drake, Ph.D.
Anthony W. England, Ph.D.; *also Electrical Engineering & Computer Science*
Lennard Fisk, Ph.D., *Thomas M. Donahue Collegiate Professor of Space Science*
Brian Gilchrist, Ph.D.; *also Electrical Engineering & Computer Science*
Gerald J. Keeler, Ph.D.; *also Civil & Environmental Engineering; Environmental Health Sciences, and Geological Sciences*
William Kuhn, Ph.D.
Guy A. Meadows, Ph.D.; *also Naval Architecture & Marine Engineering; Director, Ocean Engineering Laboratory*
Andrew Nagy, Ph.D.; *also Electrical Engineering & Computer Science*
Joyce Penner, Ph.D. *Aksel-Wiin-Nielsen Collegiate Professor of Atmospheric Sciences*
Richard Rood, Ph.D.
Christopher Ruf, Ph.D.; *also Electrical Engineering & Computer Science*
J. Hunter Waite, Ph.D.
Professors Emeritus
Roland Drayson, Ph.D.
Paul B. Hays, Ph.D., *Dwight F. Benton Professor of Advanced Technology; also Aerospace Engineering*
Stanley Jacobs, Ph.D.
Donald J. Portman, Ph.D.
John Vesecky, Ph.D.
James C. G. Walker, Ph.D.; *also Geological Sciences*
Associate Professors
Nilton Renno, Ph.D.
Thomas Zurbuchen, Ph.D.
Assistant Professor
Christiane Jablonowski, Ph.D.
Adjunct Professor
Spiro Antiochos
Research Professors
Stephen Bougher, Ph.D.
C. Robert Clauer, Ph.D.
Michael Combi, Ph.D., *Distinguished Research Professor*
Janet Kozyra, Ph.D., *George Carignan Collegiate Research Professor*
Sanford Sillman, Ph.D.
Research Associate Professors
Michael Liemohn, Ph.D.
Aaron Ridley, Ph.D.
Research Scientists
Vincent Abreu, Ph.D.
Natalia Andronova, Ph.D.
Vladimir Papitashvili, Ph.D.
Wilbert Skinner, Ph.D.
Associate Research Scientists
Jason Daida, Ph.D.
Darren De Zeeuw, Ph.D.
Frank Marsik, Ph.D.
Richard J. Niciejewski, Ph.D.
Igor Sokolov, Ph.D.
Gabor Toth, Ph.D.
Assistant Research Scientists
Roger De Roo, Ph.D.
Kenneth Hansen, Ph.D.
Susan Lepri, Ph.D.
Tariq Majeed, Ph.D.
Ward (Chip) Manchester, Ph.D.
Research Scientists Emeritus
George Carignan
Ernest G. Fontheim, Ph.D.
William Sharp
Tong Shyn
Associate Research Scientist Emeritus
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Biomedical Engineering

Academic Advisor/Counselor
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Students who enjoy math, physics and chemistry, but who also have a keen interest in biology and medicine, should consider a career in biomedical engineering. Synthetic heart valves, the MRI scanner, and automatic bio-sensors for rapid gene sequencing are each examples of biomedical engineering. Biomedical Engineering (BME) is the newest engineering discipline, integrating the basic principles of biology with the tools of engineering.

With the rapid advances in biomedical research, and the severe economic pressures to reduce the cost of health care, biomedical engineering plays an important role in the medical environment of the 21st century. Over the last decade, biomedical engineering has evolved into a separate discipline bringing the quantitative concepts of design and optimization to problems in biomedicine.

The opportunities for biomedical engineers are wide ranging. The medical-device and drug industries are increasingly investing in biomedical engineers. As gene therapies become more sophisticated, biomedical engineers will have a key role in bringing these ideas into real clinical practice. Finally, as technology plays an ever-increasing role in medicine, there will be a larger need for physicians with a solid engineering background. From biotechnology to tissue engineering, from medical imaging to microelectronic prosthesis, from biopolymers to rehabilitation engineering, biomedical engineers are in demand.

Facilities
The facilities available for student research include state-of-the-art, well-equipped laboratories in the Dental School, Medical School, and the College of Engineering, the clinical facilities of the University of Michigan Hospitals, and the Ann Arbor Veteran's Administration Hospital. Students have access to patients and real medical problems with the University of Michigan Hospital on the campus. The University of Michigan's College of Engineering and Medical School have long been regarded as among the finest in the country. Bridging these two worlds is the BME Department, consistently ranked in the top ten nationally in recent years.

Two new buildings house the primary laboratories of the BME Department and help from a Bioengineering Quadrangle including all of the core laboratories in the BME Department, the FMRI Center, the Center for Ultrafast Optical Sciences, and Biotechnology labs within the Environmental Engineering Program. The Bioengineering Quadrangle provides world-class facilities for students in the College of Engineering pursuing research in bioengineering, biomedical imaging, bioinformatics, and biotechnology.

Department Laboratories
Active research laboratories in the areas of functional magnetic resonance imaging (fMRI), biofluidics, micro- and nanoscale fabrication, molecular motors, microfluidics, biofluid mechanics, neural engineering, BioMEMS, tissue engineering, biomechanics, biomedical optics, biomedical ultrasonics, ion channel engineering, and biomaterials provide physical resources and a rich intellectual environment supporting the studies of both our graduate and undergraduate students. Teaching laboratories include both wet and dry labs, computing facilities, and student project space for design and fabrication of projects.

Accreditation
Biomedical Engineering is currently not ABET accredited.

Mission
The mission of the Biomedical Engineering Department is to serve the people of Michigan and the world through preeminence in biomedical engineering education, and in developing broad-sighted interdisciplinary leaders in medicine, industry, academia, and government. The Department challenges its students, faculty and staff to learn, to achieve, to communicate, and to serve the needs of society. The Department is a place where excellence, innovation, excitement, ethical awareness, and impact define the style and substance of its activities.

Goals
To provide students with the education needed for a rewarding career.

Objectives
Upon graduation, our students are

1. Prepared for professional practice in entry-level biomedical engineering positions or to pursue graduate study in engineering, medicine, and other professional degree programs through rigorous instruction in the engineering sciences and biology, including laboratory and design experiences.
2. Prepared for a variety of careers resulting from the opportunity to deepen their technical understanding in a particular subject by a program of related technical electives, or to obtain a broader education in bioengineering by a flexible choice of technical and free electives.

Outcomes

- An ability to apply knowledge of mathematics, science, and engineering to biomedical engineering problems;
- An ability to design and conduct experiments, as well as to analyze as to analyze and interpret data;
- An ability to design a system; component, or process to meet desired needs;
- An ability to function on multi-disciplinary teams;
- An ability to identify, formulate, and solve engineering problems;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively orally and in writing;
- The broad education necessary to understand the impact of engineering solutions in a global and societal context;
- A recognition of the need for, and an ability to engage in life-long learning;
- A knowledge of contemporary issues;
- An ability to use the techniques, skills, and modern engineering and computing tools necessary for engineering practice;
- The structure of the curriculum must provide both breadth and depth across the depth across the range of engineering topics implied by the title of the program;
- Understanding of biology and physiology, and the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology;
- Ability to be able to make the measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems.

Biomedical Engineering Undergraduate Education

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Degree Programs

BME offers a four year undergraduate degree along with a recommended one year Masters degree in a Sequential Graduate/Undergraduate Studies (SGUS) program. Qualified undergraduates can pursue a combined undergraduate/graduate program in one of three concentrations: biochemical, bioelectrics, biomechanics, leading to a Bachelor of Science in Engineering (BME) degree (B.S.E. (BME)). Six graduate concentrations: bioelectrics, biomaterials, biomechanics, biotechnology, biomedical imaging, and rehabilitation engineering, leading to a Master of Science in BME degree M.S. (BME).

Honors Program

B.S. in Cell and Molecular Biology (CMB) and M.S. in Biomedical Engineering

The Department of Molecular, Cellular, and Developmental Biology (MCDB) in the College of LS&A and the Department of Biomedical Engineering in the College of Engineering administer a five-year Honors program, awarding a concurrent B.S. degree in Cell and Molecular Biology from the College of LS&A and an M.S. in Biomedical Engineering from the College of Engineering, upon completion of all program requirements. A student will apply to both the Molecular, Cellular, and Developmental Biology and Biomedical Engineering Departments for entrance. A student will be admitted into the program only after completing the first year of concentration prerequisites (BIOL 162, CHEM 210/211, PHYSICS 140/141, MATH 115 and 116) with a GPA of 3.2 or higher.

Upon acceptance into the program, each student will be assigned two advisors, one in MCDB and one in Biomedical Engineering. Student course selections must be approved by both advisors each term. Specific requirements are listed under the Molecular, Cellular and Developmental Biology Department in Chapter VI.

A student is typically admitted into the M.S. phase at the end of the third year when the student achieves senior standing. The student must have completed all concentration prerequisites and be judged by both academic advisors as making adequate progress toward a B.S.E. degree. At this time, the student must formally apply to the Rackham Graduate School for the M.S. program in Biomedical Engineering. All students with a 3.2 GPA or higher in the B.S.E. concentration phase will automatically be admitted into the M.S. phase. Other CMB students who have reached senior standing with a 3.2 GPA or higher and have fulfilled all concentration prerequisites, but did not previously apply or were not admitted in the B.S.E phase, can also apply for admittance into the M.S. phase. Students with senior standing will have two years to mix undergraduate and graduate courses, simultaneously fulfilling requirements for both the B.S.E. and M.S. degrees. Students will be charged graduate tuition for only one academic year.

Sample Schedule

B.S.E./M.S. Biomedical Engineering

B.S.E. (Biomedical Engineering)

	Credit Hours	Terms 1	2	3	4	5	6	7	8	9	10
Subjects required by all programs (51-53 hrs.)											
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-		
Engr 100, Intro to Engineering	4	4	-	-	-	-	-	-	-		
Engr 101, Intro to Computers	4	-	4	-	-	-	-	-	-		
Chemistry 130[1]	3	3	-	-	-	-	-	-	-		
Physics 140/141, 240/241[2]	10	5	5	-	-	-	-	-	-		
Humanities and Social Sciences	16	-	4	4	4	4	-	-	-		
Advanced Science and Math (17-18 hrs.)											
Biology 162, Introduction to Biology	5	-	-	-	5	-	-	-	-		
Chemistry 210/211, Structure & Reactivity I	5	-	-	5	-	-	-	-	-		
Biology 310, Intro to Biol Chem	4	-	-	-	-	-	4	-	-		
IOE 265, Probability & Statistics for Engrs	4	-	-	-	-	4	-	-	-		
Required Program Subjects (28 hrs.)											
BiomedE 211, Circuits & Systems for Biomedical Engineers	4	-	-	-	-	4	-	-	-		
BiomedE 221, Biophysical Chemistry	4	-	-	-	-	4	-	-	-		
BiomedE 231, Intro to Biomechanics	4	-	-	-	4	-	-	-	-		
MatSci 250, Prin. of Engr. Materials	4	-	-	4	-	-	-	-	-		
BiomedE 418, Quantitative Cell Biology	4	-	-	-	-	-	4	-	-		
BiomedE 419, Quantitative Physiology	4	-	-	-	-	-	-	4	-		
BiomedE 450, Biomedical Design	4	-	-	-	-	-	-	-	4		
BiomedE 458, Biomedical Instrumentation & Design	4	-	-	-	-	-	-	4	-		
B.S.E. Concentration Requirements and Electives[3](20 hrs.)	16	-	-	-	-	-	4	4	8		
Unrestricted Electives (9-11 hrs.)	9-11	-	-	-	-	-	3	3	3	-	-
Total	128	16	17	17	17	16	15	15	15	-	-

M.S. Biomedical Engineering

	Credit Hours	Terms 1	2	3	4	5	6	7	8	9	10
Required Program Subjects M.S. (14-15 hrs.)											
Advanced Math	3	-	-	-	-	-	-	-	-	-	3
Advanced Statistics	4	-	-	-	-	-	-	-	-	4	-
BME 500, Seminar	1	-	-	-	-	-	-	-	-	1	-
BME 550, Ethics & Enterprise	1	-	-	-	-	-	-	-	-	1	-
BME 590, Directed Study	2-3	-	-	-	-	-	-	-	-	-	2-3
Life Science	3	-	-	-	-	-	-	-	-	3	-
M.S. Concentration Requirements[3](8 hrs.)	8	-	-	-	-	-	-	-	-	4	4
M.S. Total Hours	22-23	-	-	-	-	-	-	-	-	13	9-10

Candidates pursuing a five-year Sequential Graduate/Undergraduate Studies Program in BME leading to a Bachelor of Science in Engineering degree (BME) - B.S.E. (BME) - and the Master of Science (BME) - M.S. (BME) - must complete the program listed above.

Students interested in pursuing the five-year Sequential Graduate/Undergraduate Studies Program in BME should consult with a Program Advisor.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]Concentration requirements and electives: A list of approved courses is available on the department web site and in 1111 Gerstacker.

At the undergraduate level students may pursue three concentration areas: biochemical, bioelectrics, and biomechanics. Specific course requirements for the undergraduate concentrations are available on the department web site and in 1111 Gerstacker.

The undergraduate degree program provides a strong foundation in the life sciences and engineering and flows smoothly into graduate studies in BME through the S.G.U.S. program. The three undergraduate concentrations are linked to the six graduate concentrations: biomaterials and biotechnology (undergraduate biochemical), bioelectrics and biomedical imaging (undergraduate bioelectrics), biomechanics and rehabilitation engineering and ergonomics (undergraduate biomechanics).

Biomedical Engineering Graduate Education

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Graduate Degrees

- Master of Science (M.S.) in Biomedical Engineering
- Doctor of Philosophy (Ph.D.) in Biomedical Engineering

M.S. in Biomedical Engineering

The Department of Biomedical Engineering's graduate program at the University of Michigan is in the Rackham School of Graduate Studies granting the M.S. and Ph.D. degrees in Biomedical Engineering.

The department is interdisciplinary. A student may plan a widely diversified educational program to advance the student's personal goals. Research opportunities are as diversified as the range of activities conducted by the University units supporting the Department.

Entrance Requirements for the Department of Biomedical Engineering

Those students with a Bachelor of Science in Engineering or Physics degree should present a minimum background of:

- One course in biochemistry
- One course in either basic biology or introductory physiology that has laboratory experience
- One course in a generally related area of the biological sciences such as anatomy, experimental psychology, microbiology, physiology, pharmacology, etc.

Those students with a Bachelor of Science or Bachelor of Arts degree and majors in related bioengineering areas such as experimental psychology, physiology, zoology, microbiology, and biochemistry, must complete the above requirements plus the following:

- Two terms of college physics
- Mathematics through differential equations
- One course in basic electronic circuits
- Two courses of either mechanics, fluid mechanics, or thermodynamics

Students may enter prior to meeting all the prerequisites if approved by the admissions committee. These students must plan to complete the prerequisites during their enrollment in the program in addition to the stipulated requirements for the Master of Science or Doctor of Philosophy degree in Biomedical Engineering.

Degree Requirements

In order to obtain the master's degree in Biomedical Engineering, students must complete at least 30 credit hours of graduate study beyond the bachelor's degree. Within this requirement, a group of core courses or their equivalents in the biological sciences, and several graduate level engineering and physical science courses must be completed. Directed research work is required to familiarize the student with the unique problem associated with biological systems research. The core course requirements or their equivalent total 12-23 credit hours for each sub-group of the curriculum. There are six (6) curriculum options available:

- Bioelectrics
- Biomaterials
- Biomechanics
- Biotechnology
- Biomedical Imaging
- Rehabilitation Engineering and Ergonomics

Please see department booklet for further details. A grade of "B" or better must be attained in each course used toward the master's degree.

Ph.D. in Biomedical Engineering

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the result of the investigation in the form of a dissertation.

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. Candidacy is achieved when the student demonstrates competence in her/his broad field of knowledge through completion of a prescribed set of courses and passing a comprehensive examination.

There is a nine credit requirement beyond the M.S. for the doctorate. In most areas, a student must pass a comprehensive examination in a major field of specialization and be recommended for candidacy for the doctorate. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.

Requirements regarding foreign language and non-technical courses are left to individual departments or programs, and to the Graduate School. A prospective doctoral student should consult the program advisor regarding specific details.

Biomedical Engineering Fields of Study

Bioelectrics

The Bioelectrical concentration has two components:

BioMEMS:

A track emphasizing the technology of micromachined measurement and activation devices, which are components of implantable devices such as neuroprostheses or pacemakers. This program will give students a circuits background with some experience in the fabrication of solid-state devices.

Biosystems:

The theory and practice of systems related to modeling of physiological systems and the design of integrated sensor and actuator systems. Students graduating from BME with a concentration in bioelectrics will be able to work as engineers in the rapidly expanding medial diagnostic, therapeutic, and systems industry. Others could pursue Ph.D. programs in either electrical engineering: systems or biomedical fields, or advanced degrees in medicine or basic medical science.

Biomaterials

Biomaterials is the study of interactions between living and non-living materials. Students trained in biomaterials must have a thorough understanding of the materials they work with, knowledge of the properties of the biological system, and knowledge of the properties of the biological system they seek to replace. Biomaterials is an integral component in tissue engineering and life-science initiatives. Biomaterials research areas include: design of orthopaedic, dental, cardiovascular and neuro-sensory prostheses, artificial organs, blood-surface interactions, cellular and tissue engineering, drug delivery, biosensors, microencapsulation technology, and implant retrieval analysis. Students graduating from BME with a concentration in biomaterials will be capable of working in the medical device industry, academic or government laboratories, or pursuing further education in Ph.D. or professional programs.

Biomechanics

Biomechanics is a hybrid discipline requiring a thorough understanding of classic engineering mechanics, physiology and cell biology, and the interface between the two. Biomechanics also has important applications in cutting-edge fields like tissue engineering and mechanotransduction. In tissue engineering, one tries to regenerate new tissues to replace defects in existing tissues. This requires knowledge of tissue-mechanical function. Mechanotransduction is the study of how cells sense and react to mechanical stimulus, a field with applications in such diverse areas as hearing (haircell movement in fluids) and orthopaedics (bone and tendon response to physical stress). Graduates in this concentration will be prepared for a wide range of industries concerned with mechanical affects on the human body including surgical device industries, automotive safety, and biotech industries concerned with mechanically functional tissue. Students will also have excellent preparation to attend medical school or pursue a Ph.D.

Biomedical Imaging

Since the invention of x-ray computerized tomography more than 25 years ago, imaging has become the primary noninvasive diagnostic tool available to the clinician. Although many principles are common to all imaging modalities, biomedical imaging scientists and engineers must understand the basic physics and operating principles of all primary modalities including magnetic resonance imaging (MRI), radiography and nuclear medicine, optics, and ultrasound. Major biomedical imaging companies require such multi-modality expertise to design new devices and procedures. In addition, clinical problems increasingly require the techniques of cell and molecular biology to design both new contrast agents and imaging methods for a wider range of applications. The biomedical imaging curriculum recognizes trends and requires students to have a solid background in signal processing and imaging science, and simultaneously be literate in both the basic life sciences and the basic operating principles of several imaging modalities. Graduates of this program will be well prepared to work in the medical imaging industry, to attend medical school, or to study for a Ph.D. in BME.

Biotechnology

Advances in cellular and molecular biology have changed and expanded the ways therapeutic devices and drugs are designed. Modern biotechnology depends on scientists and engineers who study the fundamental properties of cell, molecular, and tissue biology, and apply these to engineer chemicals and materials to interact with living systems. Goals include production of improved biomaterials for medical implants and prosthetics, tissues engineered for specific functionality, and new therapeutic drugs. The biotechnology curriculum emphasizes critical areas of chemistry, molecular biology, and cell biology, but also exposes students to a broad range of engineering approaches necessary for this interdisciplinary field. Graduates of this program will be well prepared for jobs in the pharmaceutical or medical device industries, to attend professional schools, or to study for a Ph.D.

Rehabilitation Engineering

The program in rehabilitation engineering and ergonomics is concerned with finding ways to maximize participation of all persons in activities of work, leisure, and daily living with minimal risk of injury or illness. Students completing this program will acquire specific skills for evaluating activities of work and daily living, equipment, environments, and safety and health issues, and for applying that information to the design of equipment and procedures, so as to maximize participation by all persons, and maximize performance and minimize risk of injury. A unique aspect of the program in rehabilitation and ergonomics is that, more than other fields, it affords an overview of people in their various shapes, sizes, and ability levels, and how they interact with the world around them to accomplish a given goal. Biomedical engineers specializing in rehabilitation and ergonomics can expect to find employment with industry, government agencies, labor groups, consulting groups, insurance companies, and health-care facilities among others.

Biomedical Engineering Courses

BiomedE 211. Circuits and Systems for Biomedical Engineering.

Prerequisite: Math 214 or Math 216, and Physics 240 I (4 credits)

Students learn circuits and linear systems concepts necessary for analysis and design of biomedical systems. Theory is motivated by examples from biomedical engineering. Topics covered include electrical circuit fundamentals, operational amplifiers, frequency response, electrical transients, impulse response, transfer functions, and convolution, all motivated by circuit and biomedical examples. Elements of continuous time domain-frequency domain analytical techniques are developed.

BiomedE 221. Biophysical Chemistry and Thermodynamics

Prerequisite: Chem 130 and Math 116. Recommend Bio 310 and Chem 210 be taken concurrently. I (4 credits)

This course covers the physio-chemical concepts and processes relevant to life. The emphasis lies on the molecular level. Topics: biomimetics and motivation; energy and driving forces; biochemical equilibria; aqueous solutions; molecular self-assembly in chemistry, biology, and nanotechnology; bio-electrochemistry; biopolymers; molecular recognition and binding equilibria in biology.

BiomedE 231. Introduction to Biomechanics

Prerequisite: Math 116 II (4 credits)

This course provides students with an introduction to topics in biomechanics, including statistics, dynamics, and deformable body mechanics, as they apply to biological tissues and systems.

BiomedE 280. Undergraduate Research

Prerequisite: permission of instructor. I, II, IIIa, IIIb (1-4 credits)

This course offers research experience to first- and second-year Engineering students in an area of mutual interest to the student and to a faculty member within the College of Engineering. For each hour of credit, it is expected that the student will work three hours per week. The grade for the course will be based on a final project/report evaluated by the faculty sponsor and participation in other required UROP activities, including bimonthly research group meetings and submission of a journal chronicling the research experience.

BiomedE 295. Biomedical Engineering Seminar

Prerequisite: none. II (1 credit)

This seminar is designed for students interested in the Sequential Graduate/ Undergraduate Study (SGUS) program in which students obtain a B.S.E. degree from a participating engineering department, now including the BME Department, and a M.S. degree from BME. We will explore various BME subdisciplines with the goal of helping students choose an undergraduate major department and to gain an appreciation for the breadth of the field of biomedical engineering.

BiomedE 311. Biomedical Signals and Systems

Prerequisite: BiomedE 211, EECS 215 or EECS 314 II (4 credits)

Theory and practice of signals and systems in both continuous and discrete time domains with examples from biomedical signal processing and control. Continuous-time linear systems convolution, steady-state responses, Fourier and Laplace transforms, transfer functions, poles and zeros, stability, sampling, feedback. Discrete-time linear systems: Z transform, filters, Fourier transform, signal processing.

BiomedE 321. Bioreaction Engineering and Design

Prerequisite: BiomedE221, Bio 310 (Biology 310 may be concurrent). II (3 credits)

This course will introduce students to topics in enzyme kinetics, enzyme inhibition, mass and energy balance, cell growth and differentiation, cell engineering, bioreactor design, and analysis of the human body, organs, tissues, and cells as bioreactors. The application of bioreaction/bioreactor principles to tissue engineering will also be discussed.

BiomedE 331. Introduction to Biofluid Mechanics

Prerequisite: BiomedE 231 and math 216. I (4 credits)

This course introduces the fundamentals of biofluid dynamics and continuum mechanics, and covers the application of these principles to a variety of biological flows. Fluid flow in physiology and biotechnology is investigated at a variety of scales, ranging from subcellular to full body.

BiomedE 332. Introduction to Biosolids Mechanics

Prerequisite: BiomedE 231 II (4 credits)

This course covers the fundamentals of continuum mechanics and constitutive modeling relevant for biological tissues. Constitutive models covered include linear elasticity, nonlinear elasticity, viscoelasticity and poroelasticity. Structure-function relationships which link tissue morphology and physiology to tissue constitutive models will be covered for skeletal, cardiovascular, pulmonary, abdominal, skin, eye, and nervous tissues.

BiomedE 350. Introduction to Biomedical Instrumentation Design

Prerequisite: none. (4 credits)

Fast-paced introductory course open to all students interested in circuit design. Two terms introductory physics recommended, programming skills helpful. Topics: basic analog and digital circuit applications, sensors, micro power design, data acquisition, computer I/O, electro-mechanical and electro-optical devices, applications to biological and medical research.

BiomedE 401 (Anatomy 401). The Human Body: Its Structure and Function

I (4 credits)

A lecture-oriented, multi-media course that highlights the basic fabric of the human body as a functioning biological organism. A blend of gross anatomy, histology, developmental anatomy and neuroanatomy that takes the human body from conception to death while dealing with organization at all levels from cells to systems, system interrelations, and key features of select anatomical regions.

BiomedE 410 (MSE 410) (MACROMOL 410). Design and Applications of Biomaterials

Prerequisite: MSE 220 or 250 or permission of instructor. I (4 credits)

Biomaterials and their physiological interactions. Materials used in medicine/ dentistry: metals, ceramics, polymers, composites, resorbable smart, natural materials. Material response/degradation: mechanical breakdown, corrosion, dissolution, leaching, chemical degradation, wear. Host responses: foreign body reactions, inflammation, wound healing, carcinogenicity, immunogenicity, cytotoxicity, infection, local/systemic effects.

BiomedE 417 (EECS 417). Electrical Biophysics

Prerequisite: BME 211 and 311, or EECS 206 and 215 or graduate standing. II (4 credits)

Electrical biophysics of nerve and muscle; electrical conduction in excitable tissue; quantitative models for nerve and muscle including the Hodgkin-Huxley equations; biopotential mapping, cardiac electrophysiology, and functional electrical stimulation; group projects. Lecture and recitation.

BiomedE 418. Quantitative Cell Biology
Prerequisite: Biology 310, 311, Biochemistry 415, 451, 515, Physics 240, Math 216, Chemistry 130. II (4 credits)
This course introduces the fundamentals of cell structure and functioning. The goal is to provide a general background in cell biology, with emphasis placed on physical aspects that are of particular interest to engineers.

BiomedE 419. Quantitative Physiology
Prerequisite: Biochemistry 310. I (4 credits)
Quantitative Physiology provides learning opportunities for senior undergraduate and graduate students to understand and develop competencies in a quantitative, research oriented, systems approach to physiology. Systems examined include cellular; musculoskeletal; cardiovascular; respiratory; endocrine; gastrointestinal; and renal. Mathematical models and engineering analyses are used to describe system performance where applicable. Lectures and problem sessions are used for instruction, and performance is evaluated based on homework problem sets.

BiomedE 424. Engineering Acoustics
Prerequisite: Math 216 and Phys 240. II (3 credits)
Vibrating systems; acoustic wave equation; plane and spherical waves in fluid media; reflection and transmission at interfaces; propagation in lossy media; radiation and reception of acoustic waves; pipes, cavities and waveguides; resonators and filters; noise; selected topics in physiological, environmental and architectural acoustics.

BiomedE 430. Rehabilitation Engineering and Assistive Technology
Prerequisite: Previous or simultaneous registration in IOE 333 or IOE 433 or instructor approval. I (3 credits)
This is a lecture course which surveys the design and application of rehabilitation engineering and assistive technologies in a wide range of areas, including wheeled mobility, seating and positioning, environmental control, computer access, augmentative communication, sensory aids, as well as emerging technologies.

BiomedE 450. Biomedical Design
Prerequisite: BME 458 and senior or graduate standing. I, II (4 credits)
Interdisciplinary design groups carry out biomedical instrumentation design projects. Projects are sponsored by Medical School and College of Engineering research labs and local industry. Students are exposed to the entire design process: design problem definition, generation of a design specification, documentation, design review process, prototype fabrication, testing and calibration.

BiomedE 456 (ME 456). Biomechanics
Prerequisite: ME 211 I (3 credits)
Definition of biological tissue and orthopaedic device mechanics, including elastic, viscoelastic and non-linear elastic behavior. Emphasis on structure function relationships. Overview of tissue adaption and the interaction between tissue mechanics and physiology.

BiomedE 458 (EECS 458). Biomedical Instrumentation and Design
Prerequisite: BiomedE211, EECS 215 or EECS 314, and IOE 265, or graduate standing. I, II (4 credits)
Measurement and analysis of biopotentials and biomedical transducer characteristics; electrical safety; applications of FET's, integrated circuits, operational amplifiers for signal processing and computer interfacing; signal analysis and display on the laboratory minicomputer. Lecture and laboratory.

BiomedE 464 (Math 464). Inverse Problems
Prerequisite: Math 217, Math 417, or Math 419; and Math 216, Math 256, Math 286, or Math 316. II (3 credits)
Mathematical concepts used in the solution of inverse problems and analysis of related forward operators is discussed. Topics include ill-posedness, singular-value decomposition, generalized inverses, and regularization. Inverse problems considered (e.g., tomography, inverse scattering, image restoration, inverse heat conduction) are problems in biomedical engineering with analogs throughout science and engineering.

BiomedE 476 (ME 476). Biofluid Mechanics
Prerequisite: ME 235, ME 320, and ME 370. II (4 credits)
This is an intermediate level fluid mechanics course which uses examples from biotechnology processes and physiologic applications, including the cardiovascular, respiratory, ocular, renal, musculo-skeletal and gastrointestinal system.

BiomedE 479. Biotransport
Prerequisite: Math 216, ME 330, or permission of instructor. II (4 credits)
Fundamentals of mass and heat transport as they relate to living systems. Convection, diffusion, active transport, osmosis and conservation of momentum, mass and energy will be applied to cellular and organ level transport. Examples from circulatory, respiratory, renal and ocular physiology will be examined.

BiomedE 481 (NERS 481). Engineering Principles of Radiation Imaging
Prerequisite: none. II (2 credits)
Analytic description of radiation production, transport and detection in radiation imaging systems. Measurements methods for image quality and statistical performance of observers. Systems for radiographic and radioisotope imaging, including film/screen, storage phosphor, and electronic radiography, fluoroscopy, computed tomography, Anger camera, and PET systems. Emphasis on impact of random process on observer detection.

BiomedE 484 (NERS 484). Radiological Health Engineering Fundamentals
Prerequisite: NERS 312 or equivalent or permission of instructor. I (4 credits)
Fundamental physics behind radiological health engineering and topics in quantitative radiation protection. Radiation quantities and measurement, regulations and enforcement, external and internal dose estimation, radiation biology, radioactive waste issues, radon gas, emergencies, and wide variety of radiation sources from health physics perspective.

BiomedE 490. Directed Research
I, II, IIIa, IIIb, III (1-4 credits)
Provides an opportunity for undergraduate students to perform directed research devoted to Biomedical Engineering.

BiomedE 495. Introduction to Bioengineering
Prerequisite: permission of instructor; mandatory pass/fail. I (1 credit)
Definition of scope, challenge, and requirements of the bioengineering field. Faculty members review engineering-life sciences interdisciplinary activities as currently pursued in the College of Engineering and Medical School.

BiomedE 499. Special Topics
I, II, IIIa, IIIb, III (1-4 credits)
Topics of special interest selected by faculty. Lecture, seminar or laboratory.

BiomedE 500 (UC 500) Biomedical Engineering Seminar
Mandatory, satisfactory/unsatisfactory. I, II (1 credit)
This seminar will feature various bioengineering-related speakers.
BiomedE 506 (ME 506). Computational Modeling of Biological Tissues
(3 credits)
Biological tissues have multiple scales and can adapt to their physical environment. This course focuses on visualization and modeling of tissue physics and adaptation. Examples include electrical conductivity of heart muscle and mechanics of hard and soft tissues. Homogenization theory is used for multiple scale modeling.
BiomedE 510. Medical Imaging Laboratory
Prerequisite: BiomedE 516 or permission of instructor. II (3 credits)
This course provides the student practical, hands-on experience with research grade, medical imaging systems including x-ray, magnetic resonance, nuclear medicine, and ultrasound. Participants rotate through each of the respective areas and learn about and perform experiments to support previous theoretical instruction.
BiomedE 516 (EECS 516). Medical Imaging Systems
Prerequisite: EECS 451. I (3 credits)
Principles of modern medical imaging systems. For each modality the basic physics is described, leading to a systems model of the imager. Fundamental similarities between the imaging equations of different modalities will be stressed. Modalities covered include radiography, x-ray computed tomography (CT), NMR imaging (MRI) and real-time ultrasound.
BiomedE 519 (Physiol 519). Bioengineering Physiology
Prerequisite: Biol 105 or Biol 112 or equivalent, permission of instructor. I (4 credits)
Quantitative description of the structure and function of mammalian systems, including the neuromuscular, cardiovascular, respiratory, renal and endocrine systems. Mathematical models are used to describe system performance where applicable. Lectures, laboratories, and problem sessions.
BiomedE 525 (Microb 525). Cellular and Molecular Networks
Prerequisite: Biol 105 or Biol 112 and Math 215. II (3 credits)
This course is designed to equip the student with appropriate concepts and techniques for the quantitative analysis of the integrated behavior of complex biochemical systems. A general approach is developed from the basic postulates of enzyme catalysis and is illustrated with numerous specific examples, primarily from the microbial cell.
BiomedE 530. Rehabilitation Engineering and Technology Lab I
Prerequisite: previous or simultaneous registration in BME 430. I (1 credit)
This is a lab course which provides hands-on experience in the use of assistive technologies and in-depth consideration of rehabilitation engineering research and design of assistive technologies for a wide range of areas, including environmental control, computer access, augmentative communication, wheeled mobility, sensory aids, and seating and positioning.
BiomedE 533 (Kine 530). Neuromechanics
Prerequisite: Graduate standing. I (3 credits)
Course focuses on interactions of the nervous and musculoskeletal system during human and animal movement with a focus on basic biological and engineering principles. Topics will include neurorehabilitation, and computer simulations of neuromechanical systems. No previous knowledge of neuroscience or mechanics is assumed.
BiomedE 534 (IOE 534) (Mfg 534). Occupational Biomechanics
Prerequisite: IOE 333, IOE 334 or IOE 433 (EIH 556). II (3 credits)
Anatomical and physiological concepts are introduced to understand and predict human motor capabilities, with particular emphasis on the evaluation and design of manual activities in various occupations. Quantitative models are developed to explain: (1) muscle strength performance; (2) cumulative and acute musculoskeletal injury; (3) physical fatigue; and (4) human motion control.
BiomedE 550. Ethics and Enterprise
Prerequisite: none. I (1 credit)
Ethics, technology transfer, and technology protection pertaining to biomedical engineering are studied. Ethics issues range from the proper research conduct to identifying and managing conflicts of interest. Technology transfer studies the process and its influences on relationships between academia and industry.
BiomedE 551 (Bioinf 551) (Chem 551) (BiolChem 551) Proteome Informatics
Prerequisite: Biochemistry and calculus. (3 credits)
Introduction to proteomics, from experimental procedures to data organization and analysis. Basic syllabus: sample preparation and separations, mass spectrometry, database search analysis, de novo sequence analysis, characterizing post translational modifications, medical applications. Further topics may include, e.g.: 2-D gels, protein-protein interactions, protein microarrays. Research literature seminars required.
BiomedE 556. Molecular and Cellular Biomechanics
Prerequisite: none. I (3 credits)
This course will focus on how biomechanical and biophysical properties of subcellular structures can be determined and interpreted to reveal the workings of biological nano-machines.
BiomedE 559. (EECS 559). Advanced Signal Processing
Prerequisite: EECS 451 and EECS 501. II (3 credits)
Advanced techniques include general orthonormal bases; SVD methods; pattern recognition/classification; spectral estimation, including classical and modern; time-frequency and time-scale; nonlinear filtering, including rank order filtering. Illustrations will be drawn from a variety of signals and images. Random processes are an important component of the methods.
BiomedE 561. Biological Micro- and Nanotechnology
Prerequisite: Biology 162, Intro Physics and Chemistry, senior standing or permission of instructor. II (3 credits)
Many life processes occur at small size-scales. This course covers scaling laws, biological solutions to coping with or taking advantage of small size, micro- and nanofabrication techniques, biochemistry, and biomedical applications (genomics, proteomics, cell biology, diagnostics, etc.). There is an emphasis on micro fluidics, surface science, and non-traditional fabrication techniques.

BiomedE 569 (EECS 569). Signal Analysis in Biosystems
Prerequisite: EECS 451 and EECS 501 or permission of instructor. II (3 credits)
This course will present a variety of techniques for the analysis and understanding of biological signals and biosystems. Both signals of biological nature and images will be discussed. Techniques will include signal representation, time frequency and wavelet analysis, nonlinear filtering (median and rank order) and pattern recognition including neural networks.
BiomedE 580 (NERS 580). Computation Projects in Radiation Imaging
Prerequisite: preceded or accompanied by NERS 481. II (1 credit)
Computational projects illustrate principles of radiation imaging from NERS 481 (BiomedE 481). Students will model the performance of radiation systems as a function of design variables. Results will be in the form of computer displayed images. Students will evaluate results using observer experiments. Series of weekly projects are integrated to describe the performance of imaging systems.
BiomedE 582 (NERS 582). Medical Radiological Health Engineering
Prerequisite: NERS 484 (BiomedE 484) or graduate status. II (3 credits)
This course covers the fundamental approaches to radiation protection in radiology, nuclear medicine, radiotherapy, and research environments at medical facilities. Topics presented include health effects, radiation dosimetry and dose estimation, quality control of imaging equipment, regulations, licensing and health physics program design.
BiomedE 584 (ChemE 584) (Biomaterials 584). Tissue Engineering
Prerequisite: Bio 311, ChemE 517, or equivalent biology course; senior standing. I (3 credits)
Fundamental engineering and biological principles underlying field of tissue engineering are studied, along with specific examples and strategies to engineer specific tissues for clinical use (e.g., skin). Student design teams propose new approaches to tissue engineering challenges.
BiomedE 590. Directed Research
Mandatory, satisfactory/unsatisfactory. (to be arranged)
Provides opportunity for bioengineering students to participate in the work of laboratories devoted to living systems studies.
BiomedE 591. Thesis
Prerequisite: 2 hrs of BiomedE 590; mandatory satisfactory/ unsatisfactory. I, II, III (credit to be arranged)
To be elected by bioengineering students pursuing the master's thesis option. May be taken more than once up to a total of 6 credit hours. Graded on a satisfactory/unsatisfactory basis only.
BiomedE 599. Special Topics I, II
I, II (1-6 credits)
Topics of current interest selected by the faculty. Lecture, seminar or laboratory.
BiomedE 616 (ChemE 616). Analysis of Chemical Signalling
Prerequisite: Math 216, Biochemistry 415. II (3 credits)
Quantitative analysis of chemical signalling systems, including receptor/ligand binding and trafficking, signal transduction and second messenger production, and cellular responses such as adhesion and migration.
BiomedE 635 (IOE 635). Laboratory in Biomechanics and Physiology of Work
Prerequisite: IOE 534 (BiomedE 534). II (2 credits)
This laboratory is offered in conjunction with the Occupational Biomechanics lecture course (IOE 534) to enable students to examine experimentally: (1) musculoskeletal reactions to volitional acts; (2) the use of electromyography (EMG's) to evaluate muscle function and fatigue; (3) biomechanical models; (4) motion analysis systems; and (5) musculoskeletal reactions to vibrations.
BiomedE 646 (ME 646). Mechanics of Human Movement
Prerequisite: ME 540 (Aero 540) or ME 543 or equivalent. II alternate years (3 credits)
Dynamics of muscle and tendon, models of muscle contraction. Kinematics and dynamics of the human body, methods for generating equations of motion. Mechanics of proprioceptors and other sensors. Analysis of human movement, including gait, running, and balance. Computer simulations and discussion of experimental measurement techniques.
BiomedE 800. Biomedical Engineering Research Seminar
Prerequisites: graduate standing or permission of instructor. II (1 credit)
Invited speakers will present seminars focusing on recent developments, research or methodologies in biomedical engineering or related studies.
BiomedE 990. Dissertation/Pre-Candidate
I, II, III (1-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
BiomedE 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, III (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
Matthew O'Donnell, Ph.D., Jerry W. and Carol L. Levin Professor of Engineering and Chair; *also Electrical Engineering and Computer Science*
Professors
Larry Antonuk, Ph.D.; *also Radiation Oncology*
Thomas J. Armstrong, Ph.D.; *also Environmental Industrial Health and Industrial and Operations Engineering*
James Baker Jr., M.D.; *also Internal Medicine and Pathology*
Kate F. Barald, Ph.D.; *also Cell and Developmental Biology*
Ramon Berguer, M.D.; *also Vascular Surgery*
Robert H. Bartlett, M.D.; *also General and Thoracic Surgery*
Mark Burns, Ph.D.; *also Chemical Engineering*
Charles A. Cain, Ph.D., *also Electrical Engineering and Computer Science*
Paul L. Carson, Ph.D.; *also Radiology;*
Kenneth Casey, M.D.; *also Neurology and Physiology*
Steven L. Ceccio, Ph.D.; *also Mechanical Engineering and Naval Architecture and Marine Engineering*
Don B. Chaffin, Ph.D.; *also Industrial and Operations Engineering and Occupational and Environmental Health*
Thomas L. Chenevert, Ph.D.; *also Radiology*
Timothy E. Chupp, Ph.D.; *also Physics*

John A. Faulkner, Ph.D.; *also Physiology and Gerontology*
Stephen Feinberg, D.D.S., Ph.D.; *also Dentistry*
Jeffrey A. Fessler, Ph.D.; *also Electrical Engineering and Computer Science and Radiology*
Ari Gafni, Ph.D.; *also Biological Chemistry and Gerontology*
Steven A. Goldstein, Ph.D.; *also Orthopaedic Surgery and Mechanical Engineering*
James Grotberg, Ph.D., M.D.; *also Surgery*
Alfred O. Hero III, Ph.D.; *also Electrical Engineering and Computer Science and Statistics*
H. David Humes, M.D.; *also Internal Medicine*
Kimberlee J. Kearfott, Sc.D.; *also Nuclear Engineering and Radiological Sciences and Radiology*
David H. Kohn, Ph.D.; *also Dentistry*
Arthur D. Kuo, Ph.D.; *also Mechanical Engineering and Gerontology*
Ron Larson, Ph.D.; *also Chemical Engineering, Mechanical Engineering, and Macromolecular Science and Engineering*
Simon P. Levine, Ph.D.; *also Physical Medicine and Rehabilitation*
Jennifer J. Linderman, Ph.D.; *also Chemical Engineering*
David C. Martin, Ph.D.; *also Materials Science and Engineering and Macromolecular Science and Engineering*
Laurie McCauley, D.D.S., Ph.D.; *also Dentistry, Pathology and Periodontics*
Joseph Metzger, Ph.D.; *also Molecular and Integrated Physiology, Internal Medicine and Gerontology*
Charles R. Meyer, Ph.D.; *also Radiology*
John C. Middlebrooks, Ph.D.; *also otorhinolaryngology*
Josef M. Miller, Ph.D.; *also Communication Disorders and Otorhinolaryngology*
James Montie, .M.D.; *also Urology*
Michael D. Morris, Ph.D.; *also Chemistry*
Khalil Najafi , Ph.D.; *also Electrical Engineering and Computer Science*
Douglas C. Noll, Ph.D.; *also Radiology*
William O'Brien, Ph.D.; *also Dentistry*
Mathilde Peters, D.M.D., Ph.D.; *also Dentistry*
Stephen Rand, Ph.D.; *also Electrical Engineering and Computer Science and Applied Physics*
Paul A. Sieving, M.D., Ph.D.; *also Ophthalmic Genetics and Ophthalmology and Visual Sciences*
Henry Y. Wang, Ph.D.; *also Chemical Engineering*
Roger C. Wiggins, M.D.; *also Internal Medicine*
Alan S. Wineman, Ph.D.; *also Mechanical Engineering and Macromolecular Science and Engineering*
Kensall D. Wise, Ph.D.; *also Electrical Engineering and Computer Science*
Victor C. Yang, Ph.D.; *also Pharmacy*
Professors Emeritus
David J. Anderson, Ph.D.
Spencer L. BeMent, Ph.D.
Daniel G. Green, Ph.D.
Carl T. Hanks, D.D.S., P.h.D.
Janice M. Jenkins, Ph.D.
Glenn E. Knoll, Ph.D.
Robert Macdonald, Ph.D.
Larry S. Matthews, M.D. A.
Rees Midgley, Jr., Ph.D.
Clyde Owings, M.D., Ph.D.
W. Leslie Rogers, Ph.D.
Albert B. Schultz, Ph.D.
Wen-Jei Yang, Ph.D.
Associate Professors
Neil Alexander, M.D.; *also Internal Medicine and Gerontology*
David Burke, Ph.D.; *also Human Genetics and Gerontology*
J. Brian Fowlkes, Ph.D.; *also Radiology*
William V. Giannobile, D.D.S.; *also Periodontics*
Karl Grosh, Ph.D.; *also Mechanical Engineering* M.
Melissa Gross, Ph.D.; *also Kinesiology and Gerontology*
Scott J. Hollister, Ph.D.; *also Mechanical Engineering and Surgery*
Bret A. Hughes, Ph.D.; *also Ophthalmology and Physiology*
Alan J. Hunt, Ph.D.; *also Gerontology*
Daryl Kipke, Ph.D.; *also Electrical Engineering and Computer Science*
Denise Kirschner, Ph.D.; *also Microbiology and Immunology*
Nicholas Kotov, Ph.D.; *also Chemical Engineering and material Science and Engineering*
Paul Krebsbach, D.D.S., Ph.D.; *also Dentistry*
Christian Lastoskie, Ph.D.; *also Civil and Environmental Engineering*
Peter X. Ma, Ph.D.; *also Macromolecular Science and Engineering, and Dentistry*
Beth Malow, Ph.D.; *also Neurology*
Bernard Martin, Ph.D., D.S.; *also Industrial and Operations Engineering*
Edgar Meyhöfer, Ph.D.; *also Mechanical Engineering*
Mary-Ann Mycek, Ph.D.
Jacques E. Nor, Ph.D.; *also Dentistry*
Malini Raghavan, Ph.D.; *also Department of Microbiology and Immunology*
Ann Marie Sastry, Ph.D.; *also Mechanical Engineering*

Christoph F. Schmidt, Ph.D.; *also Physics*
J. Stuart Wolf, Jr., M.D.; *also Surgery*
Peter J. Woolf, Ph.D.; *also Chemical Engineering*

Assistant Professors

Susan V. Brooks, Ph.D.; *also Physiology; Assistant Research Scientist, Institute of Gerontology*
Joe Bull, Ph.D.
Daniel Ferris, Ph.D.; *also Kinesiology*
Kurt D. Hankenson, Ph.D.; *also Orthopedic Surgery*
Richard Hughes, Ph.D.; *also Surgery*
Marc Kessler, Ph.D.; *also Radiation Oncology*
Jinsang Kim, Ph.D.; *also Chemical Engineering, Macromolecular Science and Engineering, and Materials Science Engineering*
Joerg Lahann, Ph.D.; *also Chemical Engineering, Macromolecular Science and Engineering, and Materials Science Engineering*
Michael Mayer, Ph.D.; *also Chemical Engineering*
Eric Shelden, Ph.D.; *also Cell and Development Biology*
Shuichi Takayama, Ph.D.

Research Professor

James A. Ashton-Miller, Ph.D.; *also Mechanical Engineering and Institute of Gerontology*
Bruce Carlson, Ph.D.; *also Institute of Gerontology*
Larry Schneider, Ph.D.; *also UMTRI*
Duncan G. Steel, Ph.D.; *also Peter S. Fuss Professor of Engineering Industrial Operations and Engineering, Electrical Engineering and Computer Science and Physics*

Assistant Research Scientists

Luis Hernandez, Ph.D.; *also FMRI Laboratory*
Kyle W. Hollman, Ph.D.
Jane Huggins, Ph.D.
Kang Kim, Ph.D.
Lisa Larkin, Ph.D.; *also Institute of Gerontology*
Vijendra K. Singh, Ph.D.; *also Department of Pharmaceutics and Center for BioEngineering Research*

Research Investigator

Keith Cook, Ph.D.; *also Surgery*
Barbara McCreadie, Ph.D.; *also Surgery*
Maria Moalli, D.V.M.; *also Surgery and Unit for Laboratory Animal Medicine and Biomedical Engineering*

Chemical Engineering

The degree program in chemical engineering was established in 1898 at the University of Michigan, one of four schools to introduce the profession in the United States during the last decade of the nineteenth century. The University of Michigan student chapter of the American Institute of Chemical Engineers was the first established by that professional society.

Chemical engineering, among all branches of engineering, is the one most strongly and broadly based upon chemical and life sciences. It has been defined by the directors of the American Institute of Chemical Engineers as "the profession in which a knowledge of mathematics, chemistry, and other natural sciences gained by study, experience, and practice is applied with judgment to develop economical ways of using materials and energy for the benefit of mankind." Because of a broad and fundamental education, the chemical engineer can contribute to society in many functions: research, development, environmental protection, process design, product engineering, plant operation, marketing, sales, and corporate or government administration.

The work of the chemical engineer encompasses many industries, from the manufacture of chemicals and consumer products and the refining of petroleum, to biotechnology, food manufacturing, and the production of pharmaceuticals. Because of this breadth, there are many fields in which chemical engineers may specialize. More information on careers for chemical engineers is available at the AIChE career page, http://www.aiche.org/careers.

The program allows 10 hours of unrestricted electives, 9 hours of life science and technical electives, and 16 hours of humanities and social science electives. A student may use this elective freedom to develop individual abilities and interests, and to prepare for graduate studies or for other professional programs such as law, business administration, or medicine. The electives also provide the opportunity for combined degree programs or for preparation in fields within or related to chemical engineering such as polymers, pharmaceuticals, environmental engineering, chemical-reaction engineering, computers, biochemical processes, natural resource usage, and biotechnology. Students can choose to focus their elective courses by selecting a concentration within their ChE degree. Current concentration areas include: Electrical Engineering-Electronic Devices, Mechanical Engineering, Materials Science Engineering, Life Sciences, and Environmental Engineering.

Facilities

The facilities located in the H.H. Dow and G.G. Brown Buildings include biochemical engineering, catalysis, chemical sensors, light scattering and spectroscopy, petroleum research, fuel cells, nanotechnology, rheology, polymer physics, process dynamics, and surface science laboratories, large- and pilot-scale heat transfer, mass transfer, kinetics, and separations processes teaching laboratories.

Accreditation

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Chemical Engineering

Mission

To provide a solid and current technical foundation that prepares students for a career in chemical engineering or related fields.

Goals

To educate and support diverse students and prepare them to be leaders in chemical engineering or related fields.

Objectives

- To provide students with a solid foundation in chemical engineering, while preparing them for a broad range of career opportunities. The program's primary emphasis is on chemical engineering fundamentals, while allowing students to personalize their curriculum to prepare them for traditional chemical engineering careers and diverse careers in areas such as medicine, law, the environment, and biotechnology.
- To provide opportunities for teamwork, open ended problem solving and critical thinking.

Outcomes

The outcomes we desire are that graduates of the University of Michigan Chemical Engineering Program demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering to chemical engineering problems;
- An ability to design and conduct experiments, as well as to analyze and interpret data;
- An ability to design a system, component, or process to meet desired needs;
- An ability to function on multi-disciplinary teams;
- An ability to identify, formulate, and solve engineering problems;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively orally and in writing;
- The broad education necessary to understand the impact of engineering solutions in a global and societal context;
- A recognition of the need for, and an ability to engage in life-long learning;
- A knowledge of contemporary issues;
- An ability to use the techniques, skills, and modern engineering and computing tools necessary for engineering practice;
- A thorough grounding in chemistry and a working knowledge of advanced chemistry such as organic, inorganic, physical, analytical, materials chemistry, biochemistry, or environmental science, selected based on the student's interest;
- A working knowledge, including safety and environmental aspects, of material and energy balances applied to chemical processes; thermodynamics of physical and chemical equilibria; heat, mass, and momentum transfer; chemical reaction engineering; continuous and stage-wise separation operations; process dynamics and control; process design; and appropriate modern experimental and computing techniques.

Chemical EngineeringUndergraduate Education
Program Advisor
Susan Montgomery, Ph.D., P.E.
Chemical Engineering Department
3094 H.H. Dow
Phone: (734) 936-1890
smontgom@umich.edu
Undergraduate Program Office
Christine Moellering
3090 H.H. Dow
Phone: (734) 647-9876
garmancm@umich.edu

Degree Programs-Dual Degree Opportunities

Students who are interested in more than one program offered by the College may want to work on two bachelor's degrees concurrently. The most common second degrees for Chemical Engineering students are Materials Science and Engineering, Mechanical Engineering, and Electrical Engineering, but dual degrees with other departments can be arranged in consultation with both program advisors.

Combined Degree Opportunities

Students who have a strong desire to continue their chemistry studies as they complete a chemical engineering degree have the option of pursuing simultaneous degrees in Chemical Engineering and Chemistry.
For more information, please visit http://www.engin.umich.edu/dept/cheme/ugoffice/dualdeg.html

Sequential Graduate/Undergraduate Study (SGUS)

The following programs are available for chemical engineering students interested in pursuing joint BSE and MSE and MEng degrees. For more information, please visit http://www.engin.umich.edu/dept/cheme/ugoffice/combinedbsms.html

Contact for B.S.E. Chemical Engineering/M.S.E. Biomedical Engineering
Susan Bitzer
1111 Carl A. Gerstacker
Phone: (734) 763-5290
sbitzer@umich.edu Advisor: Professor David Kohn

B.S.E. in Chemical Engineering/
M.S.E. in Biomedical Engineering

This SGUS program is open to all undergraduate students from Chemical Engineering who have achieved senior standing (85 credit hours or more) and have an overall cumulative GPA of 3.2 or higher. Please contact the Department of Biomedical Engineering for more complete program information.

Contact for B.S.E. Chemical Engineering/M.S.E. Chemical Engineering
Susan Hamlin
3310 G. G. Brown
Phone: (734) 763-1148
hamlins@umich.eduAdvisor: Professor Robert Ziff

B.S.E. in Chemical Engineering/
M.S.E. in Chemical Engineering

A University of Michigan undergraduate with a GPA of 3.5 or greater may apply, after completing the first term of the junior year, for admission to the departmental SGUS combined degree program leading to both the baccalaureate and master's degrees. Up to 9 hours of prior approved elective coursework may be applied toward both degrees (typically leading to a total of 128 for the B.S.E. plus 30 for the M.S.E.) for 149 total credit hours. The 9 double counted elective credits must be acceptable for Rackham credit. The 21 chemical engineering graduate credits may include up to 6 hours of ChemE 698 (directed study or practical training under faculty supervision), or ChemE 695 (research). Please contact the Department of Chemical Engineering for more complete program information.

Contact for B.S.E. Chemical Engineering/M.S.E. in Environmental and Water Resources Engineering
Janet Lineer
108 A EWRE
Phone: (734) 764-8405
janetl@umich.eduAdvisor: Professor Steven J. Wright

B.S.E. in Chemical Engineering/
M.S.E. in Environmental and Water Resources Engineering

The program is open to all Chemical Engineering undergraduate students, who have completed 75 or more credit hours, with a cumulative GPA of at least 3.5. Students who do not meet the GPA requirement may petition the Civil and Environmental Engineering Graduate Committee for admission. Please contact the Environmental and Water Resources Engineering Program Office in the Civil and Environmental Engineering department for more complete program information.

Contact for B.S.E. Chemical Engineering/M.S.E. Industrial Operations Engineering
Advisor: Professor Monroe Keyserling
G620 IOE
Phone: (734) 763-0563
wmkeyser@umich.edu

B.S.E. in Chemical Engineering/M.S.E. in Industrial Operations Engineering

Non-IOE engineering students pursue the IOE master's degree for a number of reasons. Some students use it as the first step toward the IOE Ph.D. degree. Other students pursue the degree to expand their knowledge base in order to enhance their qualifications for professional engineering careers. Among this group, most students select their courses in order to specialize in one of several traditional IOE areas. Applicants must have a minimum GPA of 3.5.

Contact for B.S.E. Chemical Engineering/M.S.E. Macromolecular Science and Engineering
Advisor: Professor David Martin
2022 H.H. Dow
Phone: (734) 763-2316
milty@umich.edu

B.S.E. in Chemical Engineering/
M.S.E. in Macromolecular Science and Engineering

The Master's in Macromolecular Science and Engineering degree is a 30-credit program. There are several specializations or options from which to choose. A 3.2 GPA is required to apply for this program.

Contact for B.S.E. Chemical Engineering/M.Eng. Manufacturing Engineering
Kathy Bishar
1539 Dow
Phone: (734) 764-3312
kbishar@umich.eduAdvisor: Henia Kamil

B.S.E. in Chemical Engineering/
M.Eng. in Manufacturing Engineering

The Master of Engineering in Manufacturing (M.Eng. in Mfg.) degree is an interdisciplinary 30-credit program. This is a professional practice-oriented degree designed to further the education of engineers who already have experienced working in industry and plan to return to an industrial environment after completing their studies. The degree requirements can be completed in one calendar year (12 months). The M.Eng. in Mfg. combines course work from various engineering disciplines (80%) and business (20%). Applicants to this program must have completed 80 or more credits of course work with a GPA of 3.6 or better.

Contact for B.S.E. Chemical Engineering/M.Eng. Pharmaceutical Engineering
Advisor: Professor Henry Y. Wang
3324 G.G. Brown
Phone: (734) 763-5659
hywang@umich.edu

B.S.E. in Chemical Engineering/
M.Eng. in Pharmaceutical Engineering

This five-year B.S.E. in Chemical Engineering and M.Eng. in Pharmaceutical Engineering program allows qualified undergraduate chemical engineering students to complete the practical training but receive a B.S.E. and M.Eng. degrees simultaneously within five years. The Master of Engineering (M.Eng.) degree is intended to focus more on professional practice than the traditional Master of Science in Engineering (M.S.E.) degree. A GPA of 3.5 is required.

Honors Program

The Engineering Global Leadership Honors Program (EGL) allows students to complement their chemical engineering background with courses in the School of Business Administration, and global-focused courses in LS & A. The program produces students capable of communicating across the engineering and business boundary of operating comfortably in another culture. The program leads to two degrees; a BSE ChE and an MSE ChE degree. There is no double counting of credits.

BSE Chemical Engineering/MSE Chemical Engineering
Dr. Susan Montgomery, Chem. Eng., 3094 H.H. Dow, 936-1890
E-mail: smontgom@umich.edu
EGL Webpage: http://www.engin.umich.edu/students/support/egl/

Sample Schedule
B.S.E. (Chemical Engineering)

	Credit Hours	Terms							
		1	2	3	4	5	6	7	8
Subjects required by all programs (51-53 hrs.)									
Mathematics 115+, 116+, 215+, and 216+	16	4	4	4	4	–	–	–	–
Engr 100, Intro to Engr +	4	4	–	–	–	–	–	–	–
Engr 101, Intro to Computers +	4	–	4	–	–	–	–	–	–
Chemistry 130 +[1]	3	3	–	–	–	–	–	–	–
Physics 140/141 +; 240/241 +[2]	10	–	5	–	5	–	–	–	–
Humanities and Social Sciences *(To include a course in economics)*	16	4	–	–	–	4	–	4	4
Advanced Science (18 hrs.)									
Biology/Life Science Elective[3]	3	–	–	–	–	–	3	–	–
Chem 210/211 Struct and Reactiv I and Lab +	5	–	5	–	–	–	–	–	–
Chem 215/216 Struct and Reactiv II and Lab +	5	–	–	5	–	–	–	–	–
Chem 261 Introduction to Quantum Chemistry +	1	–	–	–	1	–	–	–	–
Chem 241/242 Analytical Chemistry	4	–	–	–	–	4	–	–	–
Related Technical Subjects (10 hrs.)									
Materials Elective (MSE 250 or 220) +	4	–	–	–	–	–	–	4	–
Technical Electives[4] (to include at least 2 credits of Engineering)	6	–	–	–	–	–	–	4	2
Program Subjects (37 hrs.)									
ChemE 230 Material and Energy Balances +	4	–	–	4	–	–	–	–	–
ChemE 330 Chemical and Engineering Thermodynamics+	3	–	–	–	3	–	–	–	–
ChemE 341 Fluid Mechanics +	4	–	–	–	4	–	–	–	–
ChemE 342 Heat and Mass Transfer +	4	–	–	–	–	4	–	–	–
ChemE 343 Separation Processes +	3	–	–	–	–	3	–	–	–
ChemE 344 Reaction Engr and Design +	4	–	–	–	–	–	4	–	–
ChemE 360 ChemE Lab I +	4	–	–	–	–	–	4	–	–
ChemE 460 ChemE Lab II	4	–	–	–	–	–	–	–	4
ChemE 466 Process Control and Dynamics	3	–	–	–	–	–	–	3	–
ChemE 487 Chem Proc Sim and Design	4	–	–	–	–	–	–	–	4
Unrestricted Electives (10-12 hrs.)	10-12	–	–	3	–	–	4	–	3
Total	128	15	18	16	17	15	15	15	17

Candidates for the Bachelor of Science degree in Engineering (Chemical Engineering) — B.S.E (Ch.E.) — must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]See department for list of courses that satisfy the Biology/Life Science elective requirement.

[4]Technical electives must include a minimum of 2 credits of engineering elective, with the other 4 credits coming from engineering electives, advanced science, or advanced math courses. See department for list of courses that meet the engineering electives, advanced science and advanced math requirements. At least one course must be outside of Chemical Engineering. Engineering courses are to be at the 200-level or higher. Courses in AOSS are not considered engineering courses for this purpose. See department for other exceptions.

(+) Students must earn a "C-" or better in prerequisite courses indicated by the (+).

All concentrations consist of 12 credits, and must include at least one 300- or 400-level course. Only technical and free electives can be used as part of a concentration. Students may not earn a concentration in a field in which they are also enrolled for a dual degree. See Dr. Montgomery for approval of other electives.

Chemical Engineering Concentrations

Chemical Engineering students have the option of focusing their technical and some free electives in a specific area, fulfilling a concentration within their chemical engineering degree. All concentrations consist of 12 credits, and must include at least one 300 or 400 level course. Only technical and free electives can be used as part of a concentration. Required course(s) and suggested electives are listed below. Students may not earn a concentration in a field in which they are also enrolled for a dual degree. See Dr. Montgomery for approval of other electives.

Electrical Engineering - Electronic Devices

Required – Must take both of these.

EECS 314 – Circuit analysis and electronics (4 cr.)
or EECS 215 – Introduction to circuits (4 cr.)
EECS 320 – Introduction to semiconductor devices (4 cr.)

Electives - Need 4 cr. for a TOTAL of 12 credits. Select from:

EECS 423 – Solid-state device laboratory (4 cr.)
EECS 429 – Semiconductor optoelectronic devices (4 cr.)
EECS 421 – Properties of Transistors (3 cr., req. EECS 230, Electromagnetics I)
EECS 414 – Introduction to MEMS (4 cr.)

NOTE: EECS students are given priority in EECS course enrollments.

Mechanical Engineering

Required – Must take both of these.

ME 211 – Introduction to solid mechanics (4 cr.)
ME 240 – Introduction to Dynamics and Vibrations (4 cr.)

Electives - Need 4 cr. for a TOTAL of 12 credits. Select from:

ME 311 – Strength of materials (3 cr.)
ME 350 – Design and manufacturing II (4 cr., requires ME 250)
ME 400 – Mechanical engineering analysis (3 cr.)
ME 401 – Engineering statistics for manufacturing systems (3 cr.)
ME 420 – Fluid mechanics II (3 cr.)
ME 432 – Combustion (3 cr., requires ME 336 and ME 330)
ME 440 – Intermediate dynamics and vibrations (4 cr.)
ME 471 – Computational heat transfer (3 cr.)
ME 509 – Patents, trademarks and copyrights (3 cr.)

Materials-Science Engineering

Required – Must take.

MSE 350 – Principles of Engineering Materials II (4 cr.)

Electives - Need 8 cr. for a TOTAL of 12 credits. Select from:

MSE 242 – Physics of materials (4 cr.)
MSE 410 – Design and applications of biomaterials (4 cr.)
MSE 412 – Polymeric materials (3 cr.)
MSE 420 – Mechanical behavior of materials (3 cr. requires ME 211)
MSE 465 – Structural and chemical characterization of materials (3 cr., req. MSE 242)
MSE 470 – Physical metallurgy (3 cr.)

Life Sciences

Required – Must take.

Biology 310 – Introductory biochemistry (4 cr.)
(or Biology 311 – Introductory biochemistry – Keller plan (4 cr.) , or Biochemistry 415 – Introduction to biochemistry (3 cr.))

Electives - Need 8 or 9 cr. for a TOTAL of 12 credits. Select from:

Biol. 305 – Genetics (4 cr.)
BME 401 – The human body, its structure and function (4 cr.)
BME 418 – Quantitative cell biology (4 cr.)
BME 419 – Quantitative physiology (4 cr.)
BME 476 – Biofluid mechanics (3 cr.)
BME 479 – Biotransport (4 cr.)
ChE 517 – Biochemical science and technology (3 cr.)
ChE 519 – Pharmaceutical engineering (3 cr.)
ChE 584 – Tissue Engineering (3 cr.)
IOE 465 – Design and analysis of experiments (4 cr., take after ChE 360)

Environmental Engineering

Required – Must take both of these.

CEE 260 – Environmental principles (4 cr.)
CEE 360 – Environmental process engineering (4 cr.)

Electives - Need 4 cr. for a TOTAL of 12 credits. Select from:

CEE 428 – Introduction to groundwater hydraulics (3 cr.), or CEE 526 , but not both
CEE 460 – Design of environmental engineering systems (3 cr.)
CEE 526 – Design of hydraulic systems (3 cr.) or CEE 428, but not both
CEE 581 – Aquatic chemistry (3 cr.)
CEE 582 – Environmental microbiology (3 cr.)
CEE 586 – Industrial Ecology (3 or 4 cr., requires senior standing)
CEE 587 – Water resource policy (3 cr.)
CEE 686 – Case studies in Environmental Sustainability (3 cr.)

Chemical Engineering Graduate Education

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Graduate Degrees

- Master of Science in Engineering (M.S.E.) in Chemical Engineering
- Doctor of Philosophy (Ph.D.) in Chemical Engineering

M.S.E. in Chemical Engineering

The minimum requirement for the M.S.E. degree for a student entering with a baccalaureate degree in chemical engineering is 30 graduate credit hours with an average grade of "B." A thesis is not required. The course work must include at least 21 hours in chemical engineering (courses with ChemE prefix), of which up to 6 credit hours of research are accepted (ChemE 695); and at least two courses outside the chemical engineering program. The required courses are Fluid Flow (ChemE 527), Statistical and Irreversible Thermodynamics (ChemE 538), Chemical Reactor Engineering (ChemE 528), Transport Processes (ChemE 542), Chemical Engineering Research Survey (ChemE 595), and one chemical engineering elective course in mathematics, modeling, or computer simulation. Each student is encouraged to develop a program to fit his or her professional objective and should consult with the graduate advisor concerning a plan of study.

Ph.D. in Chemical Engineering

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the result of the investigation in the form of a dissertation.

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. Candidacy is achieved when the student demonstrates competence in her/his broad field of knowledge through completion of a prescribed set of courses and passing a comprehensive examination.

The course requirements are the same as the M.S.E. degree, plus seven (7) additional credits (must include two 6xx ChE credits). Students must pass a comprehensive examination in chemical engineering and be recommended for candidacy for the doctorate. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.

A pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School Office, 120 Rackham Building, upon request, and on the website at http://www.rackham.umich.edu.

Chemical Engineering Courses

ChemE 230. Material and Energy Balances

Prerequisite: Eng 101, Chem 130, and Math 116. I (4 credits)

An introduction to material and energy balances in chemical engineering applications, including environmental and biological systems. Engineering problem-solving, the equilibrium concept, first law of thermodynamics. Introduction to chemical engineering as a profession.

ChemE 290. Directed Study, Research, and Special Problems

Prerequisite: First or second year standing, and permission of instructor. I, II, III, IIIa, IIIb (to be arranged)

Provides an opportunity for undergraduate students to work in chemical engineering research or in areas of special interest such as design problems. For each hour of credit, it is expected that the student will work three or four hours per week. Oral presentation and/or written report due at end of term.

ChemE 330. Chemical and Engineering Thermodynamics

Prerequisite: ChemE 230. II (3 credits)

Development of fundamental thermodynamic property relations and complete energy and entropy balances. Analysis of heat pumps and engines, and use of combined energy-entropy balance in flow devices. Calculation and application of total and partial properties in physical and chemical equilibria. Prediction and correlation of physical/chemical properties of various states and aggregates. Elements of statistical thermodynamics.

ChemE 341. Fluid Mechanics

Prerequisite: Phys 140, ChE 230, Math 215, P/A by Math 216. II (4 credits)

Fluid mechanics for chemical engineers. Mass, momentum, and energy balances on finite and differential systems. Laminar and turbulent flow in pipes, equipment, and porous media. Polymer processing and boundary layers. Potential, two-phase, and non-Newtonian flow.

ChemE 342. Heat and Mass Transfer

Prerequisite: ChemE 230, ChemE 341, and Math 216. I (4 credits)

Theories and applications of heat and mass transport phenomena, emphasizing their analogies and contrasts. Fourier's law. Steady and unsteady thermal conduction. Heat transfer coefficients. Heat exchangers. Condensation and boiling. Radiation, Kirchoff's law and view factors. Fick's law. Steady and unsteady diffusion. Mass transfer coefficients. Absorbers. Simultaneous heat and mass transfer.

ChemE 343. Separation Processes

Prerequisite: ChemE 230. I (3 credits)

Introduction and survey of separations based on physical properties, phase equilibria, and rate processes. Emphasis on analysis and modeling of separation processes. Staged and countercurrent operations. Includes applications to chemical, biological, and environmental systems.

ChemE 344. Reaction Engineering and Design

Prerequisite: ChemE 330, ChemE 342. II (4 credits)

Fundamentals of chemical reaction engineering. Rate laws, kinetics, and mechanisms of homogeneous and heterogeneous reactions. Analysis of rate data, multiple reactions, heat effects, bioreactors. Design of industrial reactors.

ChemE 360. Chemical Engineering Laboratory I

Prerequisite: ChemE 342. I, II. (4 credits)

Experimentation in thermodynamics and heat, mass, and momentum transport on a bench scale. Measurement error estimation and analysis. Lecture, laboratory, conferences, and reports. Technical communications.

ChemE 412 (MacroSE 412) (MSE 412). Polymeric Materials

Prerequisites: MSE 220 or 250. I (4 credits)

The synthesis, characterization, microstructure, rheology, and properties of polymer materials. Polymers in solution and in the liquid, liquid-crystalline, crystalline, and glassy states. Engineering and design properties, including viscoelasticity, yielding, and fracture. Forming and processing methods. Recycling and environmental issues.

ChemE 414 (MacroSE 414) (Mfg 414) (MSE 414). Applied Polymer Processing

Prerequisites: MSE 413 or equivalent. II (4 credits)

Theory and practice of polymer processing. Non-Newtonian flow, extrusion, injection-molding, fiber, film, and rubber processing. Kinetics of and structural development during solidification. Physical characterization of microstructure and macroscopic properties. Component manufacturing and recycling issues, compounding and blending.

ChemE 444. Applied Chemical Kinetics

Prerequisite: Chem 260 or 261, ChemE 344. I (3 credits)

Fundamentals of chemical and engineering kinetics from a molecular perspective. Relationship between kinetics and mechanisms. Kinetics of elementary steps in gas, liquid, and supercritical fluid reaction media. Gas-solid and surface reactions. Heterogeneous and homogeneous catalysis. Kinetics and mechanisms of chemical processes such as polymerization, combustion, and enzymatic reactions.

ChemE 460. Chemical Engineering Laboratory II

Prerequisites: ChemE 343, ChemE 360. I, II (4 credits)

Experimentation in rate and separation processes on a scale which tests process models. Introduction to the use of instrumental analysis and process control. Laboratory, conferences, and reports. Technology communications.

ChemE 466. Process Dynamics and Control

Prerequisites: ChemE 343, ChemE 344. I (3 credits)

Introduction and process control in chemical engineering. Application of linearization methods to the analysis of open-loop and closed-loop process dynamics. Stability analysis and gain/phase margins. Controller modes and settings. Applications to the control of level, flow, heat exchangers, reactors, and elementary multivariable systems.

ChemE 470. Colloids and Interfaces

Prerequisite: ChemE 343, ChemE 344. I (3 credits)

This is a first course in colloid and interface science. The repulsive forces and attractive forces at interfaces are described along with the dynamics of the interfaces. Topics include the stability of macroemulsions, the formulation and properties of microemulsions, and surface metal-support interactions of catalysts.

ChemE 472. Polymer Science and Engineering

Prerequisite: Preceded or accompanied by ChemE 344. II(4 credits)

Polymer reaction engineering, characterization and processing for chemical engineers. Polymerization mechanisms, kinetics and industrial equipment. Thermodynamics of polymer solutions, morphology, crystallization and mechanical properties. Polymer processing equipment and technology. Adhesives, diffusion in polymers, reactive polymeric resins and biological applications of macromolecules.

ChemE 487. Process Simulation and Design
Prerequisite: ChemE 360 and ChemE 344 and (MSE 250 or MSE 220). I, II (4 credits)
Process conceptualization and design. Computer simulation of process and components. A major team design project with progress reports, oral presentation, and a technical report with engineering drawings and economics.

ChemE 490. Advanced Directed Study, Research and Special Problems
Prerequisite: ChemE 230 & ChemE 341 or ChemE 290 or equivalent. I, II, III, IIIa, IIIb (to be arranged)
Provides an opportunity for undergraduate students to work in chemical engineering research or in areas of special interest such as design problem For each hour of credit, it is expected that the student will work three or four hours per week. Oral presentation and/or written report due at end of term. Not open to graduate students.

ChemE 496. Special Topics in Chemical Engineering
Prerequisite: permission of instructor. I, II, III, IIIa, IIIb (1-16 credits)
Selected topics pertinent to chemical engineering.

ChemE 510. Mathematical Methods in Chemical Engineering
Prerequisite: graduate standing, differential equations. II (3 credits)
Linear algebra, ordinary and partial differential equations, integral equations with chemical engineering applications. Analytical techniques and preliminaries for numerical methods, including: spectral analysis, orthogonal polynomials, Green's functions, separation of variables, existence and uniqueness of solutions.

ChemE 511 (MacroSE 511) (MSE 511). Rheology of Polymeric Materials
Prerequisite: a course in fluid mechanics or permission of instructor. (3 credits)
An introduction to the relationships between the chemical structure of polymer chains and their rheological behavior. The course will make freque reference to synthesis, processing, characterization, and use of polymers for high technology applications.

ChemE 512 (MacroSE 512) (MSE 512). Physical Polymers

Prerequisite: senior or graduate standing in engineering or physical science. (3 credits)

Structure and properties of polymers as related to their composition, annealing and mechanical treatments. Topics include creep, stress-relaxation, dynamic mechanical properties, viscoelasticity, transitions, fracture, impact response, dielectric properties, permeation, and morphology.

ChemE 517 (MFG 517). Biochemical Engineering

Prerequisite: ChemE 344, and Biochem 415 or equivalent; permission of instructor. II (3 credits)

Concepts necessary in the adaptation of biological and biochemical principles to industrial processing in biotechnology and pharmaceutical industries. Topics include rational screening, functional genomics, cell cultivation, oxygen transfer, etc. Lectures, problems, and library study will be used.

ChemE 519 (Pharm 519). Pharmaceutical Engineering

Prerequisite: Senior or graduate standing, permission by instructor. I (3 credits)

Concepts necessary in the adaptation of engineering principles to pharmaceutical and life sciences-related industries. Topics include process engineering in drug discovery, high throughput characterization and optimization of new chemical entities, solid-state engineering and intelligent pharmaceutical manufacturing systems. Lectures, problems, Internet and library study will be used to develop the ideas presented.

ChemE 527. Fluid Flow

Prerequisite: ChemE 341. (3 credits)

Applications of fluid dynamics to chemical engineering systems. Theory and practice of laminar and turbulent flow of Newtonian and non-Newtonian fluids in conduits and other equipment. Multi-phase flow. Introduction to the dynamics of suspended particles, drops, bubbles, foams, and froth. Selected topics relevant to chemical and other engineering disciplines.

ChemE 528. Chemical Reactor Engineering

Prerequisite: ChemE 344. I (3 credits)

Analysis of kinetic, thermal, diffusive, and flow factors on reactor performance. Topics include batch, plug flow, backmix reactors, empirical rate expressions, residence time analysis, catalytic reactions, stability, and optimization.

ChemE 530 (Bioinformatics 530). Introduction to Bioinformatics, Systems Biology and Predictive Modeling

Prerequisite: none. I (3 credits)

This course introduces the characteristics of genomic and other high throughput expression technologies. Background on molecular biology, algorithms and relational databases will be covered and the focus will be (i) Relationship between emerging technology data and biological functions and (ii) Application of systems biology and predictive modeling in drug discovery.

ChemE 538. Statistical and Irreversible Thermodynamics

Prerequisite: ChemE 330. (3 credits)

The laws of probability and statistics are applied to microscopic matter to yield properties of macroscopic systems. Relations between classical and statistical thermodynamics are developed. Coupling of irreversible processes is treated through the entropy balance and microscopic reversibility.

ChemE 542. Intermediate Transport Phenomena

Prerequisite: graduate standing. (3 credits)

Foundations of transport phenomena. Heat and mass transfer with chemical reaction in three dimensions, selective motion. Unsteady energy and mass balances in three dimensions. Distributions in more than one variable. Boundary layer theory. Estimation of interfacial transport coefficients. Dispersive flows: Taylor Dispersion. Application to equipment design.

ChemE 543. Advanced Separation Processes

Prerequisite: ChemE 343. II (3 credits)

Forces for adsorption, equilibrium adsorption isotherms, sorbent materials, pore size distribution, heterogeneity, predicting mixture adsorption, rate processes in adsorption/adsorbers, adsorber dynamics, cyclic adsorption processes, temperature and pressure swing adsorption, membrane separation processes, polymer membranes, dialysis electrolysis, pervaporation, reverse osmosis, research projects.

ChemE 548. Electrochemical Engineering

Prerequisite: ChemE 344. (3 credits)

Analysis of electrochemical systems from a theoretical and practical point of view. Topics include the application of electrochemical thermodynamics and kinetics to batteries, fuel cells, electroplating, electrosynthesis, and corrosion.

ChemE 554. (MSE 554). Computational Methods in MS&E and ChemE

Prerequisite: none. I (3 credits)

Broad introduction to the methods of numerical problem solving in Materials Science and Chemical Engineering. Topics include numerical techniques, computer algorithms, and the formulation and use of computational approaches for the modeling and analysis of phenomena peculiar to these disciplines.

ChemE 557. (MSE 557). Computational Nanoscience of Soft Matter

Prerequisites: Differential equations course, and a statistical thermodynamics or statistical mechanics course. I (3 credits)

Provides an understanding of strategies, methods, capabilities, and limitations of computer simulation as it pertains to the modeling and simulation of soft materials at the nanoscale. The course consists of lectures and hands-on, interactive simulation labs using research codes and commercial codes. Ab initio, molecular dynamics, Monte Carlo and mesoscale methods.

ChemE 558. (MATS 558). Foundations of Nanotechnology

Prerequisite: senior or graduate standing. I (3 credits)

The focus of this course is on the scientific foundations of nanotechnology. The effects of nanoscale dimensions on optical, electrical, and mechanical properties are explained based on atomistic properties and related to applications in electronics, optics, structural materials and medicine. Projects and discussions include startup technological assessment and societal implications.

ChemE 580. (Eng 580). Teaching Engineering

Prerequisite: doctoral candidate. II alternate years (3 credits)

Aimed at doctoral students from all engineering disciplines interested in teaching. Topics include educational philosophies, educational objectives, learning styles, collaborative and active learning, creativity, testing and grading, ABET requirements, gender and racial issues. Participants prepare materials for a course of their choice, including course objectives, syllabus, homework, exams, mini-lecture.

ChemE 584 (BiomedE 584) (Biomaterials 584). Tissue Engineering

Prerequisite: Bio 311, ChemE 517, or equivalent biology course; senior standing. I (3 credits)

Fundamental engineering and biological principles underlying field of tissue engineering are studied, along with specific examples and strategies to engineer specific tissues for clinical use (e.g., skin). Student design teams propose new approaches to tissue engineering challenges.

ChemE 595. Chemical Engineering Research Survey
I (1 credit)
Research activities and opportunities in Chemical Engineering program. Lectures by University of Michigan faculty and guest lecturers. Topics are drawn from current research interests of the faculty.

ChemE 596. (Pharm 596). Health Science and Engineering Seminar
Prerequisite: graduate standing. I, II (1 credit)
This seminar will feature invited speakers from pharmaceutical, biomedical, and other life sciences-related industries, and academic institutions.

ChemE 597. (Pharm 597). Regulatory Issues for Scientists, Engineers, and Managers
Prerequisite: permission of instructor. I (2 credits)
Science- and technology-based rationale behind various regulatory issues involved in pharmaceutical and related industries.

ChemE 598. Advanced Special Topics in Chemical Engineering
Prerequisite: none. I, II, IIIa, IIIb, III (min. 2, max. 4 credits)
Selected topics pertinent to chemical engineering.

ChemE 616. (BiomedE 616). Analysis of Chemical Signaling
Prerequisite: Math 216, Biochemistry 415. II (3 credits)
Quantitative analysis of chemical signaling systems, including receptor/ligand binding and trafficking, signal transduction and second messenger production, and cellular responses such as adhesion and migration.

ChemE 617. (Mfg 617). Advanced Biochemical Technology
Prerequisite: ChemE 517 or permission of instructor. II alternate years (3 credits)
Practical and theoretical aspects of various unit operations required to separate and purify cells, proteins, and other biological compounds. Topics covered include various types of chromatography, liquid/liquid extractions, solid/ liquid separations, membrane processing and field-enhanced separations. This course will focus on new and non-traditional separation methods.

ChemE 628. Industrial Catalysis
Prerequisite: ChemE 528. (3 credits)
Theoretical and experimental aspects of heterogeneous catalysis and surface science. Design, preparation, and characterization of catalysts. Kinetic of heterogeneous catalytic reactions, thermal and diffusional effects in catalytic reactors. Case studies of important industrial catalytic processes.

ChemE 629. (Physics 629). Complex Fluids
Prerequisite: ChemE 527. II alternate years (3 credits)
Structure, dynamics, and flow properties of polymers, colloids, liquid crystals, and other substances with both liquid and solid-like characteristics.

ChemE 686 (CEE 686) (ENSCEN 686). Case Studies in Environmental Sustainability
Prerequisite: Senior or Graduate Standing. I II (2-3 credits)
Case studies focusing on utilization of principles of environmental sustainability in professional practice. Development of environmental literacy through study of both current and historical environmental issues.

ChemE 695. Research Problems in Chemical Engineering
(to be arranged)
Laboratory and conferences. Provides an opportunity for individual or group work in a particular field or on a problem of special interest to the student. The program of work is arranged at the beginning of each term by mutual agreement between the student and a member of the faculty. Any problem in the field of chemical engineering may be selected. The student writes a final report on his project.

ChemE 696. Selected Topics in Chemical Engineering
Selected topics pertinent to chemical engineering.

ChemE 697. Problems in Chemical Engineering
(to be arranged)

ChemE 698. Directed Study in Chemical Engineering
I, II, III, IIIa, IIIb (1-16 credits)
This project course is intended to provide students with relevant industrial project experience. The program of work is arranged at the beginning of each term by mutual agreement between the student and a member of the faculty. Any problem in the field of chemical engineering may be selected. The student writes a final report on his project.

ChemE 751 (Chem 751) (MacroSE 751) (MSE 751) (Physics 751). Special Topics in Macromolecular Science
Prerequisite: permission of instructor. (2 credits)
Advanced topics of current interest will be stressed. The specific topics will vary with the instructor.

ChemE 895. Seminar in Chemical Engineering
(to be arranged)

ChemE 990. Dissertation/Pre-Candidate
I, II, III, IIIa, IIIb (1-8 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

ChemE 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, III, IIIa, IIIb (4 or 8 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Chemical Engineering Faculty

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Professors

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Sharon C. Glotzer, Ph.D.; *also Macromolecular Science and Engineering, and Physics*
Erdogan Gulari, Ph.D., *Donald L. Katz Collegiate Professor of Chemical Engineering; also Macromolecular Science and Engineering*
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Robert Ziff, Ph.D.; *also Macromolecular Science and Engineering*

Professors Emeritus

Dale E. Briggs, Ph.D., P.E.
Brice Carnahan, Ph.D., P.E.
Rane L. Curl, Sc.D.
Francis M. Donahue, Ph.D.
Robert H. Kadlec, Ph.D., P.E.
John E. Powers, Ph.D.
Mehmet Rasin Tek, Ph.D., P.E.
James Oscroft Wilkes, Ph.D.
Albert F. Yee, Ph.D.; *also Materials Science and Engineering and Macromolecular Science and Engineering*
Gregory S. Y. Yeh, Ph.D.
Edwin Harold Young, M.S.E., P.E.

Associate Professors

Nicholas A. Kotov, Ph.D.
Michael J. Solomon, Ph.D.

Assistant Professors

Omolola Eniola, Ph.D.; *also Biomedical Engineering*
Jinsang Kim, Ph.D.; *also Materials Science and Engineering*
Joerg Lahann, Ph.D.
Suljo Linic, Ph.D.
Michael Mayer, Ph.D.; *also Biomedical Engineering*
Angela Violi, Ph.D.; *also Mechanical Engineering*
Peter J. Woolf, Ph.D.; *also Biomedical Engineering*

Lecturers

Susan M. Montgomery, Ph.D., P.E.

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Civil and Environmental Engineering

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Civil and environmental engineers design, plan and construct infrastructure systems including buildings, bridges, highways, airports, tunnels, pipelines, channels, waste-water systems, waste site, remediation systems, power generating plants, manufacturing facilities, dams and harbors. These infrastructure systems are key to sustaining human development and activities, and civil and environmental engineers must consider technical as well as economic, environmental, aesthetic and social aspects.

Many projects are sufficiently large and complex that civil and environmental engineers seldom work alone, but usually are part of an interdisciplinary team, and so benefit from a broad-based education.

The Civil and Environmental Engineering department offers several areas of specialization including: Construction Engineering and Management, Environmental Engineering, Geotechnical Engineering, Hydraulic and Hydrological Engineering, Materials and Highway Engineering, and Structural Engineering. For more information on these fields, please go here.

Students who do well in their undergraduate program are encouraged to consider graduate work and may take some of their electives in preparation for graduate study. The Sequential Graduate/ Undergraduate Study (SGUS) programs available in this department are described here.

Information and assistance regarding fellowships and assistantships for graduate studies may be obtained in the Academic Services Office of the Department of Civil and Environmental Engineering.

Facilities
The Civil and Environmental Engineering departmental offices are in the George Granger Brown Building on the North Campus. The G. G. Brown Building houses several state-of-the-art research and teaching laboratories in the area of construction engineering and management structures and materials, hydraulics and soil mechanics.

The Environmental and Water Resources Engineering Building and the west wing of the Engineering Research Building house the laboratories for environmental and water resources engineering. Equipment is available for physical and biological studies, analytical determinations, and data analyses in environmental science as well as in water-quality engineering.

Accreditation
This program is accredited for the degree B.S.E. in Civil Engineering by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Civil and Environmental Engineering

Mission
To be a leader in the education of civil and environmental engineers in the application of engineering principles to infrastructure and environmental problems with emphasis on: infrastructure design, construction, rehabilitation, monitoring, and management; remediation technologies and pollution prevention; watershed management; and mitigation of natural hazards and risk assessment.

Goals
- To recruit, educate, and support excellent, diverse students and prepare them to be leaders in the design and construction of civil and environmental systems.
- To have the leading program in civil and environmental engineering; one that provides an engineering education that effectively prepares the student to adapt to a changing profession and a dedication to life-long learning; concluding in the B.S.E. in Civil Engineering and a variety of graduate degrees.

Objectives
- To provide students with a solid foundation in civil and environmental engineering while preparing them for success in graduate education and a broad range of career opportunities. The program's primary emphasis is on the scientific, engineering, and design aspects of infrastructure and environmental systems.
- To provide opportunities for teamwork, open ended problem solving and critical thinking.
- To provide skills for effective communication of technical/professional information in written, oral, visual and graphical form.
- To provide opportunities for awareness of moral, ethical, legal and professional obligations to protect human health, human welfare, and the environment.

Outcomes

The outcomes we desire are that graduates of the University of Michigan Civil and Environmental Engineering Program demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering within civil engineering;
- An ability to design and conduct experiments, and to critically analyze and interpret data;
- An ability to design a system, component or process to meet desired needs;
- An ability to function in multi-disciplinary teams;
- An ability to identify, formulate and solve engineering problems;
- An understanding of professional and ethical responsibility;
- An ability for effective oral, graphic and written communication;
- An understanding of the impact of engineering solutions in a global and societal context;
- A recognition of the need for, and an ability to engage in, life-long learning;
- A knowledge of contemporary issues that affect civil engineering;
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice;
- A proficiency in a minimum of four major civil engineering areas;
- An understanding of professional practice issues and the importance of licensure.

Civil and Environmental Engineering Undergraduate Education

Program Advisor
Professor Radoslaw Michalowski
2364 G. G. Brown Building
Phone: (734) 763-2146
rlmich@umich.edu

B.S.E in Civil Engineering
M.S.E. in Civil Engineering

The program is open to all Civil and Environmental Engineering undergraduate students, who have completed 80 or more credit hours with a cumulative GPA of at least 3.5. Students who have a GPA of at least 3.2 may petition the Civil and Environmental Engineering Graduate Committee for admission. Please contact the Department of Civil and Environmental Engineering for more complete program information.

Janet Lineer
janetl@umich.edu
Contact for B.S.E. Civil Engineering/M.S.E. in Construction Engineering and Management
2334A G.G. Brown Building
Phone: (734) 764-8405
Advisor: Professor Photios G. Ioannou

B.S.E. in Civil Engineering
M.S.E. in Construction Engineering and Management
B.S.E./M.Eng. in Construction Engineering and Management

The program is open to all Civil and Environmental Engineering undergraduate students who have completed 80 or more credit hours, with a cumulative GPA of at least 3.5. Students who have a GPA of at least 3.2 may petition the Civil and Environmental Engineering Graduate Committee for admission. Please contact the Department of Civil and Environmental Engineering for complete program information.

Janet Lineer
janetl@umich.edu
Contact for B.S.E. Civil Engineering/M.S.E. Environmental Engineering
2334A G.G. Brown Building
Phone: (734) 764-8405
Advisor: Professor Steven J. Wright

B.S.E. in Civil Engineering
M.S.E. in Environmental Engineering

The program is open to all Civil and Environmental Engineering undergraduate students, who have completed 80 or more credit hours with a cumulative GPA of at least 3.5, and who have selected an area of concentration. Students who have a GPA of at least 3.2 may petition the Civil and Environmental Graduate Committee for admission. Please contact the Department of Civil and Environmental Engineering for more complete program information.

Sample Schedule

B.S.E. (Civil Engineering)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engr 100, Intro to Engr	4	4	-	-	-	-	-	-	-
Engr 101, Intro to Computers +	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 211[1]	5	5	-	-	-	-	-	-	-
Physics 140/141, Physics 240/241[2]	10	-	5	5	-	-	-	-	-
Humanities and Social Sciences *(includes one 3 or 4 credit economics course)*	16	4	4	-	-	4	-	-	4
Advanced Mathematics (8 hrs.)									
CEE 270 Statistical Methods	4	-	-	4	-	-	-	-	-
CEE 303, Computational Methods	4	-	-	-	-	-	4	-	-
Technical Core Subjects (20 hrs.)[3]									
CEE 230, Thermodynamics	4	-	-	-	4	-	-	-	-
CEE 211, Statics and Dynamics	4	-	-	4	-	-	-	-	-
CEE 212, Solid and Structural Mechanics	4	-	-	-	4	-	-	-	-
CEE 260, Environmental Principles	4	-	-	-	4	-	-	-	-
CEE 325, Fluid Mechanics	4	-	-	-	-	4	-	-	-
Program Subjects (27 hrs.)									
CEE 445, Engineering Properties of Soil	4	-	-	-	-	4	-	-	-
CEE 412, Structural Engineering	4	-	-	-	-	4	-	-	-
CEE 351, Civil Engineering Materials	4	-	-	-	-	-	4	-	-
CEE 360, Environmental Process Engineering	4	-	-	-	-	-	4	-	-
CEE 421, Hydrology and Hydraulics	4	-	-	-	-	-	-	4	-
CEE 431, Construction Contracting	3	-	-	-	-	-	-	3	-
CEE 402, Professional Issues & Design	4	-	-	-	-	-	-	-	4
Technical Electives (9 hrs.)[4]	9	-	-	-	-	-	-	6	3
Construction: CEE 534, CEE 536, CEE 537, CEE 538									
Hydraulics/Hydrology: CEE 526*, CEE 428, CEE 521, CEE 590									
Environmental: CEE 460*, CEE 581, CEE 582									
Materials: CEE 547* CEE 554*									
Geotechnical: CEE 542, CEE 545, CEE 546									
Structural: CEE 413*,CEE 415*, CEE 512									
Unrestricted Electives (9-12 hrs.)	9-12	-	-	-	-	-	3	3	3
Total	128	17	17	17	16	16	15	16	14

Candidates for the Bachelor of Science degree in Engineering (Civil Engineering) - B.S.E. (C.E.) - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

*Mandatory Courses in that focus area.

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]CEE will accept equivalent courses offered by other departments in the College of Engineering.

[4]At least two of the three technical electives must be in the same focus area. The third technical elective may be selected from the same focus area as the first two technical electives. The following CEE courses are 3 credit hours: all technical electives and CEE 431.

Civil and Environmental Engineering Concentrations

The following are areas of concentration within Civil and Environmental Engineering at Michigan:

Construction Engineering and Management
Planning, estimating, scheduling, and managing the construction of engineered facilities using modern construction methods, materials, and equipment. Business and legal principles of construction contracting. Planning, analysis, design, and optimization of field construction operations. Simulation and visualization of construction processes and products. Computer applications and information technology in design, construction, operations, and maintenance of constructed facilities.

Environmental Engineering
The principles, design, and methods for implementation of sustainable environmental and earth systems; water resource development, management, conservation, and systems design; engineering of water quality and pollution control processes and systems; treatment, distribution and collection networks and infrastructures for optimal municipal and industrial water use, recovery, and recycle; environmental design for efficient energy and resource utilization and minimization of water and air pollution and solid wastes generation; modeling of the fate and transport of contaminants in environmental media and systems and quantitative assessment of associated human and ecological risks.

Geotechnical Engineering
The evaluation of soil properties and environmental conditions in foundations of earth-supported structures; mass stability in excavations and subsurface construction; use of soil characteristics and properties and soil classification in design and construction of highways, railways, airports, and other surface facilities; behavior of soils subjected to dynamic loading.

Hydraulic and Hydrological Engineering
The application of the fundamental principles of hydraulics and hydrology to the optimum development of surface water and ground-water resources; the study of flood prediction and flood control, flow and contaminant transport in surface and ground waters, transients in pipelines and channels, coastal engineering, and design of structures to interface with the water environment.

Materials and Highway Engineering
The analysis, engineering, and testing of civil engineering materials pertaining to infrastructure renewal and high-performance structures, including the study of infrastructure rehabilitation (including bridge and pavement technology), advanced emerging materials (including cement-based composites, polymers, and ceramics), micromechanics of composite materials, durability of materials, and innovative materials and structures.

Structural Engineering
The theory, analysis, design, and construction of structures such as bridges, buildings, towers, and housing, involving the use of steel, reinforced concrete, prestressed concrete, fiber reinforced concrete, advanced FRP composites, and wood; studies of inelastic behavior of materials and structures; studies of dynamic forces and their effects on structures.

Civil and Environmental Engineering Graduate Education

Graduate Advisor
Janet Lineer
2334A G. G. Brown Building
2350 Hayward St.
Ann Arbor, Michigan 48109-2125
Phone: (734) 764-8495/Fax: (734) 764-4292
janetl@engin.umich.edu

Graduate Degrees
- Master of Science in Engineering (M.S.E.) in Civil Engineering
- Master of Science in Engineering (M.S.E.) in Construction Engineering and Management
- Dual M.S.E. in Construction Engineering and Management/Master of Architecture
- Dual M.S.E. in Construction Engineering and Management/Master of Business Administration
- Master of Engineering (M.Eng.) in Construction Engineering and Management
- Master of Engineering (M.Eng.) in Structural Engineering
- Dual M.Eng. in Construction Engineering and Management/Master of Architecture
- Dual M.Eng. in Construction Engineering and Management/Master of Business Administration
- Master of Science in Engineering (M.S.E.) in Environmental Engineering
- Doctor of Philosophy (Ph.D.) in Civil Engineering
- Doctor of Philosophy (Ph.D.) in Environmental Engineering

Master of Science Programs/ Master of Engineering Programs
The Department of Civil and Environmental Engineering (CEE) offers three Master of Science in Engineering (M.S.E.) degree programs and one Master of Engineering (M.Eng.) degree program.

The M.S.E. and M.Eng. programs require 30 credit hours of graduate work (typically 10 courses) and do not require a thesis or other major research project. At least two courses, of which one is mathematically oriented, must be taken in departments other than CEE.

The Graduate Record Examination (GRE) is required for application to the M.S.E. program. Letters of recommendation are also required. Degree programs differ in the undergraduate degrees they require for regular admission.

Students who do not meet undergraduate degree requirements for regular admission may be granted conditional admission. Students may be required to take courses without graduate credit to remedy the deficiencies in their undergraduate programs.

M.S.E. in Civil Engineering
This program requires at least 15 hours of CEE courses. A student should expect to take at least eight hours in the area of specialization but will not be permitted to apply more than 21 hours in one area of specialization toward the M.S.E. degree. Study programs are available in the following areas of specialization:

- Construction Engineering and Management
- Geotechnical Engineering
- Hydraulic and Hydrologic Engineering
- Materials and Highway Engineering
- Structural Engineering

Regular admission is open to students holding an undergraduate degree in Civil Engineering or an equivalent.

M.S.E. in Construction Engineering and Management
This program requires at least 18 hours of graduate courses in the Construction Engineering and Management Program. Also available are dual degree programs by which a student can receive a M.S.E. in Construction Engineering and Management and a Master of Architecture degree or a Master of Business Administration degree. Regular admission is open to students holding a degree in any engineering discipline.

M.Eng. in Structural Engineering
This degree program requires 30 credit hours with at least 15 hours of graduate courses in structural engineering and at least 6 hours of graduate credit in a minor area of emphasis. A feature of the program is the structural engineering project course that will include seminars and some mentorship from a practicing structural engineer. An informal dual degree program, through which a student can receive the M.Eng. in Structural Engineering and a Master of Architecture degrees, is available. Regular admission is open to students holding a degree in any engineering discipline. Applicants with bachelor's degrees in architecture or other non-engineering programs may be granted admission if they have taken at least three semesters of calculus and a year of physics.

M.S.E. in Environmental Engineering
This program requires at least 15 hours of graduate courses in the Environmental and Water Resources Engineering Program. Specific course requirements are given in the departmental Guidelines for this MSE degree. Students holding an engineering or science degree will be considered for regular admission.

Environmental Sustainability Concentration
The Department of Civil and Environmental Engineering participates actively in the College of Engineering Concentrations in Environmental Sustainability (ConsEnSus) Program for M.S., M.S.E. and Ph.D. students. The general description of the ConsEnSus program can be found here. Students interested in further details on implementation of this program in the Department of Civil and Environmental Engineering should contact one of the Department ConsEnSus Advisors.

Ph.D. Programs
CEE offers the Doctor of Philosophy (Ph.D.) with two designations: Ph.D. in Civil Engineering and Ph.D. in Environmental Engineering. Ph.D. programs usually include 50 to 60 hours of graduate coursework beyond the bachelor's degree level. Foreign languages are not required. The focus of doctoral studies is the student's dissertation research, which must make a significant contribution to professional knowledge in the field. Major steps toward the Ph.D. degree include:

- qualifying examination (usually taken after completion of one or two terms of coursework beyond the master's degree)
- appointment of dissertation committee
- completion of coursework and English proficiency requirement
- preliminary examination
- advancement to candidacy
- completion of dissertation
- final oral examination

Admission to the Ph.D. program is granted only to students who show promise and provide sufficient evidence that they can meet scholastic requirements of study, including independent research, at an advanced level. The qualifying examination is only open to students with a GPA of better than B+.

Ph.D. in Civil Engineering
Areas of specialization include:

- Construction Engineering and Management
- Geotechnical Engineering
- Hydraulic and Hydrologic Engineering
- Materials and Highway Engineering
- Structural Engineering

Ph.D. in Environmental Engineering
Areas of specialization include:

- Environmental Chemistry and Microbiology
- Fate and Transport of Surface and Groundwater Contaminants
- Hazardous Waste Treatment and Management
- Water Quality Engineering
- Environmental Policy and Economics

Civil and Environmental Engineering Fields of Study
Programs of advanced study, research, and design are available in the five major areas listed below. The strength of the curriculum is enhanced by a variety of complementary programs of study and research available throughout the University of Michigan.

Construction Engineering and Management

- Construction Decision and Support Systems
- Construction Management and Cost Engineering
- Construction Methods and Equipment
- E-Commerce and Information Technologies
- Human Resources in Construction
- Occupational Health and Safety Planning, Scheduling, and Layout
- Productivity Analysis and Improvement

Environmental and Water Resources Engineering
Graduate degrees offered in either Civil or Environmental Engineering.

- Contaminant Fate and Transport
- Water Quality and Process Engineering
- Environmental Chemistry and Microbiology
- Hazardous Substance Treatment and Control Technology
- Hydraulics and Fluid Mechanics
- Sustainable Systems Engineering
- Management Policy and Economics
- Surface and Ground Water Hydrology

Geotechnical Engineering

- Foundation Engineering
- Soil and Site Improvement
- Stability of Earth Masses
- Site Characterization
- Earthquake Engineering and Soil Dynamics
- Geoenvironmental Technology
- Engineering Properties of Soils
- Rock Mechanics and Engineering Geology
- Geosynthetics Geoenvironmental Technology

Materials and Highway Engineering

- High-Performance Cement-Based Fibrous Composites
- Materials for Infrastructure Rehabilitation
- Materials/Structure Interactions
- Micromechanics and Fracture Mechanics of Materials
- Durability of Materials
- Pavement Materials and Geotextiles

Structural Engineering

- Advanced Composites in Construction
- Bridge Structures
- Earthquake Engineering and Structural Dynamics
- Elastic and Inelastic Analysis/Design
- Material and Member Behavior
- Reliability and Risk Analysis
- Repair and Strengthening of Structures

Civil and Environmental Engineering Courses

CEE 211. Statics and Dynamics
Prerequisite: Physics 140. I, II (4 credits)
Statics: review of vector mathematics; moment and force resultants; static equilibrium in two & three dimensions; centroids; center of gravity; distributed loadings. Dynamics: review of concepts of velocity and acceleration; dynamics of particles and rigid bodies; concepts of work, energy, momentum; introduction to vibrations. Four lectures per week.

CEE 212. Solid and Structural Mechanics
Prerequisite: CEE 211 or equivalent. II (4 credits)
Fundamental principles of solid and structural mechanics and their application in engineering disciplines. Covered: concepts of stress and strain, stress and strain transformations, axial, torsion, bending and combined loading, elastic deformations, energy concepts, and strength design principles. Lectures and laboratory.

CEE 230. Thermodynamics
Prerequisites: Chem 125 & 130 or Chem 210 & 211; Math 116. I, II (4 credits)
Engineering Thermodynamics. First and second law applications for closed and open systems. Heat and refrigeration cycles. Physical properties of fluids and equations of state. Phase equilibria for pure fluids and fluid mixtures. Chemical reaction equilibria and aqueous-phase chemistry. Combustion processes. Vapor-liquid and solid-liquid equilibria.

CEE 260. Environmental Principles
Prerequisites: Chem 130, Math 116. I, II (4 credits)
Basic principles which govern the use of chemicals, their fate and transport in the environment, and their removal from waste streams. Toxicology, perception of risk, government regulation, and ethics as they pertain to the design of treatment processes for the removal of environmental contaminants. Pollution prevention.

CEE 270. Statistical Methods for Data Analysis and Uncertainty Modeling
Prerequisites: Math 116 and Engin 101
Introductory probability and statistics with emphasis on data analysis and uncertainty modeling for engineering and environmental systems. Descriptive statistics, graphical representation of data, linear regression, correlation, discrete and continuous probability distributions, conditional probability, estimation, statistical inference, hypothesis testing, sampling design, load factors, extreme events, reliability analysis. Lecture, recitation and computation.

CEE 303 (Eng 303). Computational Methods for Engineers and Scientists
Prerequisites: Eng 101, Math 216. II (4 credits)
Applications of numerical methods to infrastructure and environmental problems. Development of mathematical models and computer programs using a compiled language (FORTRAN). Formulation and solution of initial and boundary-value problems with emphasis on structural analysis, fluid flow, and transport of contaminants. Lecture, recitation and computation.

CEE 325. Fluid Mechanics
Prerequisites: CEE 211 and CEE 230. I (4 credits)
Principles of mechanics applied to real and ideal fluids. Fluid properties and statics; continuity, energy, and momentum equations by control volume analysis; differential equations of motion for laminar and turbulent flow; dimensional analysis and similitude; boundary layers, drag, and lift; incompressible flow in pipes; fluid measurement and turbomachinery. Lectures and laboratory.

CEE 351. Civil Engineering Materials
Prerequisite: CEE 212 or equivalent. I, II (4 credits)
Discussion of basic mechanical and physical properties of a variety of civil engineering materials such as concrete, asphalt, wood and fiber composites. Evaluation and design for properties, load-time deformation characteristics, response to typical service environments. Lecture and laboratory.

CEE 360. Environmental Process Engineering
Prerequisites: CEE 260, CEE 325. II (4 credits)
An introduction to the analysis, characterization, and modeling of environmental processes; physical, chemical, and biological processes and reactor configurations commonly used for water quality control; applications to the development and design of specific water and wastewater treatment operations; discussion of economic and legislative constraints and requirements.

CEE 402. Professional Issues and Design
Prerequisite: senior standing. II (4 credits)
Multidisciplinary team design experience including consideration of codes, regulations, alternate solutions, economic factors, sustainability, constructability, reliability, and aesthetics in the solution of a civil or environmental engineering problem. Professionalism and ethics in the practice of engineering.

CEE 412. Structural Engineering
Prerequisite: CEE 212 or equivalent. I (4 credits)
Introduction to the field of structural engineering. Discussion of structural analysis techniques and concepts such as virtual work, flexibility method, stiffness method, and influence lines. Training in AutoCAD and exposure to commonly used structural analysis computer program(s). Discussion of basic design concepts and principles. Lecture and laboratory.

CEE 413. Design of Metal Structures
Prerequisite: CEE 412. I (3 credits)
Design of metal members and connections, and their use in buildings and bridges. Application of relevant design specifications with emphasis on structural steel. Lectures, problems, and laboratory.

CEE 415. Design of Reinforced Concrete Structures
Prerequisite: CEE 412. II (3 credits)
Design of reinforced concrete members and slabs, and their use in buildings and bridges. Application of relevant design specifications. Lectures, problems, and laboratory.

CEE 421. Hydrology and Floodplain Hydraulics
Prerequisites: CEE 303, CEE 325. I (4 credits)
Fundamentals of surface-water hydrology, flow in open channels, and flood hazard mitigation. Rainfall-runoff relations. Unit hydrograph method. Uniform and nonuniform flow in open channels. Measurement and control of river flow. Flood waves in rivers, floodplains, and reservoirs. Design of storage basins, storm channels, and culverts. Lecture, laboratory and computation.

CEE 428. Introduction to Groundwater Hydrology
Prerequisite: junior standing. I (3 credits)
Importance and occurrence of groundwater; chemical and physical properties of the groundwater environment; basic principles of groundwater flow; measurement of parameters; pump test design and analysis; transport of contaminants; use of computer models for the simulation of flow and transport problems.

CEE 430. Special Problems in Construction Engineering
Prerequisite: permission of instructor. I, II, IIIa, IIIb (1-3 credits)
Individual student may choose his or her special problem from a wide range of construction engineering and management areas.

CEE 431. Construction Contracting
Prerequisite: junior standing. I, II (3 credits)
Construction contracting for contractors, architects, owners. (1) Organization and administration; industry structure; construction contracts, bonds, insurance. (2) Planning, estimating, and control; quantity takeoff and pricing; labor and equipment estimates; estimating excavation and concrete; proposal preparation; scheduling; accounting and cost control. Students use contract documents to prepare detailed estimate.

CEE 445. Engineering Properties of Soil
Prerequisite: CEE 212. I, II (4 credits)
Soil classification and index properties; soil structures and moisture, seepage, compressibility and consolidation; stress and settlement analysis; shear strength; applications to foundations, retaining structures, slopes and landfills. Lectures, problems, laboratory, report writing.

CEE 446. Engineering Geology
Prerequisite: CEE 445 or permission of instructor. II (3 credits)
Composition and properties of rocks and soil, geologic processes, geologic structures and engineering consequences, natural and artificial underground openings, terrain analysis and site investigation, civil engineering facility siting, seismic zonation for ground motions and soil liquefaction potential, geotechnical aspects of municipal and hazardous waste disposal.

CEE 460. Design of Environmental Engineering Systems
Prerequisite: CEE 360. I (3 credits)
Design and theoretical understanding of environmental processes; biological, physical, and chemical processes, and reactor configurations commonly used for water quality control; applications to the design of specific water and wastewater treatment operations; discussion of pollution prevention and green engineering options.

CEE 490. Independent Study in Civil and Environmental Engineering
Prerequisite: permission of instructor. I, II, IIIa, IIIb (1-4 credits)
Individual or group experimental or theoretical research in any area of Civil and Environmental Engineering. The program of work is arranged at the beginning of each term by mutual agreement between the student and a faculty member. Written and oral reports may be required.

CEE 500. Environmental Systems and Processes
Prerequisite: CEE 480. I (3 credits)
Concepts of environmental systems and principles of related transport and transformation phenomena and processes; development of fundamental models for articulation of relevant process dynamics; system and process scaling factors and methods; extension of process models to ideal and nonideal natural and engineered homogeneous environmental systems.

CEE 509. (ME 512) Theory of Elasticity
Prerequisites: ME 412 or ME 511. II (3 credits)
Stress, strain and displacement, equilibrium and compatibility. Use of airy stress function in rectangular and polar coordinates, asymptotic fields at discontinuities, forces and dislocations, contact and crack problems, rotating and accelerating bodies. Galerkin and Papcovich-Neuber solutions, singular solutions, spherical harmonics. Thermoelasticity. Axisymmetric contact and crack problem. Axisymmetric torsion.

CEE 510 (NA 512). Finite Element Methods in Solid and Structural Mechanics
Prerequisite: graduate standing. II (3 credits)
Basic equations of three-dimensional elasticity. Derivation of relevant variational principles. Finite element approximation. Convergence requirements. Isoparametric elements in two and three dimensions. Implementational considerations. Locking phenomena. Problems involving non-linear material behavior.

CEE 511. Dynamics of Structures
Prerequisite: preceded or accompanied by CEE 512 or equivalent. I (3 credits)
Dynamic equilibrium of structures. Response of a single degree of freedom system to dynamic excitation: free vibration, harmonic loads, pulses and earthquakes. Response spectra. Response of multi-degree-of-freedom systems. Seismic behavior of buildings and the basis for seismic building codes.

CEE 512. Theory of Structures
Prerequisite: CEE 412 or equivalent. I (3 credits)
Presentation of the direct stiffness method of analysis for two-dimensional and three-dimensional structures. Overview of analysis techniques for arch and cable-supported structures. Brief introduction to the theory of plates and shells. Lecture.

CEE 513. Plastic Analysis and Design of Frames
Prerequisite: CEE 413. II (3 credits)
Plastic analysis and design of steel framed structures. Stepwise incremental load and mechanism methods. Behavior beyond elastic range; failure mechanisms. Use of computer programs and AISC specifications. Application to earthquake resistant design.
CEE 514. Prestressed Concrete
Prerequisite: CEE 415. II (3 credits)
Fundamental principles of prestressing; prestressing materials; prestress losses; allowable stress and ultimate strength design methods; analysis and design of beams for flexure, shear, and deflection; composite construction; bridges; slab systems; partial prestressings; FRP tendons.
CEE 515. Advanced Design of Reinforced Concrete Structures
Prerequisite: CEE 415. I (3 credits)
Analysis and design of concrete structural systems including two-way floor systems, slender columns, members subjected to torsion, structural walls and connections. Applications of computer-aided design programs. Use of design code provisions. Design projects.
CEE 516. Bridge Structures
Prerequisites: CEE 413, CEE 415. I (3 credits)
Advanced concepts and modern trends in design of bridges. Rehabilitation, repair, and retrofit of existing bridges. Use of relevant codes. Study of alternative structural forms and materials for efficiency and economy. Design problems and reports.
CEE 517. Reliability of Structures
Prerequisite: CEE 412. II (3 credits)
Fundamental concepts related to structural reliability, safety measures, load models, resistance models, system reliability, optimum safety levels, and optimization of design codes.
CEE 518. Fiber Reinforced Cement Composites
Prerequisites: CEE 415 or CEE 553. I (3 credits)
Fiber-reinforcement of cement-based matrices; continuous and discontinuous fibers and meshes. Fiber-reinforced concrete and Ferro-cement. Laminated cementitious composites. Behavior and mechanical properties. Mechanics of fiber reinforcement. Constitutive models. High-strength, high-performance fiber composites. Hybrid and smart composites. Lectures, projects and laboratory.
CEE 519. Hybrid and Composite Structures
Prerequisites: CEE 415 or equivalent and CEE 413 or equivalent. II (3 credits)
Behavior and design of hybrid and composite structural members, connections and systems, including composite frame construction, structural walls systems and braced frames; design of advanced fiber cementitious materials and applications in new and deficient structural systems; Fiber Reinforced Polymers (FRP) for structural repair and retrofit.
CEE 520. Deterministic and Stochastic Models in Hydrology
Prerequisites: CEE 420, CEE 421. II (3 credits)
Mathematical description of the Hydrologic cycle. Computation of overland flow. Flood routing through reservoirs and rivers. Unit Hydrograph theory. Linear and nonlinear models for small watershed analysis. Application of time series and spectral analysis to hydrologic data. Streamflow stimulation by autoregressive and moving average models.
CEE 521. Flow in Open Channels
Prerequisite: CEE 421. I alternate even years (3 credits)
Conservation laws for transient flow in open channels; shallow-water approximation; the method of characteristics; simple waves and hydraulic jumps; nonreflective boundary conditions; dam-break analysis; overland flow; prediction and mitigation of flood waves.
CEE 522. Sediment Transport
Prerequisite: CEE 325 or equivalent, II (3 credits)
Mechanics of sediment transport processes in Fluvial systems; initiation of motion; bed forms; resistance to flow; suspended sediment transport; bed load transport; cohesive sediments; geomorphology principles.
CEE 523 (Aero 523) (ME 523). Computational Fluid Dynamics I
Prerequisite: Aero 520 or ME 520. I (3 credits)
Physical and mathematical foundations of computational fluid mechanics with emphasis on applications. Solution methods for model equations and the Euler and the Navier-Stokes equations. The finite volume formulation of the equations. Classification of partial differential equations and solution techniques. Truncation errors, stability, conservation and monotonicity. Computer projects and homework.
CEE 524. Environmental Turbulence
Prerequisite: CEE 325 or equivalent. II alternate years (3 credits)
Introduction to the topic of turbulence with special emphasis on physical processes; characterization of fundamental turbulent flows such as shear layers, wakes, jets, plumes, and thermals; effect of stratification on turbulence; forcing and control of turbulence by acceleration and pulsation.
CEE 525. Turbulent Mixing in Buoyant Flows
Prerequisite: CEE 325 or equivalent. I alternate years (3 credits)
Analysis of submerged turbulent buoyant jets; scaling relations; consideration of ambient effects including density stratification, ambient currents, and limited depth; numerical models for buoyant jet mixing; hydraulics of two-layer stratified flow and control on mixing processes.
CEE 526. Design of Hydraulic Systems
Prerequisite: CEE 325 or equivalent. II (3 credits)
Hydraulic design of piping systems including pumps and networks; pump system design including variable speed operation, cavitation, and wet well design; waterhammer and other transient phenomena; control valves and flow metering considerations; hydraulic control structures.

CEE 527. Coastal Hydraulics
Prerequisite: CEE 325 or equivalent. I alternate even years (3 credits)
General description of wave systems including spectral representation; solutions to oscillatory wave equation; wave breaking; harbor resonance; wave shoaling, refraction, and diffraction; wave forecasting; selection of design wave conditions; forces on coastal structures; shoreline erosion processes.

CEE 528. Flow and Transport in Porous Media
Prerequisite: CEE 428 or equivalent. II (3 credits)
Basic principles governing flow and transport in porous media; development of mathematical models at pore and continuum levels; single and multiphase flow; solute transport and dispersion theory; parameter estimation; application to saturated and unsaturated groundwater flow, flow in fractured media, petroleum reservoirs, saltwater intrusion and miscible and immiscible subsurface contamination.

CEE 529. Hydraulic Transients I
Prerequisite: CEE 421. I (3 credits)
Incompressible unsteady flow through conduits; numerical, algebraic and graphical analysis of waterhammer; solution of transient problems by the method of characteristics; digital computer applications to pump failures, complex piping systems; valve stroking, and liquid column separation.

CEE 530. Construction Professional Practice Seminar
Prerequisite: permission of instructor; mandatory satisfactory/ unsatisfactory. I, II (1-3 credits)
Construction industry speakers, field trips, team projects. Student teams investigate construction technologies and work with construction industry clients as volunteer consultants to address industry, organization, and project problems. Teams prepare and present written and oral reports to seminar and clients.

CEE 531. Construction Cost Engineering
Prerequisites: graduate standing and preceded or accompanied by CEE 431. I (3 credits)
Cost engineering for construction organizations, projects, and operations. Construction financing; break-even, profit, and cash flow analyses; capital budgeting. Equipment cost and procurement decisions. Construction financial accounting, cost accounting, cost control systems, databases. Cost indices, parametric estimates, unit price proposals, measuring work and settling claims.

CEE 532. Construction Project Engineering
Prerequisites: graduate standing and preceded or accompanied by CEE 431. II (3 credits)
Project, company organization. Manpower planning, procurement; union, nonunion construction. Job site layout. Material equipment procurement. Construction operation planning, supervision, measurement, analysis, improvement, automation, robotics. Dimensions of performance: safety, quality, quality of work life, productivity, innovation. Examples, cases from construction.

CEE 533. Advanced Construction Systems
Prerequisite: preceded or accompanied by CEE 431. II (3 credits)
Human-machine interactions. Automation and robotics. Ergonomics, job analysis, and job design. Work physiology, environmental factors. Occupational health and safety with focus on underlying causes and prevention of illnesses and injuries rather than on regulation. Risk, safety, and loss management.

CEE 534. Construction Engineering, Equipment, and Methods
Prerequisite: junior standing. II (3 credits)
Major construction equipment and concrete construction. Selection of scrapers, dozers, cranes, etc. based on applications, methods, and production requirements. Power generation, transmission, and output capacity of equipment engines. Calculation of transport cycle times. Concrete methods include mixing, delivery, and placement. Design of forms for concrete walls and supported slabs.

CEE 535. Excavation and Tunneling
Prerequisite: CEE 445. II (3 credits)
Selection of methods of attack for excavation of tunnels and deep vertical-sided openings. Tunneling procedures based on behavioral characteristics of soil and rock. Study of tunnel boring machines, shielded and drill-and-blast operations, linings. Soil liner interaction. Deep excavation procedures related to support of excavation systems, methods of installation and dewatering.

CEE 536 (Mfg 536). Critical Path Methods
Prerequisite: senior or graduate standing. I, IIIa (3 credits)
Basic critical path planning and scheduling with arrow and precedence networks; project control; basic overlapping networks; introduction to resource leveling and least cost scheduling; fundamental PERT systems.

CEE 537. Construction of Buildings
Prerequisite: CEE 351. I (3 credits)
Material selection, construction details, manufacture, fabrication, and erection of building structures using steel, light wood, timber, cast-in-place concrete, precast concrete, and masonry; and of building materials for roof, floor, and wall surfaces. Field trips to fabrication plants and construction sites.

CEE 538. Concrete Construction
Prerequisite: CEE 351. I (3 credits)
Selection of concrete, batch design, additives, and batch plant. Structural design, construction of concrete formwork for buildings, civil works. Transporting, placing, and finishing equipment and methods. Plant and on-site pre-casting and prestressing methods and field erection. Sprayed, vacuum, and preplaced aggregate concrete applications. Industrialized concrete systems. Concrete grouting, repair.

CEE 540. Advanced Engineering Properties of Soil
Prerequisite: CEE 445 or equivalent. I (3 credits)
Behavior of soil examination from a fundamental soil perspective. Review of methods of laboratory and field testing to define response; rationale for choosing shear strength and deformation parameters for sands, silts, and clays for design applications

CEE 541. Soil Sampling and Testing
Prerequisite: preceded or accompanied by CEE 445. I (3 credits)
Field and laboratory practice in sampling and testing of soils for engineering purposes. Field sampling and testing; standard split-spoon sampler, Dutch Cone penetrometer, field vane, Iowa borehole shear device. Lab tests; direct shear, unconfined compression, triaxial compression, consolidation. Laboratory and lecture.
CEE 542. Soil and Site Improvement
Prerequisite: CEE 445 or equivalent. I (3 credits)
Analysis of geotechnical problems affecting site use including weak, compressible soil; high shrink-swell potential; and liquefiable soils. Stabilization techniques including compaction, earth reinforcement, admixture stabilization, deep mixing, grouting, precompression, thermal and electrokinetic stabilization, and vibro-compaction.
CEE 543. Geosynthetics
Prerequisite: CEE 445 or equivalent. I (3 credits)
Physical, mechanical, chemical, biological, and endurance properties of geosynthetics (including geotextiles, geogrids, geonets, geomembranes, geopipes and geocomposites). Standard testing methods for geosynthetics. Application and design procedures for geosynthetics in Civil and Environmental Engineering: separation, reinforcement, stabilization, filtration, drainage and containment of solids and liquids.
CEE 544. Rock Mechanics
Prerequisite: ME 211. I (3 credits)
Engineering properties and classification of rocks. Strength and deformability of intact and jointed rock; in situ stresses; lab and field test methods. Stereonets and structural geology. Rock slopes; stability and reinforcement. Foundations on rock.
CEE 545. Foundation Engineering
Prerequisite: CEE 445 or equivalent. I (3 credits)
Application of principles of soil mechanics to: determination of bearing capacity and settlement of spread footings, mats, single piles and pile groups; site investigation, evaluation of data from field and laboratory tests; estimation of stresses in soil masses; soil structure interaction.
CEE 546. Stability of Earth Masses
Prerequisite: CEE 445 or equivalent. II (3 credits)
Stability of hillsides and open cuts, geologic considerations; stability of man-made embankments including earth dams and structural fills, compaction and placement of soil in earth embankments, problems of seepage and rapid draw-down, earthquake effects, slope stabilization techniques; lateral earth pressures and retaining walls, braced excavations.
CEE 547. Soils Engineering and Pavement Systems
Prerequisite: CEE 445 or equivalent. I (3 credits)
Soils engineering as applied to the design, construction and rehabilitation of pavement systems. The design, evaluation and rehabilitation of rigid, flexible and composite pavements.
CEE 548. Geotechnical Earthquake Engineering
Prerequisite: CEE 445 or equivalent recommended. II (3 credits)
Geology of earthquakes and seismology: earthquake mechanisms, magnitude and intensity scales, seismic hazard analyses; ground motion characterization: peak parameters, response spectra, Fourier amplitude spectra; site response analyses: equivalent linear and non-linear procedures, total and effective stress analyses; liquefaction: liquefaction phenomenon, evaluation procedures; analysis and design: slopes/embankments, retaining walls.
CEE 549. Geotechnical Aspects of Landfill Design
Prerequisite: CEE 445 or equivalent. I (3 credits)
Introduction to landfill design (compacted clay and synthetic liners). Landfill slope and foundation stability analyses. Leachate collection system design including use of HELP Model. Landfill cover and gas venting systems. Case studies in vertical landfill expansion. Construction quality assurance and quality control of soil components and geosynthetic liners.
CEE 550. Quality Control of Construction Materials
Prerequisite: CEE 351. II (3 credits)
Construction material specification and test procedures. Sampling methods, data collection and statistical data distributions. Quality control charts, development of quality assurance specifications and acceptance plans. Examples using data from actual field construction and laboratory experiments collected by destructive and non-destructive methods.
CEE 551. Rehabilitation of Constructed Facilities
Prerequisite: CEE 351. II (3 credits)
Infrastructure needs. Rehabilitation studies of buildings, underground construction, bridges, streets, and highways. Types of distress; numerical condition surveys for foundation, structural, and functional deterioration; design criteria; materials and techniques; predictive performance models; evaluating alternatives; databases; maintenance management.
CEE 552. Bituminous and Cement Mixes for Construction
Prerequisite: CEE 351. II (3 credits)
Types and properties of bituminous, Portland, and other cements used in construction. Natural and synthetic aggregate characteristics and uses. Compositions and properties of different mixtures used for highways, airports, parking areas, reservoir linings and other constructed facilities. Laboratory experiments with selected compositions.
CEE 554 (Mfg 551). Materials in Engineering Design
Prerequisite: CEE 351 or permission of instructor. I (3 credits)
Integrated study of material properties, processing, performance, structure, cost and mechanics, as related to engineering design and material selection. Topics include design process, material properties and selection; scaling; materials database, processing and design, and optimization. Examples will be drawn from cement and ceramics, metals, polymers and composites.

CEE 570 (Nat Res 569). Introduction to Geostatistics
Prerequisite: IOE 265 (statistics and probability) or equivalent. I (3 credits)
Sampling design and data representativity. Univariate and bivariate data analysis: continuous and categorical environmental attributes. Description and modeling of spatial variability. Deterministic vs. stochastic models. Spatial interpolation of environmental attributes. Soil and water pollution data will be analyzed using geostatistical software.

CEE 580. Physicochemical Processes in Environmental Engineering
Prerequisite: CEE 460. II (3 credits)
Physicochemical separated and transformation processes in natural and engineered environmental systems; process modeling; design of operations involving state and phase transformation; chemical oxidation, reduction, sorption, stripping, and exchange processes, membrane separations, particle aggregation and coagulation, sedimentation and filtration.

CEE 581. Aquatic Chemistry
Prerequisite: Chem 125. II (3 credits)
Chemical principles applicable to the analysis of the chemical composition of natural waters and engineered water systems; chemistry of water purification technology and water pollution control; chemical processes which control the movement and fate of trace contaminants in aquatic environments including precipitation-dissolution, oxidation-reduction, adsorption-desorption, and complexation.

CEE 582. Environmental Microbiology
Prerequisite: Chem 130. I (3 credits)
Discussion of basic microbial metabolic processes, thermodynamics of growth and energy generation, and genetic and metabolic diversity. Emphasis is placed on the application of these concepts to biogeochemical cycling, subsurface microbiology, wastewater microbiology, pollutant degradation, and microbial ecology.

CEE 583. Surfaces and Interfaces in Aquatic Systems
Prerequisite: CEE 581 or permission of instructor. II (3 credits)
Introduction to the principles of surface and interfacial aquatic chemistry, surface complexation theory, and interfacial phenomena. Topics covered include capillarity, wetability, surface tension, contact angle, and surface active agents; surface-chemical aspects of adsorption, ion-exchange, and electrical double layer theory. Discussion of the effects of surfaces and interfaces on transformation reactions of aquatic pollutants.

CEE 584 (EIH 667). Hazardous Waste Processes
II (3 credits)
The study of thermal, chemical and other systems and processes used in the detoxification of hazardous wastes, other than radioactive wastes.

CEE 585 (ENSCEN 585). Solid Waste Management
I (3 credits)
The study of methods for managing the solid wastes generated by urban communities, evaluating alternatives and design of disposal facilities. Methods for minimizing adverse effects on the human health and environment are included.

CEE 586 (Nat Res 557). Industrial Ecology
Prerequisite: senior standing. II (3-4 credits)
Analysis of material and energy flows in industrial systems to enhance eco-efficiency and sustainability. Methods: life cycle assessment quantifies energy, waste, emissions (greenhouse gases) for materials production, manufacturing, product use, recovery/disposition. Life cycle design integrate environmental, performance, economic, and regulatory objectives. Multi-objective analysis, engineering design analysis, cross-functional teamwork, large sea modeling skills.

CEE 587 (Nat Res 558). Water Resource Policy
Prerequisite: senior or graduate standing. I (3 credits)
Consideration of policy processes associated with the development and utilization of water resources. Special attention is given to the history and development of policy related to water quality. Multi-objective planning is presented. Consideration of institutional problems associated with the implementation of water policy in the federal, state, regional, and local arenas.

CEE 589 (Nat Res 595). Risk and Benefit Analysis in Environmental Engineering
Prerequisite: senior or graduate standing. II (3 credits)
Introduction to techniques of risk-benefit analysis as applied to water resources and environmental engineering. Techniques of multi-objective water resource planning. The engineering political interfaces; consideration of political bargaining and decision-making.

CEE 590. Stream, Lake, and Estuary Analysis
Prerequisite: CEE 460 or permission of instructor. II (3 credits)
Development of mass balance equations for the characteristics and spatial and temporal distributions of contaminants in natural aquatic systems. Role of biochemical kinetics and mass transfer processes on oxygen resources in streams, lakes, and estuaries. Demonstration of case studies and applied problems.

CEE 592. Biological Processes in Environmental Engineering
Prerequisite: CEE 460. II (3 credits)
Theoretical principles, qualitative and quantitative description of suspended growth and biofilm processes, as applicable to wastewater treatment and the bioremediation of soils, sediments and groundwater. Bioremediation processes discussed include bioventing and biosparging, in situ intrinsic and enhanced bioremediation of chlorinated and non-chlorinated compounds.

CEE 593. Environmental Soil Physics
Prerequisite: CEE 428 or CEE 445. II (3 credits)
Principles of soil physics with emphasis on environmental problems. Topics include characteristics of solid, liquid and gaseous components of soil; capillarity, air entrapment and the static distribution of water in the unsaturated zone; infiltration, exfiltration and the redistribution of water. Extension of principles to movement of organic liquids in subsurface.

CEE 594. Environmental Soil Chemistry

Prerequisite: CEE 581. II (3 credits)

Introduction to the principles of soil chemistry. Topics covered include chemical composition of soils, chemical structure of minerals and soil organic matter, soil colloidal phenomena, sorption, ion-exchange, surface complexation theory, reactivity of soil constituents with inorganic and organic environmental contaminants. Emphasis on the relationship between chemical structure and reactivity.

CEE 595. Field Methods in Hydrogeochemistry

Prerequisite: CEE 428. III (3 credits)

Intensive field laboratory and lecture sessions providing hands-on experience in sampling and analysis of groundwater and aquifer materials for hydrogeologic and geochemical purposes. The course emphasizes field experimental design, execution and evaluation at actual sites of ground-water/soil contamination.

CEE 596. Chemical Fate and Transport

Prerequisite: CEE 260 or equivalent. II (3 credits)

Analysis of the fate, transport and persistence of chemical using fugacity-based modeling methods. Identification of key chemical properties affecting fate and transport. Characterization of environmental and biological media. Distribution mechanisms: partitioning, advection, reaction, diffusion. Hierarchical assessment of chemical fate for steady-state, transient, equilibrium and non-equilibrium conditions. Application to multi-media environmental systems; bioaccumulation in food webs; pharmacokinetic modeling; exposure and risk assessment.

CEE 599 (EIH 699). Hazardous Wastes: Regulation, Remediation, and Worker Protection

Prerequisites: graduate standing and EIH 503 or EIH 508 or EIH 541 or EIH 650 or EIH 667 or permission of instructor. (3 credits)

Integration of information on current regulatory climate and governmental guidelines with case studies in hazardous wastes/substances. Case studies provide examples of hazardous waste and remedial actions, with emphasis on site worker exposure and protection, and community exposures to chemical and radiological agents. Lectures, problem-solving sessions, and guest speakers.

CEE 611. Earthquake Engineering

Prerequisites: CEE 511, and CEE 512, or equivalent. II alternate years (3 credits)

This course is to serve as an introduction to the field of earthquake engineering, specifically the seismic behavior and design of structures. Topics include: tectonic theory; engineering characterization of earthquakes; probabilistic hazard analysis; structural modeling and analysis; response of structures during earthquakes; performance-based design; seismic detailing considerations; selected advanced topics.

CEE 613. Metal Structural Members

Prerequisite: CEE 413. I alternate years (3 credits)

Elastic and inelastic behavior of beams and columns. Torsion of open and box members. Combined bending and torsion. Buckling of beams and beam-columns. Frame buckling. Behavior of steel and aluminum structural members in studies with reference to their code design procedures.

CEE 614. Advanced Prestressed Concrete

Prerequisite: CEE 514. I alternate years (3 credits)

Prestressing in statically indeterminate structures: prestressed concrete slabs; analysis and design of partially prestressed concrete beams; nonlinear analysis; optimum design; members prestressed with unbonded tendons; external prestressing; prestressed tensile members; prestressing with FRPs. Special research and/or application related topics.

CEE 615. Reinforced Concrete Members

Prerequisite: CEE 415. I alternate years (3 credits)

Inelastic behavior of reinforced concrete beams, columns, and connections. Combined bending, shear, and torsion in beams. Use of strut and tie models. Behavior under load reversals, and development of appropriate hysteresis models.

CEE 617 (Aero 615) (ME 649). Random Vibrations

Prerequisites: Math 425 or equivalent, CEE 513 or ME 541, or Aero 543 or equivalent. II alternate years (3 credits)

Introduction to concepts of random vibration with applications in civil, mechanical, and aerospace engineering. Topics include: characterization of random processes and random fields, calculus of random processes, applications of random vibrations to linear dynamical systems, brief discussion on applications to nonlinear dynamical systems.

CEE 619. Advanced Structural Dynamics and Smart Structures

Prerequisites: Math 417 or equivalent, CEE 511. I alternate years (3 credits)

Smart structure systems found in civil, mechanical and aerospace engineering described using basic principles of linear system theory, domain transformations, complex plane analysis and block system modeling. Structural monitoring for effective data processing and system identification. Design of passive and active structural control systems using base isolation, tuned mass damping and active actuators.

CEE 621. Free Surface Flow

Prerequisite: CEE 521. II (3 credits)

Transient, incompressible flow in three space dimensions. Reynolds averaging and large eddy simulation of turbulent flows. Kinematic and dynamic conditions at air-water interfaces. Numerical solution by finite element and finite volume methods. Algorithms for locating a free surface. Applications to river, lake and estuary models.

CEE 622. Special Problems in Hydraulic Engineering or Hydrology

Prerequisites: permission of instructor. I, II (to be arranged)

Assigned work on an individual basis. Problems of an advanced nature may be selected from a wide variety of topics.

CEE 625 (Nat Res 624). Geostatistical Modeling of Uncertainty

Prerequisite: CEE 570. II (3 credits)

Risk assessment: parametric and non-parametric approaches. Optimal estimates. Decision making in the face of uncertainty. Classification of categorical attributes. Stochastic spatial simulation: continuous and categorical environmental attributes. Propagation of uncertainty. Soil and water pollution data will be analyzed using geostatistical software.

CEE 628. Numerical Modeling of Subsurface Flow
Prerequisites: CEE 528 or CEE 593 and Math 471. I (3 credits)
Application of numerical solution methods, including finite differences, finite elements, boundary elements, and method of characteristics to various subsurface flow problems: saturated isothermal flow, solute transport, multiphase flow, geothermal reservoirs, use and modification of existing models in addition to new code development.
CEE 630. Directed Studies in Construction Engineering
Prerequisite: graduate standing. I, II, IIIa, IIIb (1-3 credits)
Selected reading in specific construction areas.
CEE 631. Construction Decisions Under Uncertainty
Prerequisite: CEE 405 or a course in probability or statistics such as Stat 310 or Stat 311 or SMS 301. II (3 credits)
Construction project and organization decisions for the uncertain future. Selection of construction method, equipment, contract, markup, and financing alternatives having the highest expected values. Uses decision theory, competitive bid analysis, probabilistic modeling and simulation, and multiple regression analysis in managing construction.
CEE 633. Construction Management Information Systems
Prerequisites: permission of instructor. II (3 credits)
Design of computerized construction management information systems (MIS). Introduction to databases and information management systems for computer-aided construction engineering and management. Topics include engineering data modeling issues, relational and object-oriented models, and data mining for textual and graphical information systems. Students design and implement project control subsystems as an integrated MIS and apply to construction problems and case studies.
CEE 645. Theoretical Soil Mechanics
Prerequisite: permission of instructor. (3 credits)
Stress conditions for failure of soils; earth pressures and retaining walls; arching in soils; theories for elastic and plastic deformations of soil masses; theory of bearing capacity; theories for stresses in semi-infinite and layered elastic solids; theory of elastic subgrade reaction.
CEE 646. Geophysical Techniques in Environmental Geotechnology
Prerequisite: CEE 445. II (3 credits)
Introduction to geophysical techniques currently available for use in environmental geotechnology. Principles on which methods are based. Site characterization, pore fluid identification, buried object location by these non-intrusive, non-destructive tests. AI programming for selection of appropriate methods. Case studies in use of geophysical methods.
CEE 648. Dynamics of Soils and Foundations
Prerequisite: CEE 445. II (3 credits)
Transient and steady state vibrations of foundations; phase plane analysis of foundations with one and two degrees of freedom; dynamic properties of soils; vibration transmission through soils.
CEE 649. Civil Engineering Vibrations Laboratory
Prerequisites: CEE 611, preceded or accompanied by CEE 648. II (2 credits)
Field and laboratory determination of dynamic material properties; measurement of vibration of structures and foundations; introduction to electronics for dynamic measurements; introduction to holographic interferometry.
CEE 650. Fracture and Micromechanics of Fibrous Composites
Prerequisite: graduate standing. II (3 credits)
Fracture mechanics fundamentals and micromechanics of cement, ceramic- and polymer-based fibrous composites. Topics include elastic crack mechanics, energy principles, interface mechanics; shear lag models; residual stress; nonalignment problems; first crack strength, steady state cracking and reliability; multiple cracking, bridging fracture energy; and R-curve behavior.
CEE 651. Directed Studies in Civil Engineering Materials
Prerequisite: graduate standing. I, II, IIIa, IIIb (1-3 credits)
Individual studies in specific civil engineering materials areas.
CEE 682. Special Problems in Environmental Engineering
Prerequisite: permission of instructor. I, II, IIIa, IIIb (to be arranged)
Special problems designed to develop perspective and depth of comprehension in selected areas of sanitary, environmental or water resources engineering.
CEE 686 (ChE 686). Case Studies in Environmental Sustainability
Prerequisite: senior or graduate standing. I, II (2-3 credits)
Case studies focusing on utilization of the principles of industrial ecology and environmental sustainability in professional practice. Development of environmental literacy through examination of current and historical examples of environmental issues and related corporate and industrial practices.
CEE 687 (EIH 617). Special Problems in Solid Waste Engineering
Prerequisites: CEE 585 and permission of instructor; mandatory satisfactory/unsatisfactory. I, II, IIIa, IIIb (to be arranged)
Application of principles presented in CEE 585 to engineering and environmental health problems in the collection and disposal of solid wastes; comprehensive analysis and report assigned on individual student basis.
CEE 692. Biological and Chemical Degradation of Pollutants
Prerequisite: CEE 582 or permission of instructor. I (3 credits)
Biological and chemical mechanisms and pathways of organic pollutant degradation under environmental conditions. Biological: substitution, elimination, redox reactions; enzyme participation. Chemical: substitution, elimination reactions, linear free-energy, applications. Pollutants include: aliphatic and aromatic compounds, both with and without halogen substituents.

CEE 693. Environmental Molecular Biology
Prerequisite: CEE 592 or permission of instructor. I alternate years (3 credits)
Principles and techniques of molecular biology with an emphasis on genetic analysis of enzymatic systems capable of pollutant degradation: Genetic systems and gene probing in unusual prokaryotes: Use of molecular biological techniques for the enumeration and characterization of natural microbial communities; Biochemistry and kinetics of enzymatic systems. Lectures and laboratory.

CEE 810. Special Topics in Structures and Materials
I, II (to be arranged)
Preparation and presentation of reports covering assigned topics.

CEE 811. Structural Engineering Project
Prerequisite: Enforced: CEE 413 or CEE 415 or equivalent. I, II
This course provides structural engineering students an integrated view of analysis and design aspects for various structural systems. Topics include evaluation of gravity, wind and earthquake load and displacement demands, selection and proportioning of structural systems and foundation design. The course features bi-weekly seminars involving students, faculty, and practicing engineers.

CEE 830. Construction Engineering and Management Seminar
I, II (to be arranged)
Assigned reading and student reports on problems selected from the field of construction engineering and management.

CEE 880. Seminar in Environmental and Water Resources Engineering
Prerequisite: none. I, II (to be arranged)
Presentation and discussion of selected topics relating to environmental and water resources engineering. Student participation and guest lecturers.

CEE 910. Structural Engineering Research
(to be arranged)
Assigned work in structural engineering as approved by the professor of structural engineering. A wide range of subject matter is available, including laboratory and library studies.

CEE 921. Hydraulic and Hydrological Engineering Research
Prerequisite: permission of instructor. I, II (to be arranged)
Assigned work in hydraulic and hydrological research; a wide range of matter and method permissible.

CEE 930. Construction Engineering Research
(to be arranged)
Selected work from a wide range of construction engineering areas including planning, equipment, methods, estimating and costs.

CEE 946. Soil Mechanics Research
(to be arranged)
Advanced problems in soil mechanics, foundations or underground construction, selected to provide the student with knowledge of recent application and development in engineering design and construction practice. Assigned problems must be carried to a stage of completion sufficient for a written report which will normally be required for credit.

CEE 950. Structural Materials Research
Prerequisite: permission of instructor. I, II (to be arranged)
Topics dealing with mechanics and engineering of structural materials. Assigned reading and student reports.

CEE 980. Research in Environmental Engineering
Prerequisite: permission of instructor. (to be arranged)
A research study of some problems relating to water resource development and water supply, waste treatment and pollution control, or sanitation and environmental health; a wide range of both subject matter and method is available, including field investigations, laboratory experimentation, library and public record searches, and engineering design work.

CEE 990. Dissertation/Pre-Candidate
I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

CEE 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, III (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

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Electrical Engineering, Computer Engineering and Computer Science

Computer Science Mission
To provide each student with a solid foundation in the scientific, engineering, and societal aspects of computing that prepares the student for a career that can advance the creation and application of computing technologies for the benefit of society.

Goals
To educate students with core knowledge of the software, hardware, and theory of computing; to give each student in-depth knowledge in one or more computing areas; and to develop leaders in this field.

Objectives

- To provide the necessary foundation in the principles and methods of computer science while preparing students for a broad range of responsible technical positions in industry and/or advanced graduate education.
- To provide the technical skills necessary to design and implement computer systems and applications, to conduct open-ended problem solving, and apply critical thinking.
- To provide an opportunity to work effectively on teams, to communicate in written and oral form, and to develop an appreciation of ethics and social awareness needed to prepare graduates for successful careers and leadership positions.
- To offer students the opportunity to deepen their technical understanding in a particular subject area by a program of related technical electives, or to obtain a broader education in mathematics, science, or engineering by a flexible choice of technical and free electives.

Outcomes
The outcomes we desire are that our graduates demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering.
- An ability to design and conduct experiments, as well as to analyze and interpret data.
- An ability to design, implement, test, and evaluate a computer system, component, or algorithm to meet desired needs.
- An ability to function on multi-disciplinary teams.
- An ability to identify, formulate, and solve computer science problems.
- An understanding of professional and ethical responsibility.
- An ability to communicate effectively.
- The broad education necessary to understand the impact of computer science solutions in a global and societal context.
- A recognition of the need for an ability to engage in life-long learning.
- A knowledge of contemporary issues.
- An ability to use the techniques, skills, and modern tools necessary for computer science practice.
- A knowledge of probability and statistics, including applications appropriate to computer science.
- A knowledge of mathematics through differential and integral calculus, basic sciences, and engineering sciences necessary to analyze and design complex computing systems, as appropriate to program objectives.

Computer EngineeringMission
To provide a solid technical foundation that prepares students for a career that can adapt to rapidly changing technology in computer engineering.

Goals
To educate students with a broad and in-depth knowledge of computing systems, and to develop leaders in this field.

Objectives

- To provide the necessary foundation in the principles and methods of computer engineering while preparing students for a broad range of responsible technical positions in the industry and/or advanced graduate education.
- To provide the technical skills necessary to design and implement low level computer systems and applications, to conduct open ended problem solving, and apply critical thinking.
- To provide an opportunity to work effectively on teams, to communicate in written and oral form, and to develop an appreciation of ethics and social awareness needed to prepare graduates for successful careers and leadership positions.
- To offer students the opportunity to deepen their technical understanding in a particular subject area by a program of related technical electives, or to obtain a broader education in mathematics, science, or engineering by a flexible choice of technical and free electives.

Outcomes

The outcomes we desire are that our graduates demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering.
- An ability to design and conduct experiments, as well as to analyze and interpret data.
- An ability to design, implement, test, and evaluate a computer system, component, or algorithm to meet desired needs.
- An ability to function on multi-disciplinary teams.
- An ability to identify, formulate, and solve engineering problems.
- An understanding of professional and ethical responsibility.
- The broad education necessary to understand the impact of computer engineering solutions in a global and societal context.
- A recognition of the need for an ability to engage in life-long learning.
- A knowledge of contemporary issues.
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
- A knowledge of probability and statistics, including applications appropriate to computer engineering.
- A knowledge of mathematics through differential and integral calculus, basic sciences, and engineering sciences necessary to analyze and design complex systems containing hardware and software components, as appropriate to program objectives.
- A knowledge of discrete mathematics

Electrical EngineeringMission

To provide an outstanding education for engineers in electrical engineering and to develop future leaders.

Goals

To provide students with the education for a rewarding and successful career.

Objectives

- To educate and train students in the principles and methods of electrical engineering, including the mathematics and science required to analyze and solve problems.
- To graduate, in a timely manner, students for positions in industry and in graduate schools.
- To train students in the use of current laboratory equipment to perform experiments for gathering data and testing theories.
- To develop skills pertinent to design, including the ability to formulate problems, work in teams, and communicate effectively both orally and in writing.

Outcomes

The outcomes that we desire are that our graduates demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering.
- An ability to design and conduct experiments, as well as to analyze and interpret data.
- An ability to design a system, component, or process to meet desired needs.
- An ability to function on multi-disciplinary teams.
- An ability to identify, formulate, and solve engineering problems.
- An understanding of professional and ethical responsibility.
- An ability to communicate effectively.
- The broad education necessary to understand the impact of electrical engineering solutions in a global and societal context.
- A recognition of the need for an ability to engage in life-long learning.
- A knowledge of contemporary issues.
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
- Knowledge of probability and statistics, including applications appropriate to electrical engineering.
- Knowledge of mathematics through differential and integral calculus, basic sciences, and engineering sciences necessary to analyze and design complex devices and systems, containing hardware and software components, as appropriate to program objectives.
- A knowledge of advanced mathematics, typically including differential equations, linear algebra, and complex variables.

Electrical Engineering, Computer Engineering and Computer Science Undergraduate Education

Computer Science Program Advisor (Chief Advisor for CoE Students)
Mary Lou Dorf, Ph.D. (CoE Students)
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Computer Science Program Advisor (Chief Advisor for LSA Students)
Professor David Kieras, Ph.D. (LSA Students)
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Electrical Engineering Program Advisor (Chief Advisor)
Professor Fred Terry, Ph.D.
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Computer Engineering Program Advisor (Chief Advisor)
Mark Brehob, Ph.D.ceadvisr@eecs.umich.edu
Undergraduate Advising Office
3415 EECS Building
Phone: (734) 763-2305 http://www.eecs.umich.edu

Degree Program Requirements

Candidates for the Bachelor of Science in Engineering degree (Computer Science) – B.S.E. (C.S.), the Bachelor of Science in Engineering (Computer Engineering) – B.S.E. (C.E.), and Bachelor of Science in Engineering (Electrical Engineering) – B.S.E. (E.E.) must complete the respective degree requirements. The following Sample Schedules are examples that lead to graduation in eight terms. Candidates for the Bachelor of Science or Bachelor of Arts degree in Computer Science through the College of Literature, Science, and the Arts should consult the LS&A Bulletin for degree requirements.

C- Rule

Among science, engineering and mathematics courses, a grade of C- or below is considered unsatisfactory.

Declaration Requirements

The EECS Department follows the College of Engineering rules for Program Selection (i.e. Declaration) for more information see: "Registration, Grading Options and Program Selection" section of the College Bulletin.

Sample Schedule
B.S.E. (Computer Science)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	–	–	–	–
Engr 100, Introduction to Engineering	4	–	4	–	–	–	–	–	–
Engr 101, Introduction to Computers & Programming	4	4	–	–	–	–	–	–	–
Chemistry 125/126 and 130 or Chemistry 210 and 211[1]	5	5	–	–	–	–	–	–	–
Physics 140 with Lab 141; Physics 240 with Lab 241[2]	10	–	5	5	–	–	–	–	–
Humanities and Social Sciences	16	4	4	–	4	4	–	–	–
Program Subjects (28 hrs.)									
EECS 203, Discrete Mathematics	4	–	–	4	–	–	–	–	–
EECS 280, Programming & Elem. Data Structures	4	–	–	4	–	–	–	–	–
EECS 281, Data Structures & Algorithms	4	–	–	–	4	–	–	–	–
EECS 370, Intro to Computer Architecture	4	–	–	–	–	4	–	–	–
Stat 412 or IOE 265[3]	3	–	–	–	3	–	–	–	–
EECS 376, Foundations of Computer Science	4	–	–	–	–	–	4	–	–
EECS 496, Major Design Experience Professionalism	2	–	–	–	–	–	–	2	–
TCHNCLCM 300[4]	1	–	–	–	1	–	–	–	–
TCHNCLCM 497[4]	2	–	–	–	–	–	–	2	–
Technical Electives (30 hrs.)									
Flexible Technical Electives[5]	14	–	–	–	–	4	4	–	6
Upper Level CS Technical Electives[6]	16	–	–	–	–	–	4	8	4
Unrestricted Electives (15-18)	15-18	–	–	–	–	3	4	4	4
Total	128	17	17	17	16	15	16	16	14

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE. Students who qualify are encouraged to take Chem. 210 (4 hrs.) & Chem. 211 (1 hr.) as a replacement for Chem. 130 (3 hrs.), Chem. 125 (1 hr.), and Chem. 126 (1 hr).

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]Probability/Statistics Course: IOE 265 is a 4 credit course; if this is elected, the extra credit is counted toward free electives.

[4]Technical Communication: TCHNCLCM 300 can be taken independently of any EECS course, but it is a prerequisite for TCHNCLCM 497. TCHNCLCM 497 must be taken with a major Design Experience (MDE) course.

[5]Flexible Technical Electives (FTEs): Computer Science courses* at the 200+ level, or approved courses at the 200+ level that are required by a program/concentration in Engineering, Math, or Science. Upper Level CS Technical Electives can also be used as FTEs. See the EECS Undergraduate Advising Office for the current list. At least 2 credits in CS.

[6]Upper Level CS Technical Electives: Computer Science courses* at the 300-level or higher (excluding EECS 398, 498, 499, 598, 599). This includes an approved Major Design Experience (MDE) course. See the Undergraduate Advising Office for the current list. Preapproved MDE courses include EECS 481, 494, and 497. Other courses may be acceptable with prior approval of the Chief Program Advisor.

*Computer Science (CS) Courses: A complete list of CS courses is available in the EECS undergraduate advising office, 3415 EECS.

A maximum of 4 credits of EECS 499 may be applied to Flexible Technical Electives. Anything beyond 4 credits will be applied toward Free Electives.

Sample Schedule
B.S.E. (Computer Engineering)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, and 216	12	4	4	–	4	–	–	–	–
Mathematics 215	4	–	–	–	–	4	–	–	–
Engr 100, Introduction to Engineering	4	–	4	–	–	–	–	–	–
Engr 101, Introduction to Computers & Programming	4	4	–	–	–	–	–	–	–
Chemistry 125/126 and 130 or Chemistry 210 and 211[1]	5	–	5	–	–	–	–	–	–
Physics 140 with Lab 141; Physics 240 with Lab 241[2]	10	5	–	5	–	–	–	–	–
Humanities and Social Sciences	16	4	4	–	4	–	4	–	–
Program Subjects (32 hrs.)									
EECS 203, Discrete Mathematics	4	–	–	4	–	–	–	–	–
EECS 215, Introduction to Circuits	4	–	–	–	4	–	–	–	–
EECS 216, Introduction to Signals and Systems	4	–	–	–	–	4	–	–	–
EECS 270, Intro to Logic Design	4	–	–	4	–	–	–	–	–
EECS 280, Programming & Elem. Data Structures	4	–	–	–	4	–	–	–	–
EECS 370, Intro to Computer Organization	4	–	–	–	–	4	–	–	–
EECS 401 or Math 425 or Stat 412	3	–	–	–	–	–	3	–	–
TCHNCLCM 300[3]	1	–	–	–	–	1	–	–	–
TCHNCLCM 496 and EECS 496[4]	4	–	–	–	–	–	–	–	4
Technical Electives (28 hrs.)[5]									
Flexible Technical Electives[6]	7	–	–	–	–	–	–	5	2
EECS Elective[7]	3	–	–	–	–	–	–	3	–
Core Electives[8]	8	–	–	–	–	–	8	–	–
Upper Level CE Electives[9]	10	–	–	–	–	–	–	4	6
Unrestricted Electives (13-16 hrs.)	13-16	–	–	3	–	3	–	4	3
Total	128	17	17	16	16	16	15	16	15

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]TCHNCLCM 300. Can be taken independently of any EECS course, but it is a prerequisite for TCHNCLCM 496.

[4]TCHNCLCM 496 and EECS 496: Must be elected concurrently with a Major Design Experience (MDE) course.

[5]Technical Electives: At least one of these classes must be a Major Design Experience Course in some ABET accredited program in the College of Engineering.

[6]Unused credits from Upper Level CE Electives or EECS Elective courses may be used to satisfy this requirement.

[7]Unused credits from Upper Level CE Electives courses may be used to satisfy this requirement.

[8]Core Electives: 8 credits from the following list: EECS 281, (306 or 452), 312, 373.

[9]Upper Level CE Electives: 10 credits from the following list: EECS 427*, 452*, 461, 470*, 478, 482, 489, 527, 570, 573, 578, 582, 583*, 589, 627. Must include at least one Major Design Experience course taken concurrently with EECS 496 and TCHNCLCM 496 (MDE courses are indicated with an *). Other courses may be acceptable with prior approval of the Chief Program Advisor.
A maximum of 4 credits of EECS 499 may be applied to Technical Elective requirements and only in the area of Flexible Technical Electives. Anything beyond 4 credits will be applied toward Free Electives.
Lists of "selected courses" for the various Technical Electives can be found in the EECS advising office.

Sample Schedule
B.S.E. (Electrical Engineering)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 216, and 215[1]	16	4	4	4	4	–	–	–	–
Engr 100, Introduction to Engineering	4	4	–	–	–	–	–	–	–
Engr 101, Intro. to Computers & Programming	4	–	4	–	–	–	–	–	–
Chemistry 125/126 and 130 or Chemistry 210 and 211[2]	5	5	–	–	–	–	–	–	–
Physics 140 with Lab 141; Physics 240 with Lab 241[3]	10	–	5	5	–	–	–	–	–
Humanities and Social Sciences	16	4	4	4	4	–	–	–	–
Program Subjects (29 hrs.)									
EECS 215, Introduction to Circuits	4	–	–	4	–	–	–	–	–
EECS 216, Introduction to Signals and Systems	4	–	–	–	4	–	–	–	–
EECS 230, Electromagnetics I	4	–	–	–	–	4	–	–	–
EECS 280, Programming & Elem. Data Structures	4	–	–	–	4	–	–	–	–
EECS 320, Intro to Semiconductor Device Theory	4	–	–	–	–	4	–	–	–
EECS 401 Probabilistic Methods in Engineering[4]	4	–	–	–	–	–	4	–	–
TCHNCLCM 300[5]	1	–	–	–	1	–	–	–	–
TCHNCLCM 496 and EECS 496[5]	4	–	–	–	–	–	–	–	4
Technical Electives (33 hrs.)									
Flexible Technical Electives[6]	14	–	–	–	–	3	4	4	3
Core Electives[7]	8	–	–	–	–	4	4	–	–
Upper Level EE Technical Electives[8]	7	–	–	–	–	–	–	7	–
Major Design Experience[9]	4	–	–	–	–	–	–	–	4
Unrestricted Electives (11-14 hrs.)	11-14	–	–	–	–	–	4	4	3
Total	128	17	17	17	17	15	16	15	14

Notes:

[1]EE students are advised to take MATH 216 before MATH 215 since EECS 216 is to be preceded or accompanied by MATH 216.

[2]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[3]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[4]EE students may select only EECS 401to fulfill this requirement. At most 4 credits of undergraduate probability may be applied towards the B.S.E.-(EE) degree requirements. For student declaring prior to Fall, 2006: MATH 425 will not suffice as a prerequisite for any class that requires EECS 401; if a student chooses MATH 425 in place of EECS 401, then he/she will be required to take 11 credits of Upper-level EE Technical Electives, and 11 credits of Flexible Technical Electives; the total number of credits required to graduate (128) remains the same.

[5]Technical Communication: TCHNCLCM 300 can be taken independently of any EECS course, but it is a prerequisite for TCHNCLCM 496. TCHNCLCM 496 must be taken with a Major Design Experience (MDE) course.

[6]Flexible Technical Electives: The flexible technical elective requirement may be fulfilled by taking selected courses in EECS, other engineering departments, biology, chemistry, economics, math, or physics. See the EECS Undergraduate Advising Office for the current list. All other courses must be approved by an EE program advisor.

[7]Core Electives: At least 8 credits from at least two categories: Systems (353, 451, 455, 460), Circuits (311 or 312), Electromagnetics/optics (330) or Computers 270 or 370.

[8]Upper Level EE Technical Electives: EECS courses at the 300-level or higher, excluding EECS 496, 497, and EECS 499; at least 3 credits must be at the 400-level or higher. Excludes software courses. See the EECS Undergraduate Advising Office for the current list.

[9]Major Design Experience: Pre-approved courses: EECS 411, 413, 425, 427, 430, 438, 452, 470; other courses that are MDEs in other engineering programs may be acceptable with prior approval of the Chief Program Advisor. Students must enroll concurrently in EECS 496, TCHNCLM 496 and MDE course.

A maximum of 4 credits of EECS 499 may be applied to Technical Elective requirements, and only in the area of Flexible Technical Electives. Anything beyond 4 credits will be applied toward Free Electives.

Combined Degrees Program
Sequential Graduate/Undergraduate Study (SGUS)

Susan Bitzer
sbitzer@umich.edu
http://www.bme.umich.edu
1111 Carl A. Gerstacker Bldg.
(734) 763-5290
Program Advisor: Professor David H. Kohn

BSE in Electrical Engineering/
MS Biomedical Engineering
This SGUS program is open to all undergraduate students from Electrical Engineering who have achieved senior standing (85 credit hours or more) and have an overall cumulative GPA of 3.2 or higher. Please contact the Department of Biomedical Engineering for more complete program information.

Concurrent Undergraduate/Graduate Studies (CUGS)
admit@eecs.umich.edu
http://www.eecs.umich.edu
EECS Graduate Office
3310 EECS Bldg.
(734) 764-2390

BSE or BS in one of the EECS programs or Computer Science/
MSE or MS in one of the Electrical Engineering and Computer Science (EECS) Programs
This is a Concurrent Undergraduate/Graduate Studies (CUGS) program through Rackham that is open to all EECS and Computer Science undergraduates who have completed 85 or more credit hours with a cumulative GPA of at least 3.6. Please contact the EECS Department for more complete program information.

Electrical Engineering, Computer Engineering and Computer Science Concentrations

Computer Science
Computer scientists are experts on the subject of computation, both in terms of the theory of what fundamental capabilities and limitations of computation are, as well as how computation can be practically realized and applied. A computer scientist understands how to design and analyze algorithms that apply computation effectively, how to store and retrieve information efficiently, how computers work to deliver computation, and how to develop software systems that solve complex problems. Specialists within computer science might have expertise in developing software applications, in designing computer hardware, or in analyzing algorithms, among many other current possibilities, and even more emerging specialties.

The new computer science (CS) program at the University of Michigan is available to students in both the Colleges of Engineering and of Literature, Science, and the Arts. The program requires students to have a solid foundation in computer software, hardware, and theory, but also gives a student ample opportunity to take advanced electives in areas of computer science such as databases, architecture, networks, artificial intelligence, and graphics, or in emerging interdisciplinary areas such as electronic commerce, web information systems, and computer game design.

Computer Engineering
The program in Computer Engineering provides each student with a broad and well-integrated background in the concepts and methodologies that are needed for the analysis, design, and utilization of information processing systems. Although such systems are often popularly called "computers," they involve a far wider range of disciplines than merely computation, and the Computer Engineering Program is correspondingly broad. A set of required technical courses (along with the college-wide requirements) gives the essential material in circuits, digital logic, discrete mathematics, computer programming, data structures, signals and systems, and other topics. Following completion of this work, the student can select courses in a wide range of subject areas. These include operating systems, programming languages and compilers, computer architecture, microprocessor-based systems, computer aided design and VLSI, digital signal processing, and computer networking, among others. A broad selection from several areas is recommended for most undergraduate students. Specialization in particular areas is more typical of graduate programs of study.

Electrical Engineering

The Electrical Engineering program provides students with a fundamental background in the basic theoretical concepts and technological principles of modern electrical engineering. A flexible curriculum allows students to emphasize a wide variety of subject areas within the field, including: analog and digital circuits, communication systems, control systems, electromagnetics, integrated circuit (microprocessor) design, signal processing, microelectromechanical devices, solid state electronics, and optics.

As seen from the list of subject areas, a degree in electrical engineering can lead to a wide range of work opportunities. Automotive applications include engine control processors and sensors to trigger airbags or activate antilock brake systems. Electrical engineers work in the wireless communications field, including mobile phone systems and global positioning systems. Electrical engineers also work in remote sensing to infer characteristics of a region of the earth from the air or from space. They design, manufacture, test and market the microprocessor, analog and RF integrated circuits from which computers, digital movie and still cameras, the internet, communication systems, and many other modern conveniences are made. Electrical engineers develop signal processing algorithms and hardware for multimedia devices and develop control algorithms and electronics for mechanical systems such as automobiles, planes and spacecraft. They embed microprocessors in everything from entertainment gadgets to industrial plants. Electrical engineers develop optical fiber communication systems and laser technology for applications ranging from astrophysics to eye surgery. Electrical engineers use semiconductor fabrication technology to make miniature machines called microelectromechanical devices. A common effort of electrical engineers is to make components smaller, faster, more energy efficient and less costly.

Electrical Engineering, Computer Engineering, Computer Engineering and Computer Science Graduate Education

Computer Science and Engineering
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Graduate Degrees

Electrical Engineering and Computer Science (EECS) is one of the highest-ranking EECS departments in the country, and many of its faculty are recognized as leaders in their field. The department offers three graduate degree programs: Computer Science and Engineering (CSE); Electrical Engineering (EE); and Electrical Engineering Systems (EE:S). The department's size and scope mean that students may choose from a variety of research areas and participate in integrated research projects. This system provides for multidisciplinary studies, allows students to tailor a program to their needs, and is responsive to changes in rapidly emerging fields. Also, students may have an opportunity to take advantage of other excellent programs at the University of Michigan. Faculty members in EECS have joint projects in other engineering departments and in a wide range of non-engineering programs including medicine, music, physics, information and library science, education, and others.

Computer Science and Engineering:

- Master of Science in Engineering (M.S.E.) in Computer Science and Engineering
- Master of Science (M.S.) in Computer Science and Engineering
- Doctor of Philosophy (Ph.D.) in Computer Science and Engineering

Electrical Engineering:

- Master of Science (M.S.) in Electrical Engineering
- Master of Science in Engineering (M.S.E.) in Electrical Engineering
- Doctor of Philosophy (Ph.D.) in Electrical Engineering

Electrical Engineering: Systems:

- Master of Science (M.S.) in Electrical Engineering: Systems
- Master of Science in Engineering (M.S.E.) in Electrical Engineering: Systems
- Doctor of Philosophy (Ph.D.) in Electrical Engineering: Systems

Master of Science
Master of Science in Engineering
Generally, the M.S.E. and M.S. degree programs in a given area are identical except for admission requirements. Application procedures and individual degree requirements for the M.S. and M.S.E. degree programs are available on the EECS Web site listed below. The principal requirements for the specific M.S.E. and M.S. degrees are listed below. (A more complete statement on master's degree requirements is available on the Web: http://www.eecs.umich.edu/eecs/graduate/).

M.S. and M.S.E. in Computer Science and Engineering
The graduate program in CSE is organized into five broad areas: (1) hardware systems, (2) intelligent systems, (3) software and programming languages, (4) theory of computation, and (5) VLSI (Very Large Scale Integration.)
A student must satisfy the regulations of the Rackham School of Graduate Studies, the College of Engineering, and the regulations as specified by the program brochure(s) and the program office.

A student must earn at least 30 credit hours of graduate level coursework, of which at least 24 hours must be technical courses, at least 15 hours must be CSE coursework at the 500 level or higher (excluding credit hours earned in individual study, research or seminar courses). The student must also satisfy course requirements in "kernel" areas of software, hardware, artificial intelligence and theory. A maximum of six credit hours of individual study, research and seminar courses will be accepted toward the master's degree. The VLSI concentration has slightly different course requirements; please refer to the CSE Brochure available on the Web for details.

The program requires that the grade point average received in CSE coursework must be at least 5.0 (based on Rackham's 9.0 scale). An individual course grade of B- or better (4.0 or better on Rackham's 9.0 scale) is required for the credit hours received in any course to be counted towards any master's degree requirement. A master's thesis is optional. Credit hours transferred may be applied to meet any master's degree requirement except the 15 credit hours of 500 level CSE coursework required. (Rackham specifies limitations to the circumstances under which credits may be transferred. See the *Rackham Student Handbook.*) Courses of an insufficiently advanced level, or which substantially duplicate in level and/or content courses already completed by the student, may not be counted as meeting any master's degree requirements.

M.S. and M.S.E. in Electrical Engineering
The Graduate Program in Electrical Engineering covers topics such as circuits and microsystems, electronics, VLSI, applied electromagnetics and RFC circuits, optics, solid state materials, devices, and integrated circuits. A student must earn at least 30 credit hours of graduate-level coursework, of which at least 24 credit hours must be in technical courses, at least 12 credit hours must be EECS coursework at the 500-level or higher (excluding credit hours earned in individual study, research, or seminar courses), and at least 3 credit hours must be in mathematics. The student must also choose a major area and satisfy the requirement in circuits and microsystems, applied electromagnetics and RF circuits, optics, solid state, or VSLI.

For each designated major area there is a set of courses called the "kernel." The major requirements are to be satisfied by taking courses from the respective kernels. Specifically, at least nine credit hours must be earned from the kernel of the major area, with at least six of these at the 500-level or higher. A grade point average of "B" or higher is required overall and also in EECS coursework. Course grades must be "B-" or higher to earn credit toward the master's degree.

A maximum of four credit hours of individual study, research, and seminar courses (EECS 599 and similar courses) will be accepted toward the master's degree. A master's thesis is optional.

Up to six credit hours may be transferred from other universities if the department grants approval. The student must also satisfy the regulations of the Rackham School of Graduate Studies and the College of Engineering.
Courses of an insufficiently advanced level, or which substantially duplicate in level and content courses already completed by the student, may not be counted as meeting any master's degree requirements.

M.S. and M.S.E. in Electrical Engineering: Systems
The Graduate Program in Electrical Engineering: Systems is identified with the disciplines of communications, control, signal and image processing. Systems theory, stochastic systems, information theory, modulation and coding, estimation and detection, robotics, networks, manufacturing, bioelectrical science, and other disciplines in which the emphasis is on the design and analysis of systems of interacting components or devices—rather than on the physical components or devices themselves—comprise the essential nature of the program.

A student must earn at least 30 credit hours of graduate-level coursework of which at least 24 credit hours must be in technical courses, at least 12 credit hours must be in EECS coursework at the 500-level or higher (excluding credit hours earned in individual study, research or seminar courses). The student must also choose major and minor areas, and complete a "kernel" of courses in each. The major area must be in communication, control systems, or signal processing. The minor area must be different from the major and must be chosen from either (i) the previous list, (ii) the following: biosystems, circuits and microsystems, computers, electromagnetics, manufacturing, optics or solid state, or (iii) an outside area of concentration.

At least nine credit hours must be earned from the kernel of the major area, with at least six of these at the 500-level or higher. At least six credit hours must be earned from the kernel of the minor area, with at least three of these at the 500-level or higher. Course grades must be "B-" or better in order to be counted towards any requirements. A grade point average of "B" or higher is required overall.

A maximum of four credit hours of individual study, research and seminar courses will be accepted toward the degree. A master's thesis is optional. Up to six credit hours may be transferred if the department grants approval. The student must also satisfy the regulations of the Rackham School of Graduate Studies and the College of Engineering.

Doctor of Philosophy
Ph.D. in Computer Science and Engineering
Ph.D. in Electrical Engineering
Ph.D. in Electrical Engineering: Systems
The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the result of the investigation in the form of a dissertation.

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. Candidacy is achieved when the student demonstrates competence in her/his broad field of knowledge through completion of a prescribed set of courses and passing a comprehensive examination.

Thirty-six hours (18 with a relevant master's degree) must be completed in graduate level coursework. In most areas, a student must pass a comprehensive examination in a major field of specialization and be recommended for candidacy for the doctorate. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.
Requirements regarding foreign language and nontechnical courses are left to individual departments or programs, and to the Graduate School. A prospective doctoral student should consult the program advisor regarding specific details.

A pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School office, 1004 Rackham Building, upon request.

The 3.4 Program for EECS majors only
Students with at least a 3.4 G.P.A. in their major course work and as an overall G.P.A. at the time of graduation can be admitted to EECS Masters Degree programs. See any Program Advisor for details.

Facilities
EECS departmental academic units, faculty members, and most of the research laboratories are housed in the modern EECS Building and in several nearby research buildings. EECS is home to more than a dozen state-of-the-art research laboratories, and it supports other interdepartmental research laboratories. The EECS research environment is strengthened by a university-wide computer network infrastructure. The College of Engineering's CAEN network, one of the largest campus networks, supports both instructional and research computing and has links to research facilities throughout Michigan, the nation, and the world.

Electrical Engineering and Computer Science Fields of Study

Master's and Ph.D. degrees are available in the following degree programs:
Computer Science and Engineering
Hardware
Intelligent Systems
Software Theory
VLSI

Electrical Engineering
Circuits and Microsystems
Applied Electromagnetics and RF Circuits
Optics Solid State VLSI

Electrical Engineering: Systems
Control Communications
Signal Processing

Electrical Engineering, Computer Engineering and Computer Science Courses

EECS 183. Elementary Programming Concepts
Prerequisite: none. (Credit for only one: EECS 183, Eng 101) I, II (4 credits)
Fundamental concepts and skills of programming in a high-level language. Flow of control: selection, iteration, subprograms. Data structures: strings, arrays, records, lists, tables. Algorithms using selection and iteration (decision making, finding maxima/minima, searching, sorting, simulation, etc.) Good program design, structure and style are emphasized. Testing and debugging. Not intended for Engineering students (who should take ENGR 101), nor for CS majors in LSA who qualify to enter EECS 280.
EECS 203. Discrete Mathematics
Prerequisite: Math 115. I, II (4 credits)
Introduction to the mathematical foundations of computer science. Topics covered include: propositional and predicate logic, set theory, function and relations, growth of functions and asymptotic notation, introduction to algorithms, elementary combinatorics and graph theory, and discrete probability theory.
EECS 215. Introduction to Electronic Circuits
Prerequisite: Math 116, Engr 101, Corequisite PHYS 240 (or 260). Cannot receive credit for EECS 314 and EECS 215. I, II (4 credits)
Introduction to electronic circuits. Basic Concepts of voltage and current; Kirchhoff's voltage and current laws; Ohm's law; voltage and current sources; Thevenin and Norton equivalent circuits; DC and low frequency active circuits using operational amplifiers, diodes, and transistors; small signal analysis; energy and power. Time- and frequency-domain analysis of RLC circuits. Basic passive and active electronic filters. Laboratory experience with electrical signals and circuits.
216. Introduction to Signals and Systems
Prerequisite: EECS 215; Preceded or accompanied by Math 216. I, II (4 credits)
Theory and practice of signals and systems engineering in continuous and discrete time. Continuous-time linear time-invariant systems, impulse response, convolution. Fourier series, Fourier transforms, spectrum, frequency response and filtering. Sampling leading to basic digital signal processing using the discrete-time Fourier and the discrete Fourier transform. Laplace transforms, transfer functions, poles and zeros, stability. Applications of Laplace transform theory to RLC circuit analysis. Introduction to communications, control, and signal processing. Weekly recitations and hardware/Matlab software laboratories.
EECS 230. Electromagnetics I
Prerequisite: Math 215, PHYS 240 (or 260). Co-requisite: EECS 215. I, II (4 credits)
Vector calculus. Electrostatics. Magnetostatics. Time-varying fields: Faraday's Law and displacement current. Maxwell's equations in differential form. Traveling waves and phasors. Uniform plane waves. Reflection and transmission at normal incidence. Transmission lines. Laboratory segment may include experiments with transmission lines, the use of computer-simulation exercises, and classroom demonstrations.
EECS 250 (Nav Sci 202). Electronic Sensing Systems
Prerequisite: preceded or accompanied by EECS 230 or Physics 240. II (3 credits)
Introduction to properties and behavior of electromagnetic energy as it pertains to naval applications of communication, radar, and electro-optics. Additional topics include sound navigation and ranging (SONAR) tracking and guidance systems, and computer controlled systems. Several laboratory demonstrations will illustrate applications of the theories and concepts learned in the classroom.
EECS 270. Introduction to Logic Design
Prerequisite: EECS 183 or Eng 101 or equivalent. I, II (4 credits)
Binary and non-binary systems, Boolean algebra, digital design techniques, logic gates, logic minimization, standard combinational circuits, sequential circuits, flip-flops, synthesis of synchronous sequential circuits, PLAs, ROMs, RAMs, arithmetic circuits, computer-aided design. Laboratory includes design and CAD experiments.
EECS 280. Programming and Introductory Data Structures
Prerequisite: Math 115 and prior programming experience. I, II (4 credits)
Techniques and algorithm development and effective programming, top-down analysis, structured programming, testing, and program correctness. Program language syntax and static and runtime semantics. Scope, procedure instantiation, recursion, abstract data types, and parameter passing methods. Structured data types, pointers, linked data structures, stacks, queues, arrays, records, and trees.
EECS 281. Data Structures and Algorithms
Prerequisite: EECS 203 and 280. I, II (4 credits)
Introduction to algorithm analysis and O-notation; Fundamental data structures including lists, stacks, queues, priority queues, hash tables, binary trees, search trees, balanced trees and graphs; searching and sorting algorithms; recursive algorithms; basic graph algorithms; introduction to greedy algorithms and divide and conquer strategy. Several programming assignments.
EECS 283. Programming for Science and Engineering
Prerequisite: EECS 183 or Eng 101 or equivalent. II (4 credits)
Programming concepts with numeric applications for mathematics, the sciences, and engineering. Object-oriented programming, abstract data types, and standard class libraries with numeric and non-numeric applications. Elementary data structures, linked lists, and dynamic allocation. Searching and sorting methods. Not intended for CS majors.
EECS 285. A Programming Language or Computer System
Prerequisite: some programming experience. I, II (2 credits)
A course covering a complex computer system or programming language. Programming problems will be assigned. Specific languages or systems to be offered will be announced in advance.

EECS 306. Signals and Systems II

Prerequisite: Math 216 or EECS 206, and (EECS 215 or EECS 314). I, II (4 credits)

Theory and practice of signals and systems engineering in continuous and discrete time. Hands-on experience in laboratory sessions with communications, control and signal processing. Continuous-time linear systems: convolution, Fourier and Laplace transforms, transfer functions, poles and zeros, stability, sampling, introductions to communications and feedback control. Discrete-time linear systems: Z transform, filters, Fourier transform, signal processing. State space models of systems using finite-state machines.

EECS 311. Electronic Circuits

Prerequisite: EECS 216 or (EECS 206 and EECS 215). II (4 credits)

Circuit models for bipolar junction and field-effect transistors; nonlinear elements; small-signal and piecewise analysis of nonlinear circuits; analysis and design of basic single-stage transistor amplifiers: gain, biasing, and frequency response; digital logic circuits; memory circuits (RAM, ROM). Design projects. Lecture and laboratory.

EECS 312. Digital Integrated Circuits

Prerequisite: EECS 216 or (EECS 206 and EECS 215). I, II (4 credits)

Design and analysis of static CMOS inverters and complex combinational logic gates. Dynamic logic families, pass-transistor logic, ratioed logic families. Sequential elements (latches, flip-flops). Bipolar-based logic; ECL, BiCMOS. Memories; SRAM, DRAM, EEPROM, PLA. I/O circuits and interconnect effects. Design project(s). Lecture, recitation and software labs.

EECS 314. Electrical Circuits, Systems, and Applications

Prerequisite: Math 214 or 216, Physics 240. Credit for only one: EECS 215, or 314. Not open to CE or EE students. I (4 credits)

Students will learn about EE systems operation, specifications and interactions with other modules. Theory will be motivated/introduced by the use of practical examples taken from a variety of fields. Topics covered include electrical circuit fundamentals, frequency response and electrical transients, analog and digital electronics. Optional hands-on experiences will be offered.

EECS 320. Introduction to Semiconductor Devices

Prerequisite: EECS 215, PHYS 240 or 260. I (4 credits)

Introduction to semiconductors in terms of atomic bonding and electron energy bands. Equilibrium statistics of electrons and holes. Carrier dynamics; continuity, drift, and diffusion currents; generation and recombination processes, including important optical processes. Introduction to: PN junctions, metal-semiconductor junctions, light detectors and emitters; bipolar junction transistors, junction and MOSFETs.

EECS 330. Electromagnetics II

Prerequisite: EECS 230. I, II (4 credits)

Time-varying electromagnetic fields and Maxwell's equations. Plane-wave propagation, reflection, and transmission. Geometric optics. Radiation and antennas. System applications of electromagnetic waves. Laboratory segment consists of experiments involving microwave and optical measurements and the design of practical systems.

EECS 334. Principles of Optics

Prerequisite: Physics 240. A student can receive credit for only one: EECS 334 or Physics 402. II (4 credits)

Basic principles of optics: light sources and propagation of light; geometrical optics, lenses and imaging; ray tracing and lens aberrations; interference of light waves, coherent and incoherent light beams; Fresnel and Fraunhofer diffraction. Overview of modern optics with laboratory demonstrations.

EECS 353. Introduction to Communications Systems

Prerequisite: EECS 216 or EECS 306. II (4 credits)

Mathematical analysis of signals and signal processing used in analog and digital communication systems; sampling; quantization; pulse transmission; intersymbol interference; Nyquist criterion; partial response signals; eye diagrams; equalization; mixing; analog modulation and demodulation; receiver architectures; phase-locked loops; signal-to-noise ratio analysis; digital modulation and demodulation; spread spectrum communications.

EECS 370. Introduction to Computer Organization

Prerequisite: (EECS 203 or EECS 270) and (EECS 280 or EECS 283). I, II (4 credits)

Basic concepts of computer organization and hardware. Instructions executed by a processor and how to use these instructions in simple assembly-language programs. Stored-program concept. Datapath and control for multiple implementations of a processor. Performance evaluation, pipelining, caches, virtual memory, input/output.

EECS 373. Design of Microprocessor Based Systems

Prerequisite: EECS 270 and 370 and Junior Standing. I, II (4 credits)

Principles of hardware and software microcomputer interfacing; digital logic design and implementation. Experiments with specially designed laboratory facilities. Introduction to digital development equipment and logic analyzers. Assembly language programming. Lecture and laboratory.

EECS 376. Foundations of Computer Science

Prerequisite: EECS 203 and 280 or equivalent. I, II (4 credits)

An introduction to computation theory: finite automata, regular languages, pushdown automata, context-free languages, Turing machines, recursive languages and functions, and computational complexity.

EECS 381. Object Oriented and Advanced Programming

Prerequisite: EECS 281. I, II (4 credits)

Programming techniques in Standard C++ for large-scale, complex, or high-performance software. Encapsulation, automatic memory management, exceptions, generic programming with templates and function objects, Standard Library algorithms and containers. Using single and multiple inheritance and polymorphism for code reuse and extensibility; basic design idioms, patterns, and notation.

EECS 385. Speed Programming

Prerequisite: EECS 281. II (1 credit)

A course to help students prepare for programming competitions such as the International Collegiate Programming competition. Students will learn fast problem solving and program writing techniques, quick classification of problems, common data structures and algorithms, team strategies, and standard libraries. Students will compete in weekly contests.

EECS 398. Special Topics

Prerequisite: permission of instructor. (1-4 credits)

Topics of current interest selected by the faculty. Lecture, seminar, or laboratory.

EECS 401. Probabilistic Methods in Engineering

Prerequisite: EECS 216 or EECS 306 or Graduate Standing. I, II (4 credits)

Basic concepts of probability theory. Random variables: discrete, continuous, and conditional probability distributions; averages; independence. Statistical inference: hypothesis testing and estimation. Introduction to discrete and continuous random processes.

EECS 411. Microwave Circuits I

Prerequisite: EECS 330 or Graduate Standing. I (4 credits)

Transmission-line theory, microstrip and coplanar lines, S-parameters, signal-flow graphs, matching networks, directional couplers, low-pass and band-pass filters, diode detectors. Design, fabrication, and measurements (1-10GHz) of microwave-integrated circuits using CAD tools and network analyzers.

EECS 413. Monolithic Amplifier Circuits

Prerequisite: EECS 311 and EECS 320 or Graduate Standing. I (4 credits)

Analysis and design of BJT and MOS multi-transistor amplifiers. Feedback theory and application to feedback amplifiers. Stability considerations, pole-zero cancellation, root locus techniques in feedback amplifiers. Detailed analysis and design of BJT and MOS integrated operational amplifiers. Lectures and laboratory.

EECS 414. Introduction to MEMS

Prerequisite: Math 215, Math 216, Physics 240 or Graduate Standing I (4 credits)

Micro electro mechanical systems (MEMS), devices, and technologies. Micro-machining and microfabrication techniques, including planar thin-film processing, silicon etching, wafer bonding, photolithography, deposition, and etching. Transduction mechanisms and modeling in different energy domains. Analysis of micromachined capacitive, piezoresistive, and thermal sensors/actuators and applications. Computer-aided design for MEMS layout, fabrication, and analysis.

EECS 417 (BiomedE 417). Electrical Biophysics

Prerequisite: EECS 206 and 215 or Graduate Standing. II (4 credits)

Electrical biophysics of nerve and muscle; electrical conduction in excitable tissue; quantitative models for nerve and muscle, including the Hodgkin Huxley equations; biopotential mapping, cardiac electrophysiology, and functional electrical stimulation; group projects. Lecture and recitation.

EECS 420. Physical Principles Underlying Smart Devices

Prerequisite: (EECS 320 and EECS 330) or Graduate Standing. I (4 credits)

Structural properties of materials. Basic quantum mechanics of electrons in solids. Band theory and trap states. Charge transport, band conduction and hopping conduction. Optical properties of materials. Piezoelectric and ferro-electric phenomena. Magnetic effects in materials. Physical phenomena will be related transistors, light emitters, sensor and memory devices.

EECS 421. Properties of Transistors

Prerequisite: EECS 320 or Graduate Standing. I (4 credits)

In depth understanding of the device physics and working principle of some basic IC components: metal-semiconductor junctions, P-N junctions, metal-oxide-semiconductor junctions, MOSFETs and BJTs

EECS 423. Solid-State Device Laboratory

Prerequisite: EECS 320 or Graduate Standing. I (4 credits)

Semiconductor material and device fabrication and evaluation: diodes, bipolar and field-effect transistors, passive components. Semiconductor processing techniques: oxidation, diffusion, deposition, etching, photolithography. Lecture and laboratory. Projects to design and simulate device fabrication sequence.

EECS 425. Integrated Microsystems Laboratory

Prerequisite: EECS 311 or EECS 312 or EECS 414 or Graduate Standing. II (4 credits)

Development of a complete integrated microsystem, from functional definition to final test. MEMS-based transducer design and electrical, mechanical and thermal limits. Design of MOS interface circuits. MEMS and MOS chip fabrication. Mask making, pattern transfer, oxidation, ion implantation and metallization. Packaging and testing challenges. Students work in interdisciplinary teams.

EECS 427. VLSI Design I

Prerequisite: (EECS 270, EECS 312, EECS 320) or Graduate Standing. I, II (4 credits)

Design techniques for rapid implementations of very large-scale integrated (VLSI) circuits, MOS technology and logic. Structured design. Design rules, layout procedures. Design aids: layout, design rule checking, logic, and circuit simulation. Timing. Testability. Architectures for VLSI. Projects to develop and lay out circuits.

EECS 429. Semiconductor Optoelectronic Devices

Prerequisite: EECS 320 or Graduate Standing. II (4 credits)

Materials for optoelectronics, optical processes in semiconductors, absorption and radiation, transition rates and carrier lifetime. Principles of LEDs, lasers, photodetectors, modulators and solar cells. Optoelectronic integrated circuits. Designs, demonstrations and projects related to optoelectronic device phenomena.

EECS 430 (AOSS 431). Radiowave Propagation and Link Design

Prerequisite: EECS 330 and Senior Standing or Graduate Standing. II (4 credits)

Fundamentals of electromagnetic wave propagation in the ionosphere, the troposphere, and near the Earth. Student teams will develop practical radio link designs and demonstrate critical technologies. Simple antennas, noise, diffraction, refraction, absorption, multi-path interference, and scattering are studied.

EECS 434. Principles of Photonics

Prerequisite: EECS 330 or EECS 334 or permission of instructor or Graduate Standing. I (4 credits)

Introduction to photonics, opto-electronics, lasers and fiber-optics. Topics include mirrors, interferometers, modulators and propagation in waveguides and fibers. The second half treats photons in semiconductors, including semi-conductor lasers, detectors and noise effects. System applications include fiber lightwave systems, ultra-high-peak power lasers, and display technologies.

EECS 435. Fourier Optics

Prerequisite: EECS 306 or EECS 216, preceded or accompanied by EECS 334 and Junior standing or Graduate standing. II odd years. (3 credits)

Basic physical optics treated from the viewpoint of Fourier analysis. Fourier-transform relations in optical systems. Theory of image formation and Fourier transformation by lenses. Frequency response of diffraction-limited and aberrated imaging systems. Coherent and incoherent light. Comparison of imagery with coherent and with incoherent light. Resolution limitations. Optical information processing, including spatial matched filtering.

EECS 438. Advanced Lasers and Optics Laboratory

Prerequisite: EECS 334 or EECS 434 or Graduate Standing. II (4 credits)

Construction and design of lasers; gaussian beams; nonlinear optics; fiber optics; detectors; dispersion; Fourier optics; spectroscopy. Project requires the design and set-up of a practical optical system.

EECS 442. Computer Vision

Prerequisite: EECS 281 or Graduate Standing. alternate years (4 credits)

Computational methods for the recovery, representation, and application of visual information. Topics from image formation, binary images, digital geometry, similarity and dissimilarity detection, matching, curve and surface fitting, constraint propagation relaxation labeling, stereo, shading texture, object representation and recognition, dynamic scene analysis, and knowledge based techniques. Hardware, software techniques.

EECS 451. Digital Signal Processing and Analysis

Prerequisite: EECS 216 or EECS 306 or Graduate Standing. I, II (4 credits)

Introduction to digital signal processing of continuous and discrete signals. The family of Fourier Transforms including the Discrete Fourier Transform (DFT). Development of the Fast Fourier Transform (FFT). Signal sampling and reconstruction. Design and analysis of digital filters. Correlation and spectral estimation.

EECS 452. Digital Signal Processing Design Laboratory

Prerequisite: EECS 280, and (EECS 216 or EECS 306) and (EECS 206 or EECS 451) or Graduate Standing. I, II (4 credits)

Architectures of single-chip DSP processors. Laboratory exercises using two state-of-the-art fixed-point processors; A/D and D/A conversion, digital wave-form generators, and real-time FIR and IIR filters. Central to this course is a team project in real-time DSP design (including software and hardware).

EECS 455. Digital Communication Signals and Systems

Prerequisite: (EECS 216 or EECS 306), EECS 401 or Graduate Standing I (3 credits)

Digital transmission techniques in data communications, with application to computer and space communications; design and detection of digital signals for low error rate; forward and feedback transmission techniques; matched filters; modems, block and convolutional coding; Viterbi decoding.

EECS 458 (BiomedE 458). Biomedical Instrumentation and Design

Prerequisite: EECS 215 or 314 or consent of instructor or Graduate Standing. I, II (4 credits)

Measurement and analysis of biopotentials and biomedical transducer characteristics; electrical safety; applications of FETs, integrated circuits, operational amplifiers for signal processing and computer interfacing; signal analysis and display on the laboratory minicomputer. Lectures and laboratory.

EECS 460. Control Systems Analysis and Design

Prerequisite: EECS 216 or EECS 306 or Graduate Standing. I (3 credits)

Basic techniques for analysis and design of controllers applicable in any industry (e.g. automotive, aerospace, computer, communication, chemical, bioengineering, power, etc.) are discussed. Both time- and frequency-domain methods are covered. Root locus, Nyquist and Bode plot-based techniques are outlined. Computer-based experiment and discussion sessions are included in the course.

EECS 461. Embedded Control Systems

Prerequisite: EECS 216 or EECS 306 or EECS 373 or Graduate Standing. I (4 credits)

Basic interdisciplinary concepts needed to implement a microprocessor based control system. Sensors and actuators. Quadrature decoding. Pulse width modulation. DC motors. Force feedback algorithms for human computer interaction. Real time operating systems. Networking. Use of MATLAB to model hybrid dynamical systems. Autocode generation for rapid prototyping. Lecture and laboratory.

EECS 470. Computer Architecture

Prerequisite: EECS 370 and EECS 270, or Graduate Standing. I, II (4 credits)

Basic concepts of computer architecture and organization. Computer evolution. Design methodology. Performance evaluation. Elementary queuing models. CPU architecture. Introduction sets. ALU design. Hardware and micro-programmed control. Nanoprogramming. Memory hierarchies. Virtual memory. Cache design. Input-output architectures. Interrupts and DMA. I/O processors. Parallel processing. Pipelined processors. Multiprocessors.

EECS 475. Introduction to Cryptography

Prerequisite: (EECS 203 or Math 312 or Math 412) and (EECS 183 or EECS 280). I, alternating years (4 credits)

Covers fundamental concepts, algorithms, and protocols in cryptography. Topics: ancient ciphers, Shannon theory, symmetric encryption, public key encryption. hash functions, digital signatures, key distribution. Highlights AES, RSA, discrete log, elliptic curves. Emphasizes rigorous mathematical study in terms of algorithmic complexity. Includes necessary background from algorithms, probability, number theory, and algebra.

EECS 477. Introduction to Algorithms

Prerequisite: EECS 281 or Graduate Standing. I (4 credits)

Fundamental techniques for designing efficient algorithms and basic mathematical methods for analyzing their performance. Paradigms for algorithm design: divide-and-conquer, greedy methods, graph search techniques, dynamic programming. Design of efficient data structures and analysis of the running time and space requirements of algorithms in the worst and average cases.

EECS 478. Logic Circuit Synthesis and Optimization

Prerequisite: (EECS 203, EECS 270, and Senior Standing) or Graduate Standing. I, II (4 credits)

Advanced design of logic circuits. Technology constraints. Theoretical foundations. Computer-aided design algorithms. Two-level and multilevel optimization of combinational circuits. Optimization of finite-state machines. High-level synthesis techniques: modeling, scheduling, and binding. Verification and testing.

EECS 480. Logic and Formal Verification

Prerequisite: EECS 281 and (EECS 376 or EECS 270). II, alternating years (4 credits)

An introduction to current methodologies for verifying computer systems. Topics covered include logic and theorem proving; transition systems; temporal logic and the mu-calculus; modeling sequential and concurrent systems; model checking methods; binary decision diagrams; and controlling state explosion. Students will complete a project using current model checking technology.

EECS 481. Software Engineering

Prerequisite: EECS 281 or Graduate Standing. I, II (4 credits)

Pragmatic aspects of the production of software systems, dealing with structuring principles, design methodologies and informal analysis. Emphasis is given to development of large, complex software systems. A term project is usually required.

EECS 482. Introduction to Operating Systems

Prerequisite: EECS 281 and EECS 370 or Graduate Standing. I, II (4 credits)

Operating system design and implementation: multi-tasking; concurrency and synchronization; inter-process communication; deadlock; scheduling; resource allocation; memory and storage management; input-output; file systems; protection and security. Students write several substantial programs dealing with concurrency and synchronization in a multi-task environment, with file systems, and with memory management.

EECS 483. Compiler Construction

Prerequisite: EECS 281 or Graduate Standing. I (4 credits)

Introduction to compiling techniques including parsing algorithms, semantic processing and optimization. Students implement a compiler for a substantial programming language using a compiler generating system.

EECS 484. Database Management Systems

Prerequisite: EECS 281 or Graduate Standing. I, II (4 credits)

Concepts and methods for the design, creation, query and management of large enterprise databases. Functions and characteristics of the leading database management systems. Query languages such as SQL, forms, embedded SQL, and application development tools. Database design, integrity, normalization, access methods, query optimization, transaction management and concurrency control and recovery.

EECS 485. Web Database and Information Systems

Prerequisites: EECS 484 or permission of instructor or Graduate Standing. II (4 credits)

Design and use of databases in the Web context; data models, database design, replication issues, client/server systems, information retrieval, web server design; substantial project involving the development of a database-backed web site.

EECS 487. Interactive Computer Graphics

Prerequisite: EECS 281 or Graduate Standing. I, II (4 credits)

Computer graphics hardware, line drawing, rasterization, anti-aliasing, graphical user interface (GUI), affine geometry, projective geometry, geometric transformation, polygons, curves, splines, solid models, lighting and shading, image rendering, ray tracing, radiosity, hidden surface removal, texture mapping, animation, virtual reality, and scientific visualization.

EECS 489. Computer Networks

Prerequisite: EECS 482 or Graduate Standing. II (4 credits)

Protocols and architectures of computer networks. Topics include client-server computing, socket programming, naming and addressing, media access protocols, routing and transport protocols, flow and congestion control, and other application-specific protocols. Emphasis is placed on understanding protocol design principles. Programming problems to explore design choices and actual implementation issues assigned.

EECS 490 Programming Languages

Prerequisite: EECS 281. II (4 credits)

Fundamental concepts in programming languages. Course covers different programming languages including functional, imperative, object-oriented, and logic programming languages; different programming language features for naming, control flow, memory management, concurrency, and modularity; as well as methodologies, techniques, and tools for writing correct and maintainable programs.

EECS 492. Introduction to Artificial Intelligence

Prerequisite: EECS 281 or Graduate Standing. I, II (4 credits)

Fundamental concepts of AI, organized around the task of building computational agents. Core topics include search, logic, representation and reasoning, automated planning, decision making under uncertainty, and machine learning.

EECS 493. User Interface Development
Prerequisite: EECS 281 or Graduate Standing. II (4 credits)
Concepts and techniques for designing computer system user interfaces to be easy to learn and use, with an introduction to their implementation. Task analysis, design of functionality, display and interaction design, and usability evaluation. Interface programming using an object-oriented application framework. Fluency in a standard object-oriented programming language is assumed.

EECS 494. Computer Game Design and Development
Prerequisite: EECS 281 or Graduate Standing. I (4 credits)
Concepts and methods for the design and development of computer games. Topics include: history of games, 2D graphics and animation, sprites, 3D animation, binary space partition trees, software engineering, game design, interactive fiction, user interfaces, artificial intelligence, game SDK's, networking, multi-player games, game development environments, commercialization of software.

EECS 495. Patent Fundamentals for Engineers
Prerequisite: (Junior or Senior Standing) or Graduate Standing. I Alternate years. (4 credits)
This course covers the fundamentals of patents for engineers. The first part of the course focuses on the rules and codes that govern patent prosecution, and the second part focuses on claim drafting and amendment writing. Other topics covered include litigation, ethics and licensing.

EECS 496. Major Design Experience Professionalism
Prerequisite: Senior Standing. I, II (2 credits)
Design principles for multidisciplinary team projects, team strategies, entrepreneurial skills, ethics, social and environmental awareness, and life long learning. Each student *must* take (simultaneously) Tech Comm 496 (2 cr.) and one of the approved 400-level team project courses in computing (4 cr.).

EECS 497. EECS Major Design Projects
Prerequisite: Senior Standing and successful completion of at least two-thirds of the credit hours required for the program subjects. I, II (4 credits)
Professional problem-solving methods developed through intensive group studies. Normally one significant design project is chosen for entire class requiring multiple EECS disciplines and teams. Use of analytic, computer, design, and experimental techniques where applicable are used. Projects are often interdisciplinary allowing non-EECS seniors to also take the course (consult with instructor).

EECS 498. Special Topics
Prerequisite: permission of instructor. (1-4 credits)
Topics of current interest selected by the faculty. Lecture, seminar or laboratory.

EECS 499. Directed Study
Prerequisite: Senior Standing in EECS. I, II, III (1-4 credits)
Individual study of selected topics in Electrical Engineering and Computer Science. May include experimental investigation or library research. Primarily for undergraduates.

EECS 500. Tutorial Lecture Series in System Science
Prerequisite: Graduate Standing; mandatory satisfactory/ unsatisfactory. I, II (1 credit)
Students are introduced to the frontiers of System Science research. Sections 01, 02, and 03 are devoted, respectively, to Communications, Control, and Signal Processing. The tutorials are delivered by leaders of the respective research fields, invited from academia and industry. The presentations are self-contained and accessible to all graduate students in System Science.

EECS 501. Probability and Random Processes
Prerequisite: EECS 401 or Graduate Standing. I, II (4 credits)
Introduction to probability and random processes. Topics include probability axioms, sigma algebras, random vectors, expectation, probability distributions and densities, Poisson and Wiener processes, stationary processes, autocorrelation, spectral density, effects of filtering, linear least-squares estimation, and convergence of random sequences. A student may receive credit for only one: EECS 401 or EECS 501.

EECS 502. Stochastic Processes
Prerequisite: EECS 501. II alternate years (3 credits)
Correlations and spectra. Quadratic mean calculus, including stochastic integrals and representations, wide-sense stationary processes (filtering, white noise, sampling, time averages, moving averages, autoregression). Renewal and regenerative processes, Markov chains, random walk and run, branching processes, Markov jump processes, uniformization, reversibility, and queuing applications.

EECS 503. Introduction to Numerical Electromagnetics
Prerequisite: EECS 330. I (3 credits)
Introduction to numerical methods in electromagnetics including finite difference, finite element and integral equation methods for static, harmonic and time dependent fields; use of commercial software for analysis and design purposes; applications to open and shielded transmission lines, antennas, cavity resonances and scattering.

EECS 509. BioMEMS
Prerequisite: none. II alternate years (3 credits)
Latest advances in bioMEMS, specifically microsystems targeting developmental biology and cell culture. Organism's development, from genome to multicellular tissue. BioMEMS devices: microPCR chips, microfluidic mixers, tissue scaffolds. Familiarize students with microfabrication and microsystems. View and evaluate bioMEMS devices and innovations. Implantable and diagnostic microsystems. Critical evaluation of publications required. A principal component of the grade will be a written NSF or NIH exploratory proposal.

EECS 510. Intelligent Transportation Systems Research Topics
Prerequisite: two ITS-Certificate courses (may be taken concurrently). II (2 credits)
Topics include driver-highway interactions (traffic modeling, analysis and simulation), driver-vehicle interactions (human factors), vehicle-highway interactions (computer/communications systems architecture), collision prevention, ITS technologies (in-vehicle electronic sensors, etc.), socioeconomic aspects (user acceptance and liability), and system integration (comprehensive modeling and competitive strategy).

EECS 511. Integrated Analog/Digital Interface Circuits
Prerequisite: EECS 413 or permission of instructor. II (4 credits)
This course covers most of the well known analog to digital conversion schemes. These include the flash, folding, multi-step and pipeline Nyquist rate, architectures. Oversampling converters are also discussed. Practical design work is a significant part of this course. Students design and model complete converters.
EECS 512. Amorphous and Microcrystalline Semiconductor Thin Film Devices
Prerequisite: EECS 421 and/or permission of instructor. I (3 credits)
Introduction and fundamentals of physical, optical and electrical properties of amorphous and microcrystalline semiconductor based devices: MIM structures, Schottky diodes, p-i-n junctions, heterojunctions, MIS structures, thin-film transistors, solar cells, threshold and memory switching devices and large area x-ray radiation detectors.
EECS 513. Flat Panel Displays
Prerequisite: EECS 423, EECS 512 and/or permission of instructor. II (3 credits)
Introduction and fundamentals to the passive, active, reflective and emissive flat panel display technologies. This course will discuss the physics, operating principles, properties and technology of the flat panel displays.
EECS 514. Advanced MEMS Devices and Technologies
Prerequisite: EECS 414. II (4 credits)
Advanced micro electro mechanical systems (MEMS) devices and technologies. Transduction techniques, including piezoelectric, electrothermal, and resonant techniques. Chemical, gas, and biological sensors, microfluidic and biomedical devices. Micromachining technologies such as laser machining and microdrilling, EDM, materials such as SiC and diamond. Sensor and actuator analysis and design through CAD.
EECS 515. Integrated Microsystems
Prerequisite: EECS 414. I (4 credits)
Review of interface electronics for sense and drive and their influence on device performance, interface standards, MEMS and circuit noise sources, packaging and assembly techniques, testing and calibration approaches, and communication in integrated microsystems. Applications, including RF MEMS, optical MEMS, bioMEMS, and microfluidics. Design project using CAD and report preparation.
EECS 516 (BiomedE 516). Medical Imaging Systems
Prerequisite: EECS 451. I (3 credits)
Principles of modern medical imaging systems. For each modality the basic physics is described, leading to a systems model of the imager. Fundamental similarities between the imaging equations of different modalities will be stressed. Modalities covered include radiography, x-ray computed tomography (CT), NMR imaging (MRI) and real-time ultra-sound.
EECS 517 (NERS 578). Physical Processes in Plasmas
Prerequisite: EECS 330. II, even years (3 credits)
Plasma physics applied to electrical gas discharges used for material processing. Gas kinetics; atomic collisions; transport coefficients; drift and diffusion; sheaths; Boltzmann distribution function calculation; plasma simulation; plasma diagnostics by particle probes, spectroscopy, and electromagnetic waves; analysis of commonly used plasma tools for materials processing.
EECS 518 (AOSS 595). Magnetosphere and Solar Wind
Prerequisite: Graduate Standing. I, even years (3 credits)
General principles of magnetohydrodynamics; theory of the expanding atmospheres; properties of solar wind, interaction of solar wind with the magneto-sphere of the Earth and other planets; bow shock and magnetotail, trapped particles, auroras.
EECS 519 (NERS 575). Plasma Generation and Diagnostics Laboratory
Prerequisite: preceded or accompanied by a course covering electromagnetism. II (4 credits)
Laboratory techniques for plasma ionization and diagnosis relevant to plasma processing, propulsion, vacuum electronics, and fusion. Plasma generation includes: high voltage-DC, radio frequency, and electron beam sustained discharges. Diagnostics include: Langmuir probes, microwave cavity perturbation, microwave interferometry, laser schlieren, and optical emission spectroscopy. Plasma parameters measured are: electron/ion density and electron temperature.
EECS 520. Electronic and Optical Properties of Semiconductors
Prerequisite: EECS 420 or EECS 540. II (4 credits)
The course discusses in detail the theory behind important semiconductor-based experiments such as Hall effect and Hall mobility measurement; velocity-field measurement; photoluminescence; gain; pump-probe studies; pressure and strain-dependent studies. Theory will cover: Bandstructure in quantum wells; effect of strain on bandstructure; transport theory; Monte Carlo methods for high field transport; excitons, optical absorption, luminescence and gain.
EECS 521. High-Speed Transistors
Prerequisite: EECS 421 II (3 credits)
Detailed theory of high-speed digital and high-frequency analog transistors. Carrier injection and control mechanisms. Limits to miniaturization of conventional transistor concepts. Novel submicron transistors including MESFET, heterojunction and quasi-ballistic transistor concepts.
EECS 522. Analog Integrated Circuits
Prerequisite: EECS 413. II (4 credits)
Review of integrated circuit fabrication technologies and BJT and MOS transistor models. Detailed analysis and design of analog integrated circuits, including power amplifiers, voltage references, voltage regulators, rectifiers, oscillators, multipliers, mixers, phase detectors, and phase-locked loops. Design projects. Lectures and discussion.

EECS 523. Digital Integrated Technology

Prerequisite: EECS 423 or 425 and EECS 311 and EECS 320. I (4 credits)

Integrated circuit fabrication overview, relationships between processing choices and device performance characteristics. Long-channel device I-V review, short-channel MOSFET I-V characteristics including velocity saturation, mobility degradation, hot carriers, gate depletion. MOS device scaling strategies, silicon-on-insulator, lightly-doped drain structures, on-chip interconnect parasitics and performance. Major CMOS scaling challenges. Process and circuit simulation.

EECS 525. Advanced Solid State Microwave Circuits

Prerequisite: EECS 411, EECS 421 or EECS 521. I (3 credits)

General properties and design of linear and nonlinear solid state microwave circuits including: amplifier gain blocks, low-noise, broadband and power amplifiers, oscillators, mixer and multiplier circuits, packaging, system implementation for wireless communication.

EECS 526. High-Performance Dynamic Device Models and Circuits

Prerequisite: EECS 413, or both EECS 311 and EECS 320. II (4 credits)

Models for devices (BJTs, FETs, and integrated circuits), with primary emphasis on large-signal dynamic charge-control models. Mathematics and physics fundamentals for measurement concepts and methods. Mathematical and computer analysis and design of high-speed dynamic circuits. Dynamic circuit functional blocks, level detection/comparison circuits; sweep/ramp, multivibrator, and logic gate circuits.

EECS 527. Layout Synthesis and Optimization

Prerequisite: EECS 281 or EECS 478 or Graduate Standing. II (3 or 4 credits)

Theory of circuit partitioning, floorplanning and placement algorithms. Techniques for routing and clock tree design. Timing analysis and cycle time optimization. Topics in low-power design. Large-scale optimization heuristics, simulated annealing and AI techniques in CAD. Modern physical design methodologies and CAD software development.

EECS 528. Principles of Microelectronics Process Technology

Prerequisite: EECS 421, EECS 423. II (3 credits)

Theoretical analysis of the chemistry and physics of process technologies used in micro-electronics fabrication. Topics include: semiconductor growth, material characterization, lithography tools, photo-resist models, thin film deposition, chemical etching, plasma etching, electrical contact formation, micro-structure processing, and process modeling.

EECS 529. Semiconductor Lasers and LEDs

Prerequisite: EECS 429. I (3 credits)

Optical processes in semiconductors, spontaneous emission, absorption gain, stimulated emission. Principles of light-emitting diodes, including transient effects, spectral and spatial radiation fields. Principles of semiconducting lasers; gain-current relationships, radiation fields, optical confinement and transient effects.

EECS 530 (Appl Phys 530). Electromagnetic Theory I

Prerequisite: EECS 330 or Physics 438. I (3 credits)

Maxwell's equations, constitutive relations and boundary conditions. Potentials and the representation of electromagnetic fields. Uniqueness, duality, equivalence, reciprocity and Babinet's theorems. Plane, cylindrical, and spherical waves. Waveguides and elementary antennas. The limiting case of electro- and magneto-statics.

EECS 531. Antenna Theory and Design

Prerequisite: EECS 330. II (3 credits)

Theory of transmitting and receiving antennas. Reciprocity. Wire antennas: dipoles, loops and traveling-wave antennas. Analysis and synthesis of linear arrays. Phased arrays. Input impedance and method of moments. Mutual impedance. Aperture antennas: slot, Babinet's principle. Microstrip antennas. Horns, reflector and lens antennas.

EECS 532. Microwave Remote Sensing I: Radiometry

Prerequisite: EECS 330, Graduate Standing. I odd years (3 credits)

Radiative transfer theory: blackbody radiation; microwave radiometry; atmospheric propagation and emission; radiometer receivers; surface and volume scattering and emission; applications to meteorology, oceanography, and hydrology.

EECS 533. Microwave Measurements Laboratory

Prerequisite: EECS 330, Graduate Standing. II (3 credits)

Advanced topics in microwave measurements: power spectrum and noise measurement, introduction to state-of-the-art microwave test equipment, methods for measuring the dielectric constant of materials, polarimetric radar cross section measurements, near field antenna pattern measurements, electromagnetic emission measurement (EM compatibility). Followed by a project that will include design, analysis, and construction of a microwave subsystem.

EECS 535. Optical Information Processing

Prerequisite: EECS 334. I even years (3 credits)

Theory of image formation with holography; applications of holography; white light interferometry; techniques for optical digital computing; special topics of current research interest.

EECS 536. Classical Statistical Optics

Prerequisite: EECS 334 or EECS 434, and EECS 401 or Math 425. I odd years (3 credits)

Applications of random variables to optics; statistical properties of light waves. Coherence theory, spatial and temporal. Information retrieval; imaging through inhomogeneous media; noise processes in imaging and interferometric systems.

EECS 537 (Appl Phys 537). Classical Optics

Prerequisite: EECS 330 and EECS 334. I (3 credits)

Theory of electromagnetic, physical, and geometrical optics. Classical theory of dispersion. Linear response, Kramers-Kronig relations, and pulse propagation. Light scattering. Geometrical optics and propagation in inhomogeneous media. Dielectric waveguides. Interferometry and theory of coherence. Diffraction, Fresnel and Fraunhofer. Gaussian beams and ABCD law.

EECS 538 (Appl Phys 550) (Physics 650). Optical Waves in Crystals
Prerequisite: EECS 434. I (3 credits)
Propagation of laser beams: Gaussian wave optics and the ABCD law. Manipulation of light by electrical, acoustical waves; crystal properties and the dielectric tensor; electro-optic, acousto-optic effects and devices. Introduction to nonlinear optics; harmonic generation, optical rectification, four-wave mixing, self-focusing, and self-phase modulation.

EECS 539 (Appl Phys 551) (Physics 651). Lasers
Prerequisite: EECS 537 and EECS 538. II (3 credits)
Complete study of laser operation: the atom-field interaction; homogeneous and inhomogeneous broadening mechanisms; atomic rate equations; gain and saturation; laser oscillation; laser resonators, modes, and cavity equations; cavity modes; laser dynamics, Q-switching and modelocking. Special topics such as femto-seconds lasers and ultrahigh power lasers.

EECS 540 (Appl Phys 540). Applied Quantum Mechanics I
Prerequisite: permission of instructor. I (3 credits)
Introduction to nonrelativistic quantum mechanics. Summary of classical mechanics, postulates of quantum mechanics and operator formalism, stationary state problems (including quantum wells, harmonic oscillator, angular momentum theory and spin, atoms and molecules, band theory in solids), time evolution, approximation methods for time independent and time dependent interactions including electromagnetic interactions, scattering.

EECS 541 (Appl Phys 541). Applied Quantum Mechanics II
Prerequisite: EECS 540. II (3 credits)
Continuation of nonrelativistic quantum mechanics. Advanced angular momentum theory, second quantization, non-relativistic quantum electrodynamics, advanced scattering theory, density matrix formalism, reservoir theory.

EECS 542. Vision Processing
Prerequisite: EECS 442. Alternate years (3 credits)
Details of image formation theory, including the consideration of dynamic image sequences. The theoretical frameworks for edge detection, feature extraction, and surface description are presented. The relationship between image formation and object features is examined in detail. Programming required.

EECS 543. Knowledge-Based Systems
Prerequisite: EECS 281 and Graduate Standing or permission of instructor. I (3 credits)
Techniques and principles for developing application software based on explicit representation and manipulation of domain knowledge, as applied to areas such as pattern matching, problem-solving, automated planning, and natural-language processing. Discussion of major programming approaches used in the design and development of knowledge-based systems.

EECS 545. Machine Learning
Prerequisite: EECS 492. (3 credits)
Survey of recent research on learning in artificial intelligence systems. Topics include learning based on examples, instructions, analogy, discovery, experimentation, observation, problem-solving and explanation. The cognitive aspects of learning will also be studied.

EECS 546 (Appl Phys 546). Ultrafast Optics
Prerequisite: EECS 537. II (3 credits)
Propagation of ultrashort optical pulses in linear and nonlinear media, and through dispersive optical elements. Laser mode-locking and ultrashort pulse generation. Chirped-pulse amplification. Experimental techniques for high time resolution. Ultrafast Optoelectronics. Survey of ultrafast high field interactions.

EECS 547 (SI 652). Electronic Commerce
Prerequisites: EECS 281 or SI 502 or permission of instructor. II (3 credits)
Introduction to the design and analysis of automated commerce systems, from both a technological and social perspective. Infrastructure supporting search for commerce opportunities, negotiating terms of trade, and executing transactions. Issues of security, privacy, incentives, and strategy.

EECS 550. Information Theory
Prerequisite: EECS 501. I (3 credits)
The concepts of source, channel, rate of transmission of information. Entropy and mutual information. The noiseless coding theorem. Noisy channels; the coding theorem for finite state zero memory channels. Channel capacity. Error bounds. Parity check codes. Source encoding.

EECS 551. Mathematical Methods for Signal Processing
Prerequisite: Preceded or accompanied by EECS 501. I (3 credits)
Linear shift-invariant systems in continuous time and discrete time. Sampling theory. Fourier analysis. Sample rate conversion. Signal representation in vector spaces. Projection theorem and least-squares approximations. Eigendecompositions and signal subspace methods. Applications in signal processing.

EECS 552 (Appl Phys 552). Fiber Optical Communications
Prerequisite: EECS 434 or EECS 538 or permission of instructor. II odd years (3 credits)
Principles of fiber optical communications and networks. Point-to-point sys-tems and shared medium networks. Fiber propagation including attenuation, dispersion and nonlinearities. Topics covered include erbium-doped amplifiers, Bragg and long period gratings, fiber transmission based on solitons and non-return-to-zero, and time- and wavelength-division-multiplexed networks.

EECS 554. Introduction to Digital Communication and Coding
Prerequisite: EECS 306 and EECS 401. I (3 credits)
Digital transmission of information across discrete and analog channels. Sampling; quantization; noiseless source codes for data compression: Huffman's algorithm and entropy; block and convolutional channel codes for error correction; channel capacity; digital modulation methods: PSK, MSK, FSK, QAM; matched filter receivers. Performance analysis: power, bandwidth, data rate, and error probability.

EECS 555. Digital Communication Theory
Prerequisite: EECS 501, EECS 554. II (3 credits)
Theory of digital modulation and coding. Optimum receivers in Gaussian noise. Signal space and decision theory. Signal design. Bandwidth and dimensionality. Fundamental limits in coding and modulation. Capacity and cutoff rate. Block, convolutional and trellis coding. Continuous phase modulation. Filtered channels and intersymbol interference. Equalization. Spread-spectrum. Fading channels. Current topics.
EECS 556. Image Processing
Prerequisite: EECS 501, EECS 551. II (3 credits)
Theory and application of digital image processing. Random field models of images. Sampling, quantization, image compression, enhancement, restoration, segmentation, shape description, reconstruction of pictures from their projections, pattern recognition. Applications include biomedical images, time-varying imagery, robotics, and optics.
EECS 557. Communication Networks
Prerequisite: Graduate Standing, preceded by EECS 401 or accompanied by EECS 501. I (3 credits)
System architectures. Data link control: error correction, protocol analysis, framing. Message delay: Markov processes, queuing, delays in statistical multiplexing, multiple users with reservations, limited service, priorities. Network delay: Kleinrock independence, reversibility, traffic flows, throughput analysis, Jackson networks. Multiple access networks: ALOHA and splitting protocols, carrier sensing, multi-access reservations.
EECS 558. Stochastic Control
Prerequisite: EECS 501, EECS 560. I, odd years (3 credits)
Analysis and optimization of controlled stochastic systems. Models: linear and nonlinear stochastic controlled systems, controlled Markov chains. Optimization of systems described by Markov processes; dynamic programming under perfect and imperfect information, finite and infinite horizons. System identification: off-line, recursive. Stochastic adaptive control: Markov chains, self-tuning regulators, bandit problems.
EECS 559. Advanced Signal Processing
Prerequisite: EECS 551 and EECS 501. I (3 credits)
Estimators of second order properties of random processes: nonparametric and model-based techniques of spectral estimation, characterization of output statistics for nonlinear systems, time-frequency representations. Performance evaluation using asymptotic techniques and Monte Carlo simulation. Applications include speech processing, signal extrapolation, multidimensional spectral estimation, and beamforming.
EECS 560 (Aero 550) (ME 564). Linear Systems Theory
Prerequisite: Graduate Standing. I (4 credits)
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability.
EECS 561 (Aero 571) (ME 561). Design of Digital Control Systems
Prerequisite: EECS 460 or ME 461. I (3 credits))
·Sampling and data reconstruction. Z-transforms and state variable descriptions of discrete-time systems. Modeling and identification. Analysis and design using root locus, frequency response, and state space techniques. Linear quadratic optimal control and state estimation. Quantization and other nonlinearities.
EECS 562 (Aero 551). Nonlinear Systems and Control
Prerequisite: Graduate Standing. II (3 credits)
Introduction to the analysis and design of nonlinear systems and nonlinear control systems. Stability analysis using Liapunov, input-output and asymptotic methods. Design of stabilizing controllers using a variety of methods: linearization, absolute stability theory, vibrational control, sliding modes and feedback linearization.
EECS 564. Estimation, Filtering, and Detection
Prerequisite: EECS 501. II (3 credits)
Principles of estimation, linear filtering and detection. Estimation: linear and nonlinear minimum mean squared error estimation, and other strategies. Linear filtering: Wiener and Kalman filtering. Detection: simple, composite, binary and multiple hypotheses. Neyman-Pearson and Bayesian approaches.
EECS 565 (Aero 580). Linear Feedback Control Systems
Prerequisite: EECS 460 or Aero 345 or ME 461 and Aero 550 (EECS 560). II (3 credits)
Control design concepts for linear multivariable systems. Review of single variable systems and extensions to multivariable systems. Purpose of feedback. Sensitivity, robustness, and design tradeoffs. Design formulations using both frequency domain and state space descriptions. Pole placement/observer design. Linear quadratic Gaussian based design methods. Design problems unique to multivariable systems.
EECS 567 (Mfg 567) (ME 567). Introduction to Robotics: Theory and Practice
Prerequisite: EECS 281. II (3 credits)
Introduction to robots considered as electro-mechanical computational systems performing work on the physical world. Data structures representing kinematics and dynamics of rigid body motions and forces and controllers for achieving them. Emphasis on building and programming real robotic systems and on representing the work they are to perform.
EECS 569. Production Systems Engineering
Prerequisite: none. II Alternate Years (3 credits)
Production systems in large volume manufacturing (e.g., automotive, semiconductor, computer, etc.) are studied. Topics include quantitative methods for analysis of production systems; analytical methods for design of lean in-process and finished goods buffering; measurement-based methods for identification and elimination of production system bottlenecks; and system-theoretic properties of production lines.

EECS 570. Parallel Computer Architecture
Prerequisite: EECS 470. I (4 credits)
Architectures for explicit parallelism. Multithreaded processors, small- and large-scale multiprocessor systems. Shared-memory coherence and consistency. Effect of architecture on communication latency, bandwidth, and overhead. Latency tolerance techniques. Interconnection networks. Case studies. Term projects.

EECS 571. Principles of Real-Time Computing
Prerequisite: EECS 470, EECS 482 or permission of instructor. I (4 credits)
Principles of real-time computing based on high performance, ultra reliability and environmental interface. Architectures, algorithms, operating systems and applications that deal with time as the most important resource. Real-time scheduling, communications and performance evaluation.

EECS 573. Microarchitecture
Prerequisite: EECS 470 or permission of instructor. II alternate years (3 credits)
Graduate-level introduction to the foundations of high performance microprocessor implementation. Problems involving instruction supply, data supply, and instruction processing. Compile-time vs. run-time tradeoffs. Aggressive branch prediction. Wide-issue processors, in-order vs. out-of-order execution, instruction retirement. Case studies taken from current microprocessors.

EECS 574. Computational Complexity
Prerequisite: EECS 376. I (4 credits)
Fundamentals of the theory of computation and complexity theory. Computability, undecidability, and logic. Relations between complexity classes, NP-completeness, P-completeness, and randomized computation. Applications in selected areas such as cryptography, logic programming, theorem proving, approximation of optimization problems, or parallel computing.

EECS 575. Advanced Cryptography
Prerequisite: EECS 203 or equivalent (EECS 574 recommended) II. (4 credits)
A rigorous introduction to the design of cryptosystems and to cryptanalysis. Topics include cryptanalysis of classical cryptosystems; theoretical analysis of one-way functions; DES and differential cryptanalysis; the RSA cryptosystem; ElGamal, elliptic, hyperelliptic and hidden mononomial cryptosystems; attacks on signature schemes, identification schemes and authentication codes; secret sharing; and zero knowledge.

EECS 578. Computer-Aided Design Verification of Digital Systems
Prerequisite: EECS 478. II (3 credits)
Design specification vs. implementation. Design errors. Functional and temporal modeling of digital systems. Simulation vs. symbolic verification techniques. Functional verification of combinational and sequential circuits. Topological and functional path delays; path sensitization. Timing verification of combinational and sequential circuits. Clock schedule optimization.

EECS 579. Digital System Testing
Prerequisite: Graduate Standing. I (3 credits)
Overview of fault-tolerant computing. Fault sources and models. Testing process. Combinational circuit testing. D-Algorithm and PODEM. Sequential circuit testing. Checking experiments. RAM and microprocessor testing. Fault simulation. Design for testability. Testability measures. Self-testing circuits and systems.

EECS 580. Advanced Computer Graphics
Prerequisite: EECS 487 (or equivalent) Or Graduate Standing. II (4 credits)
Geometric modeling: spline curves and surfaces, subdivision surfaces, polygonal meshes, point-based and implicit surfaces. Real-time rendering: fixed and programmable pipeline, shadows. Acceleration algorithms: culling and level-of-detail. Collision detection. Delaunary triangulations and Voronoi diagrams. Non-photorealistic rendering. Pattern synthesis. Image-based rendering.

EECS 581. Software Engineering Tools
Prerequisite: EECS 481 or equivalent programming experience. II (3 credits)
Fundamental areas of software engineering including life-cycle-paradigms, metrics, and tools. Information hiding architecture, modular languages, design methodologies, incremental programming, and very high level languages.

EECS 582. Advanced Operating Systems
Prerequisite: EECS 482. II (4 credits)
Course discusses advanced topics and research issues in operating systems. Topics will be drawn from a variety of operating systems areas such as distributed systems and languages, networking, security, and protection, real-time systems, modeling and analysis, etc.

EECS 583. Advanced Compilers
Prerequisite: EECS 281 and 370 (EECS 483 is also recommended) II (4 credits)
In-depth study of compiler backend design for high-performance architectures. Topics include control-flow and data-flow analysis, optimization, instruction scheduling, register allocation. Advanced topics include memory hierarchy management, instruction-level parallelism, predicated and speculative execution. The class focus is processor-specific compilation techniques, thus familiarity with both computer architecture and compilers is recommended.

EECS 584. Advanced Database Systems
Prerequisite: EECS 484 or permission of instructor. I (4 credits)
Advanced topics and research issues in database management systems. Distributed databases, advanced query optimization, query processing, transaction processing, data models and architectures. Data management for emerging application areas, including bioinformatics, the internet, OLAP, and data mining. A substantial course project allows in-depth exploration of topics of interest.

EECS 586. Design and Analysis of Algorithms
Prerequisite: EECS 281. II (4 credits)
Design of algorithms for nonnumeric problems involving sorting, searching, scheduling, graph theory, and geometry. Design techniques such as approximation, branch-and-bound, divide-and-conquer, dynamic programming, greed, and randomization applied to polynomial and NP-hard problems. Analysis of time and space utilization.

EECS 587. Parallel Computing

Prerequisite: EECS 281 and Graduate Standing. I (4 credits)

The development of programs for parallel computers. Basic concepts such as speedup, load balancing, latency, system taxonomies. Design of algorithms for idealized models. Programming on parallel systems such as shared or distributed memory machines, networks. Grid Computing. Performance analysis. Course includes a substantial term project.

EECS 588. Computer and Network Security

Prerequisite: EECS 482 or EECS 489 or Graduate Standing. I (4 credits)

Survey of advanced topics and research issues in computer and network security. Topics will be drawn from a variety of areas such as mandatory and discretionary security policies, secure storage, security kernels, trust management, preventing software vulnerabilities, applied cryptography, network security.

EECS 589. Advanced Computer Networks

Prerequisite: EECS 489. II (4 credits)

Advanced topics and research issues in computer networks. Topics include routing protocols, multicast delivery, congestion control, quality of service support, network security, pricing and accounting, and wireless access and mobile networking. Emphasis is placed on performance trade-offs in protocol and architecture designs. Readings assigned from research publications. A course project allows in-depth exploration of topics of interest.

EECS 590. Advanced Programming Languages

Prerequisite: EECS 281 or equivalent. II (4 credits)

Fundamental concepts in Programming Languages (PL) as well as recent topics and trends in PL research. Topics include semantics, type systems, program verification using theorem provers, software model checking, and program analysis. Course focuses on applying PL concepts to improve software reliability. Course includes semester long individual research project.

EECS 591. Distributed Systems

Prerequisite: EECS 482 and Graduate Standing. I (4 credits)

Principles and practice of distributed system design. Computations, consistency semantics, and failure models. Programming paradigms including group communication, RPC, distributed shared memory, and distributed objects. Operating system kernel support; distributed system services including replication, caching, file system management, naming, clock synchronization, and multicast communication. Case studies.

EECS 592. Advanced Artificial Intelligence

Prerequisite: EECS 492 or permission of instructor. II (4 credits)

Advanced topics in artificial intelligence. Issues in knowledge representation, knowledge-based systems, problem solving, planning and other topics will be discussed. Students will work on several projects.

EECS 594. Introduction to Adaptive Systems

Prerequisite: EECS 203, Math 425 (Stat 425). Alternate years (3 credits)

Programs and automata that "learn" by adapting to their environment; programs that utilize genetic algorithms for learning. Samuel's strategies, realistic neural networks, connectionist systems, classifier systems, and related models of cognition. Artificial intelligence systems, such as NETL and SOAR, are examined for their impact upon machine learning and cognitive science.

EECS 595 (Ling 541) (SI 661). Natural Language Processing

Prerequisite: Senior Standing. I (3 credits)

A survey of syntactic and semantic theories for natural language processing, including unification-based grammars, methods of parsing, and a wide range of semantic theories from artificial intelligence as well as from philosophy of language. Programming will be optional, though a project will normally be required.

EECS 596. Master of Engineering Team Project

Prerequisite: enrollment in the Masters of Engineering program in EECS. I, II, IIIa, IIIb, and III (1-6 credits)

To be elected by EECS students pursuing the Master of Engineering degree. Students are expected to work in project teams. May be taken more than once up to a total of 6 credit hours.

EECS 597 (SI 760) (Ling 702). Language and Information

Prerequisite: SI 503 or EECS 281 and Graduate Standing or permission of instructor. I alternate years (3 credits)

A survey of techniques used in language studies and information processing. Students will learn how to explore and analyze textual data in the context of Web-based information retrieval systems. At the conclusion of the course, students will be able to work as information designers and analysts.

EECS 598. Special Topics in Electrical Engineering and Computer Science

Prerequisite: permission of instructor or counselor. I, II, IIIa, IIIb, and III (1-4 credits)

Topics of current interest in electrical engineering and computer science. Lectures, seminar, or laboratory. Can be taken more than once for credit.

EECS 599. Directed Study

Prerequisite: prior arrangement with instructor; mandatory satisfactory/unsatisfactory. I, II, IIIa, IIIb and III (1-4 credits)

Individual study of selected advanced topics in electrical engineering and computer science. May include experimental work or reading. Primarily for graduate students. To be graded on satisfactory/unsatisfactory basis ONLY.

EECS 600 (IOE 600). Function Space Methods in System Theory

Prerequisite: Math 419. II (3 credits)

Introduction to the description and analysis of systems using function analytic methods. Metric spaces, normed linear spaces, Hilbert spaces, resolution spaces. Emphasis on using these concepts in systems problems.

EECS 627. VLSI Design II
Prerequisite: EECS 427. I (4 credits)
Advanced very large scale integrated (VLSI) circuit design. Design methodologies (architectural simulation, hardware description language design entry, silicon compilation, and verification), microarchitectures, interconnect, packaging, noise sources, circuit techniques, design for testability, design rules, VLSI technologies (silicon and GaAs), and yield. Projects in chip design.
EECS 631. Electromagnetic Scattering
Prerequisite: EECS 530 and Graduate Standing. Alternate years (3 credits)
Boundary conditions, field representations. Low and high frequency scattering. Scattering by half plane (Wiener-Hopf method) and wedge (Maliuzhinets method); edge diffraction. Scattering by a cylinder and sphere: Watson transformation, Airy and Fock functions, creeping waves. Geometrical and physical theories of diffraction.
EECS 632. Microwave Remote Sensing II - Radar
Prerequisite: EECS 532. II even years (3 credits)
Radar equation; noise statistics; resolution techniques; calibration; synthetic aperture radar; scatterometers; scattering models; surface and volume scattering; land and oceanographic applications.
EECS 633. Numerical Methods in Electromagnetics
Prerequisite: EECS 530. Alternate years (3 credits)
Numerical techniques for antennas and scattering; integral representation: solutions of integral equations: method of moments, Galerkin's technique, conjugate gradient FFT; finite element methods for 2-D and 3-D simulations; hybrid finite element/boundary integral methods; applications: wire, patch and planar arrays; scattering composite structures.
EECS 634 (Appl Phys 611) (Physics 611). Nonlinear Optics
Prerequisite: EECS 537 or EECS 538 or EECS 530. I (3 credits)
Formalism of wave propagation in nonlinear media; susceptibility tensor; second harmonic generation and three-wave mixing; phase matching; third order nonlinearities and four-wave mixing processes; stimulated Raman and Brillouin scattering. Special topics: nonlinear optics in fibers, including solitons and self-phase modulation.
EECS 638 (Appl Phys 609) (Physics 542). Quantum Theory of Light
Prerequisite: quantum mechanics electrodynamics and atom physics. II (3 credits)
The atom-field interaction; density matrix; quantum theory of radiation including spontaneous emission; optical Bloch equations and theory of resonance fluorescence; coherent pulse propagation; dressed atoms and squeezed states; special topics in nonlinear optics.
EECS 643 (Psych 643). Theory of Neural Computation
Prerequisite: Graduate Standing or permission of instructor. II alternate years (2-4 credits)
This course will review computational models of human cognitive processes with four goals in mind: (1) to learn about the wide variety of approaches to cognitive modeling (e.g., self-organizing nets, multi-layer nets, and back-propagation, production systems, ACT*, EPIC, Soar…) and the advantages and disadvantages of each, (2) to study some of the most important cognitive models of specific domains (e.g., dual task performance, reasoning, explicit learning, working memory), (3) to evaluate when cognitive modeling is an appropriate and useful research strategy, and (4) to give students an opportunity to gain hands-on experience in implementing their own cognitive models. Students will be expected to take turns in leading discussion of specific papers and to work in groups in implementing a computational model.
EECS 644 (Psych 644). Computational Modeling of Cognition
Prerequisite: Graduate Standing or permission of instructor. II alternate years (2-4 credits)
This course will examine computational models of human cognitive processes. Course goals include learning about important computational models of specific cognitive domains and evaluating the appropriateness and utility of different computational approaches to substantive problems in cognition.
EECS 650. Channel Coding Theory
Prerequisite: EECS 501 and Math 419. II alternate years (3 credits)
The theory of channel coding for reliable communication and computer memories. Error correcting codes; linear, cyclic and convolutional codes; encoding and decoding algorithms; performance evaluation of codes on a variety of channels.
EECS 651. Source Coding Theory
Prerequisite: EECS 501. II odd years (3 credits)
Introduction to a variety of source coding techniques such as quantization, block quantization; and differential, predictive, transform and tree coding. Introduction to rate-distortion theory. Applications include speech and image coding.
EECS 659. Adaptive Signal Processing
Prerequisite: EECS 559 or 564. I odd years (3 credits)
Theory and applications of adaptive filtering in systems and signal processing. Iterative methods of optimization and their convergence properties: transversal filters; LMS (gradient) algorithms. Adaptive Kalman filtering and least-squares algorithms. Specialized structures for implementation: e.g., least-squares lattice filters, systolic arrays. Applications to detection, noise cancelling, speech processing, and beam forming.
EECS 661. Discrete Event Systems
Prerequisite: Graduate Standing. I even years (3 credits)
Modeling, analysis, and control of discrete event systems; untimed (logical) and timed models considered. Defining characteristics of discrete event systems. Logical models: languages, automata, and Petri nets. Analysis: safety, blocking, state estimation and diagnostics. Supervisory control: controllability, nonblocking and nonconflicting languages, observability and co-observability. Timed models: timed automata and timed Petri nets. Analysis using dioid algebras. Control of Petri nets. Introduction to stochastic models.

EECS 662 (Aero 672) (ME 662). Advanced Nonlinear Control
Prerequisite: EECS 562 or ME 548. I (3 credits)
Geometric and algebraic approaches to the analysis and design of nonlinear control systems. Nonlinear controllability and observability, feedback stabilization and linearization, asymptotic observers, tracking problems, trajectory generation, zero dynamics and inverse systems, singular perturbations, and vibrational control.
EECS 670. Special Topics in Computer Architecture
Prerequisite: permission of instructor. (3 credits)
Current topics of interest in computer architecture. This course may be repeated for credit.
EECS 674. Special Topics in Theoretical Computer Science
Prerequisite: permission of instructor. (3 credits)
Current topics of interest in theoretical computer science. This course may be repeated for credit.
EECS 682. Special Topics in Software Systems
Prerequisite: permission of instructor. (3 credits)
Current topics of interest in software systems. This course may be repeated for credit.
EECS 684. Current Topics in Databases
Prerequisite: EECS 484. I (3 credits)
Research issues in database systems chosen for in-depth study. Selected topics such as spatial, temporal, or real-time databases; data mining, data warehousing, or other emerging applications. Readings from recent research papers. Group projects.
EECS 691. Mobile Computing
Prerequisite: EECS 582 or EECS 589 or EECS 591 or equivalent. II Alternate years. (3 credits)
In-depth study of research issues in mobile and pervasive computing systems. Topics include location and context awareness, mobile data access, resource management, consistency protocols, mobile and ad hoc networking, networked sensors, security and privacy.
EECS 692. Special Topics in Artificial Intelligence
Prerequisites: permission of instructor. (3 credits)
Current topics of interest in artificial intelligence. This course can be repeated for credit.
EECS 695 (Psych 640). Neural Models and Psychological Processes
Prerequisite: permission of instructor. II (3 credits)
Consideration of adaptively and biologically oriented theories of human behavior. Emphasis on both the potential breadth of application and intuitive reasonableness of various models. There is a bias toward large theories and small simulations.
EECS 698. Master's Thesis
Prerequisite: election of an EECS master's thesis option. I, II, IIIa, IIIb, and III (1-6 credits)
To be elected by EE and EES students pursuing the master's thesis option. May be taken more than once up to a total of 6 credit hours. To be graded on a satisfactory/unsatisfactory basis ONLY.
EECS 699. Research Work in Electrical Engineering and Computer Science
Prerequisite: Graduate Standing, permission of instructor; mandatory satisfactory/unsatisfactory. I, II, IIIa, IIIb, III (1-6 credits)
Students working under the supervision of a faculty member plan and execute a research project. A formal report must be submitted. May be taken for credit more than once up to a total of 6 credit hours. To be graded satisfactory/ unsatisfactory ONLY.
EECS 700. Special Topics in System Theory
Prerequisite: permission of instructor (to be arranged)
EECS 720. Special Topics in Solid-State Devices, Integrated Circuits, and Physical Electronics
Prerequisite: permission of instructor. (1-4 credits)
Special topics of current interest in solid-state devices, integrated circuits, microwave devices, quantum devices, noise, plasmas. This course may be taken for credit more than once.
EECS 730. Special Topics in Electromagnetics
Prerequisite: permission of instructor. (1-4 credits) (to be arranged)
EECS 735. Special Topics in the Optical Sciences
Prerequisite: Graduate Standing, permission of instructor (to be arranged) (1-4 credits)
Key topics of current research interest in ultrafast phenomena, short wavelength lasers, atomic traps, integrated optics, nonlinear optics and spectroscopy. This course may be taken for credit more than once under different instructors.
EECS 750. Special Topics in Communication and Information Theory
Prerequisite: permission of instructor. (to be arranged)
EECS 755. Special Topics in Signal Processing
Prerequisite: permission of instructor. (to be arranged) (1-4 credits)
Advanced topics in Signal and/or image processing. The specific topics vary with each offering. This course may be taken for credit more than once.
EECS 760. Special Topics in Control Theory
Prerequisite: permission of instructor. (to be arranged)
EECS 765. Special Topics in Stochastic Systems and Control
Prerequisite: permission of instructor. (to be arranged) (3 credits)
Advanced topics on stochastic systems such as stochastic calculus, nonlinear filtering, stochastic adaptive control, decentralized control, and queuing networks.

EECS 767 (SI 767). Advanced Natural Language Processing and Information Retrieval
Prerequisite: SI 661, SI 761, or 760 or permission of instructor. II (3 credits)
Course is focused on reading recent research papers on topics in natural-language processing and information retrieval, such as statistical machine translation, expectation maximization, text classification, sentiment and polarity analysis, information extraction using conditional random fields, document models for information retrieval, semi-supervised learning, and latent semantic analysis. The course is appropriate for students who have already taken either of the following classes: "Natural Language Processing," "Information Retrieval," and/or "Language and Information."

EECS 770. Special Topics in Computer Systems
Prerequisite: permission of instructor. (to be arranged)

EECS 792. Advanced AI Techniques
Prerequisite: EECS 492. II (3 credits)
Formulating and solving problems using artificial intelligence techniques. Projects employ advanced methods from knowledge representation, search, machine learning, and other AI areas. This is a component of the Intelligent Systems qualification process.

EECS 792. Advanced AI Techniques
Prerequisite: EECS 492. II (3 credits)
Formulating and solving problems using artificial intelligence techniques. Projects employ advanced methods from knowledge representation, search, machine learning, and other AI areas. This is a component of the Intelligent Systems qualification process.

EECS 800. Seminar in Optical Science and Engineering
Prerequisite: Graduate Standing. I, II (1 credit)
Advanced overviews of research, industrial and governmental projects not covered by the optics curriculum. Recent advances on important topics presented by renowned speakers in areas like hyperspectral imaging, laser cooling, biological manipulation, displays, laser metrology, holography and astrophysical instrumentation plus an annual site tour of local industrial optics facilities.

EECS 820. Seminar in Solid-State Electronics
Prerequisite: Graduate Standing, permission of instructor. I (1 credit)
Advanced graduate seminar devoted to discussing current research topics in areas of solid-state electronics. Specific topics vary each time the course is offered. Course may be elected more than once.

EECS 892. Seminar in Artificial Intelligence
Prerequisite: EECS 592 or equivalent. I, II (2 credits)
Advanced graduate seminar devoted to discussing current research papers in artificial intelligence. The specific topics vary each time the course is offered.

EECS 990. Dissertation/Pre-Candidate
I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

EECS 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, III (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Electrical Engineering, Computer Engineering and Computer Science Faculty

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Professors

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Engineering Physics

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Basic physics is an integral part of every engineering curriculum. However, in many areas of engineering the sophistication of the field, coupled with the staggering rate of technological advance, has created a need for engineers with much stronger backgrounds in math and physics—people who can work in an engineering environment and who are capable of applying advanced physics concepts to bring innovations to the marketplace. For example, the development of the computer closely followed the invention of the transistor. Consider the number of other recently discovered physical phenomena (lasers, nuclear reactors, particle accelerators, etc.) that have been successfully brought to fruition by engineers.

Engineering Physics is particularly attractive to those students who may attend graduate school, even if they have not decided on a particular field. An advanced physics and mathematics background coupled with an engineering curriculum is excellent preparation for most graduate engineering programs and for a traditional physics or applied physics program.

Engineering Physics meets these needs by providing a thorough curriculum in basic and advanced engineering courses combined with sufficient physics and mathematics to be equivalent to a traditional degree in physics. A unique feature of the curriculum is the elective sequence of engineering courses that the student may select in a specialized field of engineering. This sequence of courses can be chosen by the student (with the advisor's agreement) in any field of interest, such as microprocessor design, plasma processing, electro-optics, radiological health, computational methods, or bioengineering, to name just a few. With 46 credit hours of electives in math, engineering and physics, the student has a high degree of flexibility and opportunity for exploring or specializing in fields of interest.

Mission

To provide students with a high-quality education that prepares them for careers in engineering and science.

Goals

- To educate students in the scientific fundamentals as well as in an engineering discipline of their choice, to provide the depth and breadth required to adapt to changes in technology.

Engineering Physics Undergraduate Education

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Degree Program

B.S.E. in Engineering Physics

Sample Schedule

B.S.E. (Engineering Physics)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 214	16	4	4	4	4	-	-	-	-
Engr 100, Intro to Engr	4	4	-	-	-	-	-	-	-
Engr 101, Intro to Computers	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 211[1]	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 241[2]	10	-	5	5	-	-	-	-	-
Humanities and Social Sciences	16	4	4	4	4	-	-	-	-
Advanced Mathematics (8 hrs.)									
Mathematics Electives[3]	8	-	-	-	-	-	4	4	-
Related Technical Subjects (18 hrs.)									
MSE 250, Princ of Eng Materials	4	-	-	-	4	-	-	-	-
CEE 211, Statics and Dynamics or ME 240, Intro to Dynamics	4	-	-	4	-	-	-	-	-
ME 235, Thermodynamics I	3	-	-	-	-	-	3	-	-
ME 320, Fluid Mechanics I or Phys 406, Stat/Thermal Physics	3	-	-	-	-	-	-	3	-
EECS 314, Elect Cir, Sys, and Appl or EECS 215, Intro to Circuits	4	-	-	-	-	4	-	-	-
Physics Technical Subjects (18 hrs.)									
Physics 340, Waves, Heat and Light	3	-	-	-	-	3	-	-	-
Physics 390, Intro to Modern Physics or NERS 311, Ele of Nuc Engr & Rad Sci I	4	-	-	-	-	4	-	-	-
Physics 401, Int Mech[4]	3	-	-	-	-	-	3	-	-
Physics 405, Int Elect and Mag	3	-	-	-	-	-	-	3	-
Physics Elective (300-level +)	3	-	-	-	-	-	-	-	3
Physics Lab Elective or Directed Study with Research Lab Component	2	-	-	-	-	-	-	-	2
Engr Technical Electives (20 hrs.)									
Engineering Electives[5]	16	-	-	-	-	4	4	4	4
Engineering Laboratory Elective (400-level or higher)	4	-	-	-	-	-	-	-	4
Unrestricted Electives (9-12 hrs.)[6]	9-12	-	-	-	3	-	3	-	3
Total	128	17	17	17	15	15	17	14	16

Candidates for the Bachelor of Science degree in Engineering for Engineering Physics - B.S.E. Eng. Physics - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]Math Electives must be 300-level or higher.

[4]ME 440 or ME 540 can be substituted with faculty program advisor approval.

[5]Engineering Electives are to be chosen in consultation with the faculty advisor to form a coherent sequence that clearly defines professional goals for the student. Sample elective sequences for a number of different subject areas are available from the academic or faculty counselors.

[6]Students contemplating graduate studies in Physics should elect Physics 453, Quantum Mech and Physics 463, Solid State for a complete background.

Industrial and Operations Engineering

Program Advisor
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Industrial and operations engineering is concerned with integrated systems of people, machines, environments and information. Drawing upon their specialized skills in mathematical, physical, and social sciences (together with principles and methods of engineering analysis), industrial and operations engineers specify, predict, and evaluate systems. Applications arise in industrial and manufacturing systems as well as a variety of nonindustrial settings, ranging from health care and education to financial and governmental organizations.

The wide range of tasks an industrial engineer is called upon to perform requires knowledge of operations research, ergonomics, management engineering, statistics, manufacturing engineering, and computer information processing.

Facilities

The department has well-equipped laboratories in human performance, industrial systems, plant flow analysis, quality control, and computation.

In addition to the facilities on campus, the department has excellent relationships with various firms within the Ann Arbor-Detroit area so that students are exposed to actual operating industrial, service, and other business systems.

Accreditation

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Industrial and Operations EngineeringMission

To be an international leader in developing and teaching theory and methods for the design, analysis, implementation, and improvement of integrated systems of people, materials, information, facilities, and technology.

Goals

- To recruit, educate, and support excellent, diverse students and prepare them to be leaders in the practice and further development of industrial and operations engineering.
- To have one of the leading undergraduate programs in the world in industrial and operations engineering.
- To engender the skills and desire to continually learn and grow through a lifelong professional career.

Objectives

We will work with honesty and integrity to provide all of our students with an outstanding education and to advise and assist them in fulfilling their educational and career objectives. Our undergraduate program will provide students with a diverse range of professional objectives with the knowledge, skills and tools to:

- Address contemporary and future problems in enterprises;
- Develop skills in critical thinking, teamwork, problem solving and communicating with others;
- Initiate and manage change in organizations and processes;
- Understand their professional and ethical responsibilities;
- Appropriately employ information systems and technology; and
- Enable enterprises to make optimal decisions under conditions of uncertainty.

Outcomes

All Industrial and Operations Engineering graduates should have:

- An ability to apply knowledge of mathematics, science, and engineering;
- An ability to design and conduct experiments, as well as analyze and interpret data;
- An ability to design and improve integrated systems of people, materials, information, facilities, and technology;
- An ability to function as a member of a multidisciplinary team;
- An ability to identify, formulate, and solve industrial and operations engineering problems;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively;
- The broad education necessary to understand the impact of engineering solutions in a global and societal context;
- A recognition of the need for, and an ability to engage in life-long learning;
- A knowledge of contemporary issues;
- An ability to use updated techniques, skills and tools of industrial and operations engineering throughout their professional careers; and
- A base set of skills and knowledge, regardless of specific professional goals, in human resource management, personal management, macro analysis, critical thinking, operations management, operations research, and information systems (see IOE Core skills list).

Industrial and Operations Engineering Undergraduate Education

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Degree Program

The program in Industrial and Operations Engineering at the University of Michigan is designed to prepare students for challenges in the areas described above,
or for continuing their academic work to acquire an M.S.E. or Ph.D. degree. Approximately 40 percent of the courses required for the B.S.E. (I.O.E.) degree are common College of Engineering core requirements, in mathematics, basic physical sciences, digital computing, humanities, and social sciences, along with a broad base in engineering fundamentals. Fundamental topics in industrial engineering are provided by the nine 200-and 300-level IOE courses. A solid technical foundation is obtained through 12 credits of departmental IOE electives. In addition, students gain valuable experience applying their knowledge in a senior-level design course.

The opportunity for students to tailor their studies in pursuit of individual interests is provided by an additional 6 credits of technical electives and 9 credits of unrestricted electives. The goal of the technical electives is to provide a background in areas related to industrial and operations engineering. This allows students to deepen their knowledge in specific areas of industrial and operations engineering and provides an opportunity to prepare for advanced studies in other engineering disciplines, or in medicine, law, or business.

Sequential Graduate/Undergraduate Study (SGUS)
B.S.E in Industrial and Operations Engineering/
M.S.E in Industrial and Operations Engineering

Celia Eidex
ceidex@engin.umich.edu
1603 IOE Bldg.
Phone: (734) 764-6480
Program Advisor: Professor W. Monroe Keyserling

The IOE SGUS program is open to College of Engineering undergraduate students who have achieved senior standing (85 credit hours) with a minimum cumulative GPA of 3.5. SGUS students are allowed to "double count" six credit hours of graduate courses toward the B.S.E and M.S.E degrees. Students considering the SGUS program must "reserve" at least six undergraduate elective credit hours for courses that are eligible for credit in the IOE Masters degree program. SGUS students must enroll in Rackham for at least two (9 credit) terms, paying full Rackham tuition with no other U of M registration.

B.S.E in Industrial and Operations Engineering/
M.S. in Biomedical Engineering

Susan Bitzer
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Phone: (734) 763-5290
Program Advisor: Professor David E. Kohn

This SGUS program is open to all undergraduate students from Industrial and Operations Engineering who have achieved senior standing (85 credit hours), and have an overall cumulative GPA of 3.5 or higher. Please contact the Department of Biomedical Engineering for more complete program information, http://www.bme.umich.edu.

Engineering Global Leadership (EGL)
Honors Program

The Engineering Global Leadership Honors Program (EGL) is an exciting honors program offered across all disciplines in engineering for those students with strong GPAs who enjoy learning foreign languages, and studying other cultures. The program is designed to maximize and focus free electives, language, humanities, and social science courses around a region of economic importance to the U.S. In addition, EGL students are required to take business courses and complete a built-in practical experience to place technical knowledge in an industrial context. This honors program is very rigorous (full class loads every semester and maintenance of a high GPA) but EGL students graduate with both a B.S.E. and a Master's degree and tend to have higher starting salaries than other engineering undergrads. For more details, please go here.

Sample Schedule

B.S.E. (Industrial and Operations Engineering)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 214	16	4	4	4	4	–	–	–	–
Engr 100, Intro to Engr	4	4	–	–	–	–	–	–	–
Engr 101, Intro to Computers	4	–	4	–	–	–	–	–	–
Chemistry 125/126 and 130[1]	5	5	–	–	–	–	–	–	–
Physics 140 with Lab 141; 240 with Lab 241 [2]	10	–	5	5	–	–	–	–	–
Humanities and Social Sciences	16	–	4	4	–	–	4	4	–
Related Engineering Subjects (12 hrs.)									
Non-IOE Engineering Courses (11-12 hrs.)[3]	12	–	–	–	4	4	–	–	4
Required Program Subjects (34 hrs.)									
IOE 201, Industrial, Operations Modeling	2	–	–	2	–	–	–	–	–
IOE 202, Operations Modeling	2	–	–	2	–	–	–	–	–
IOE 265, Engr Probability and Statistics	4	–	–	–	4	–	–	–	–
IOE 310, Intro to Optim Methods	4	–	–	–	–	4	–	–	–
IOE 333, Ergonomics	3	–	–	–	3	–	–	–	–
IOE 334, Ergonomics Lab	1	–	–	–	1	–	–	–	–
IOE 316, Intro to Markov Processes	2	–	–	–	–	2	–	–	–
IOE 366, Linear Statistical Models	2	–	–	–	–	2	–	–	–
IOE 373, Data Processing	4	–	–	–	–	–	4	–	–
IOE 474, Simulation	4	–	–	–	–	–	–	4	–
IOE Senior Design Course[4]									
IOE 424, 481 or 499	4	–	–	–	–	–	–	–	4
TC 380, Technical Communication in IOE	2	–	–	–	–	–	2	–	–
Technical Electives (18 hrs.)[5]	18	–	–	–	–	4	6	4	4
Unrestricted Electives (9-12 hrs.)	9-12	3	–	–	–	–	–	3	3
Total	128	16	17	17	16	16	16	15	15

Candidates for the Bachelor of Science degree in Engineering (Industrial and Operations Engineering) — B.S.E. (I.O.E.) — must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]Non-IOE Engineering Courses:

Select 12 hours; 4 hours from any three different groups:

a. ME 211 or CEE 211 or ME 240
b. ME 235 or ChemE 230
c. MSE 220 or ME 382
d. BiomedE 458 or EECS 270 or EECS 314
e. CEE 260 or NERS 211
f. EECS 280

[4]IOE Senior Design courses are restricted to IOE students only.
[5]Technical Electives:
Select at least 12 hours from the following four groups; at least one course each from three of the following five groups:

a. IOE 441, 447, 449
b. IOE 432, 434, 436, 438, 439, 463
c. IOE 416, 460, 461*, 465*, 466*
d. IOE 421, 422, 425, 452, 453
e. IOE 473

The remaining 6 hours may be selected from any 400-level IOE courses (except IOE 490, IOE 499, IOE 424, and IOE 481) and/or from the approved list of non-IOE courses.
*Maximum of 6 credits allowed from IOE 461, 465, 466.

Industrial and Operations Engineering Concentrations

Operations Research
Operations research is an applied science devoted to describing, understanding, and predicting the behavior of systems, and guiding them towards better performance. Courses in this area cover the use of mathematics in constructing models to analyze and design operational systems. Students study a variety of model structures and their application to real-world processes such as production, maintenance, inspection, resource allocation, distribution, and scheduling.

Ergonomics
Ergonomics emphasizes the technical knowledge necessary to analyze and predict the performance of humans in human-machine systems. Basic courses cover the capabilities and limitations of major human subsystems including cardiovascular, muscular, and cognitive (information processing) systems. Knowledge of these human subsystems is used to aid in the design of effective and safe working environments.

Management Engineering
In the design and implementation of integrated systems, industrial engineers must be able to master the technology of new systems, to understand the technical change process, and to achieve the benefits of such systems. Management engineering courses emphasize the role of people acting as individuals, and in groups, in operating systems.

Theories of administration, group dynamics, and human motivation are applied to specific managerial problems related to the establishment, clarification and modification of an organization's objectives.

They also cover the design, evaluation, and improvement of human-machine systems for accomplishing these objectives.

Production, Distribution, and Logistics
How does one add maximum value to an organization through world-class operations in the service and the manufacturing sectors? One needs highly effective production/transformation, inventory/sales, and delivery/fulfillment operations that are cost effective as well. The PDL area educates engineers and managers to lead through operational excellence. Emphasis is placed on global supply chain design, inventory management, production planning and control, facilities layout and planning, material handling, manufacturing strategy, and related issues.

Quality Engineering
Industrial and Operations Engineering graduates understand how to cope with uncertainty in the design of engineered systems. In particular, they design quality control systems and apply reliability analysis and experimental design techniques to design better products and processes.

Computer and Information Processing
Computers and information systems are important components in most modern systems. Students are introduced to the basic terminology and concepts of information system design, construction, and usage. The values and limitations of computing capabilities are explored. Emphasis is placed on the use of computer hardware and software systems in information processing and on the interface of information systems with management in helping to achieve the objectives of an organization.

Industrial and Operations Engineering Graduate Education

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Graduate Degrees

- Master of Science (M.S.) in Industrial and Operations Engineering
- Master of Science in Engineering (M.S.E.) in Industrial and Operations Engineering
- Dual M.S. in Industrial and Operations Engineering/ Master of Business Administration (M.B.A.)
- Doctor of Philosophy (Ph.D.) in Industrial and Operations Engineering

M.S. and M.S.E. in Industrial and Operations Engineering

The Master of Science degree in Engineering in Industrial and Operations Engineering is available to students who complete the M.S.E. course requirements and have a bachelor's degree from a recognized program in engineering. The Master of Science degree in Industrial and Operations Engineering is available to students with a bachelor's degree from a recognized program in physics, mathematics, or other field related to engineering. Students who hold bachelor's degrees from other fields and who wish to receive an M.S. in Industrial and Operations Engineering should consult with the program advisor as specialized programs (usually involving additional credit hours over basic requirements) can be developed.

The basic requirements include 30 credit hours of approved graduate courses subject to the following restrictions:

1. At least 18 credit hours of IOE courses
2. At least five courses (equal or greater than 14 credit hours) must be at a 500 or greater level; with at least three IOE courses (equal or greater than 8 credit hours) at a 500 or greater level. Directed study courses, courses graded S/U, and one-credit seminar classes may not be used to satisfy 500 level requirements.
3. At least two cognate courses (equal or greater than 4.5 credit hours) from outside the IOE Department.
4. No more than six credit hours of independent study.

Students are required to make up deficiencies in their preparation in probability, statistics, computer programming, Linear Algebra and English. An overall grade point average of "B" or higher in graduate courses taken in the program is required.

Special options, for which sequences of courses have been defined, include:

1. Operations Research
2. Ergonomics, Human Performance, and Occupational Safety
3. Production/Manufacturing/Distribution Systems
4. Quality Engineering and Applied Statistics
5. Management Engineering

Material describing these options and other details of the graduate programs are available online at http://ioe.engin.umich.edu/.

Dual M.B.A./M.S. in Industrial and Operations Engineering

The School of Business Administration and the College of Engineering Department of Industrial and Operations Engineering offer a dual degree program enabling a student to pursue concurrent work in Business Administration and Industrial and Operations Engineering leading to the M.B.A and M.S. (I.O.E) degrees. The program is arranged so that all requirements for the degrees are completed in two and one-half years of enrollment with the required 65 credit hours completed.

Students interested in the M.B.A./M.S. (I.O.E) dual program must apply to, and be admitted by, both schools, using their respective application forms and indicating that application is being made to the joint program. Only one application fee is necessary. Students are expected to meet the prerequisites for each program. In particular, the statistics requirement for the IOE program should be discussed with an advisor prior to beginning either program. This program is not open to students who have earned either the M.B.A. or M.S. (I.O.E) degrees. However, students registered in the first year of either program may apply.

Students admitted to this joint program must satisfy the following degree requirements:

1. The M.B.A 60-credit-hour degree program including:
   a. the 31.5-credit-hour M.B.A core (no credit is awarded for Business Administration core courses successfully waived; credit must be earned with Business electives);
   b. 13.5 elective hours in Business Administration (12 of the 13.5 must be approved by IOE);
   c. 15 credit hours of transferable electives from the Department of Industrial and Operations Engineering.
2. The 18 hours of graduate-level IOE courses, including at least eight credit hours in courses numbered 500 or above. Directed study courses and seminar classes may not be counted toward the IOE 500-level or above requirement.
3. A 2-credit independent study in IOE or the Business School which would lead to a paper integrating business and IOE perspectives on a particular area of interest.

The total credit hours for the joint degree program will be at least 65.
The dual program can begin with studies in either school; however, because of the sequential nature of the core course in the M.B.A program, most students will find it advantageous to start the first year in the Business School. Students who wish to begin with Industrial Operations Engineering should consult a counselor in the Business School to work out an appropriate plan of study.

Ph.D. in Industrial and Operations Engineering
The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the result of the investigation in the form of a dissertation.

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. There is no general course or credit requirement for the doctorate.

At the end of the first year in the program, a student must pass a qualifying examination to continue in the program. This exam is given in six courses, chosen with the consent of the student's advisor. Most students, at the end of their second year, take a preliminary examination in their chosen area of concentration. At present there are five such areas. The student must also satisfy a breadth requirement before taking the exam. After successfully passing this exam, the student is admitted to candidacy and selects a doctoral committee to supervise preparation of the dissertation. A defense of the dissertation in the presence of this committee is required.

A pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School Office, 1004 Rackham Building, upon request.

Industrial and Operations Engineering Courses

IOE 201. Economic Decision Making

Prerequisite: ENG 100 and ENG 101. I, II (2 credits) (7-week course)

Overview of business operations, valuation and accounting principles. Time value of money and net present values. Practical team project experience.

IOE 202. Operations Modeling

Prerequisite: ENG 100 and ENG 101. I, II (2 credits) (7-week course)

Process of mathematically modeling operational decisions including the role of uncertainty in decision-making. Basic tools for solving the resulting models, particularly mathematical programs, statistical models and queuing models. Cases may come from manufacturing and service operations and ergonomics.

IOE 265 (Stats 265). Probability and Statistics for Engineers

Prerequisite: Math 116 and ENG 101. I, II (4 credits)

Graphical Representation of Data; Axioms of Probability; Conditioning, Bayes Theorem; Discrete Distributions (Geometric, Binomial, Poisson); Continuous Distributions (Normal Exponential, Weibull), Point and Interval Estimation, Likelihood Functions, Test of Hypotheses for Means, Variances, and Proportions for One and Two Populations.

IOE 310. Introduction to Optimization Methods

Prerequisite: Math 214, IOE 202 and ENG 101. I, II (4 credits)

Introduction to deterministic models with emphasis on linear programming; simplex and transportation algorithms, engineering applications, relevant software. Introduction to integer, network, and dynamic programming, critical path methods.

IOE 316. Introduction to Markov Processes

Prerequisite: IOE 265 and Math 214. I, II (2 credits) (7-week course)

Introduction to discrete Markov Chains and continuous Markov processes, including transient and limiting behavior. The Poisson/Exponential process. Applications to reliability, maintenance, inventory, production, simple queues and other engineering problems.

IOE 333. Ergonomics

Prerequisite: preceded or accompanied by IOE 265. I, II (3 credits)

Introduction to human sensory, decision, control, and motor systems in the context of visual, auditory, cognitive, and manual task evaluation and design. Problems with computer displays, illumination, noise, eye-hand coordination, as well as repetitive and high physical effort tasks are presented. Workplace and vehicle design strategies used to resolve these are discussed.

IOE 334. Ergonomics Lab

Prerequisite: preceded or accompanied by IOE 333. I, II (1 credit)

Principles of measurement and prediction of human performance in man-machine systems. Laboratory experiments investigating human capabilities of vision, hearing, information processing, memory, motor processes, strength, and endurance.

IOE 366. Linear Statistical Models

Prerequisite: IOE 265 and Math 214. I, II (2 credits) (7-week course)

Linear statistical models and their application to engineering data analysis. Linear regression and correlation; multiple linear regression, analysis of variance, introduction to design of experiments.

IOE 373. Data Processing

Prerequisite: ENG 101. I, II (4 credits)

Introduction to the systems organization and programming aspects of modern digital computers. Concepts of algorithms and data structure will be discussed with practical business applications.

IOE 416. Queueing Systems

Prerequisite: IOE 316. (2 credits)

Introduction to queueing processes and their applications. The M/M/s and M/G/1 queues. Queue length, waiting time, busy period. Examples from production, transportation, communication, and public service.

IOE 421. Work Organizations

Prerequisite: IOE 201, 202 and Senior Standing. I (3 credits)

Applications of organizational theory to the analysis and design of work organizations is taught through lectures, projects in real organizations, experiential exercises, and case studies. Topics include: open-systems theory, organizational structure, culture, and power. A change strategy: current state analysis, future state vision, and strategies for organizational transformation.

IOE 422. Entrepreneurship

Prerequisite: Senior Standing. Not for graduate credit. I, II (3 credits)

Engineering students will learn the dynamics of turning an innovative idea into a successful commercial venture, including the role of e-commerce. By creating an actual business plan they will learn about innovation and creativity, risk management, stress and failure, ethics and other necessary business skills.

IOE 424. Practicum in Production and Service Systems

Prerequisite: Senior Standing. Not for graduate credit. I, II (4 credits)

Student teams will work with an organization on an Industrial and Operations Engineering design project with potential benefit to the organization and the students. The final report should demonstrate a mastery of the established technical communication skills. The report will be reviewed and edited to achieve this outcome.

IOE 425 (Mfg 426). Manufacturing Strategies

Prerequisite: Senior Standing. I, II (2 credits)

Review of philosophies, systems, and practices utilized by world-class manufacturers to meet current manufacturing challenges, focusing on "lean production" in the automotive industry, including material flow, plant-floor quality assurance, job design, work and management practices. Students tour plants to analyze the extent and potential of the philosophies.

IOE 432. Industrial Engineering Instrumentation Methods

Prerequisite: IOE 265. I (3 credits)

The characteristics and use of analog and digital instrumentation applicable to industrial engineering problems. Statistical methods for developing system specifications. Applications in physiological, human performance, and production process measurements are considered.

IOE 433 (Mfg 433). Occupational Ergonomics

Prerequisite: not open to students who have credit for IOE 333. (3 credits)

Principles, concepts, and procedures concerned with worker performance, health, and safety. Topics include biomechanics, work physiology, psychophysics, work stations, tools, work procedures, work standards, musculoskeletal disorders, noise, vibration, heat stress, and the analysis and design of work.

IOE 434. Human Error and Complex System Failures

Prerequisite: IOE 333 or IOE 536 or Permission of Instructor. II (3 credits)

Introduction to a new systems-oriented approach to safety management and the analysis of complex system failures. The course covers a wide range of factors contributing to system failures: human perceptual and cognitive abilities and limitations, the design of modern technologies and interfaces, and biases in accident investigation and error analysis. Recent concepts in the area of high reliability organizations and resilience engineering are reviewed. Students perform systems analysis of actual mishaps and disasters in various domains, including various modes of transportation, process control, and health care.

IOE 436. Human Factors in Computer Systems

Prerequisite: IOE 333. II (3 credits)

This course discusses how to design and evaluate computer systems for ease of use. Topics to be covered include keyboards and how people type, vision and video display design, human body size and computer furniture, regulations concerning working conditions, software issues, methods for studying user performance, documentation, and information systems of the future.

IOE 438. Occupational Safety Management

Prerequisite: IOE 265. II (2 credits)

Survey of occupational safety management methods, theories and activities. Topics include: history of safety engineering, management, and worker compensation; collection and critical analysis of accident data; safety standards, regulations and regulatory agencies; theories of self-protective behavior and accident prevention; and analysis of safety program effectiveness.

IOE 439. Advanced Topic in Safety Management

Prerequisite: IOE 438. II (2 credits)

Lectures and case studies addressing advanced topics in occupational and product safety management. Topics include: analysis of human factors related to injury prevention; research methods related to accident/incident data; safety standards development; methods of risk assessment and reduction; and advanced hazard communication. A wide variety of case studies are analyzed.

IOE 441 (Mfg 441). Production and Inventory Control

Prerequisite: IOE 310, IOE 316. I, II (3 credits)

Basic models and techniques for managing inventory systems and for planning production. Topics include deterministic and probabilistic inventory models; production planning and scheduling; and introduction to factory physics.

IOE 447 (Mfg 447). Facility Planning

Prerequisite: IOE 310, IOE 316. I (3 credits)

Fundamentals in developing efficient layouts for single-story and multi-story production and service facilities. Manual procedures and microcomputer-based layout algorithms. Algorithms to determine the optimum location of facilities. Special considerations for multi-period, dynamic layout problems.

IOE 449 (Mfg 449). Material Handling Systems

Prerequisite: IOE 310, IOE 316. II alternate years (2 credits)

Review of material handling equipment used in warehousing and manufacturing. Algorithms to design and analyze discrete parts material storage and flow systems such as Automated Storage/Retrieval Systems, order picking, conveyors, automated guided vehicle systems, and carousels.

IOE 452 (Mfg 455). Corporate Finance

Prerequisite: IOE 201, IOE 310, IOE 366. I (3 credits)

The goal of this course is to introduce a basic understanding of financial management. The course develops fundamental models of valuation and investment from first principles and applies them to problems of corporate and individual decision-making. The topics of discussion will include the net present valuation, optimal portfolio selection, risk and investment analysis, issuing securities, capital structure with debt financing, and real options.

IOE 453 (Mfg 456). Derivative Instruments

Prerequisite: IOE 201, IOE 310, IOE 366. Credit not granted for both IOE 453/MFG 456 and MATH 423. II (3 credits)

The main objectives of the course are first, to provide the students with a thorough understanding of the theory of pricing derivatives in the absence of arbitrage, and second, to develop the mathematical and numerical tools necessary to calculate derivative security prices. We begin by exploring the implications of the absence of static arbitrage. We study, for instance, forward and futures contracts. We proceed to develop the implications of no arbitrage in dynamic trading models: the binomial and Black-Scholes models. The theory is applied to hedging and risk management.

IOE 460. Decision Analysis

Prerequisite: IOE 265, IOE 310. (2 credits)

Analysis of decisions under uncertainty. Decision trees, influence diagrams, value of information, attitudes towards risk, expected utility; applications from production, inspection, quality control, medicine, finance.

IOE 461. Quality Engineering Principles and Analysis
Prerequisite: IOE 366. I (3 credits)
This course provides students with the analytical and management tools necessary to solve manufacturing quality problems and implement effective quality systems. Topics include voice of the customer analysis, the Six Sigma problem solving methodology, process capability analysis, measurement system analysis, design of experiments, statistical process control, failure mode and effects analysis, quality function deployment, and reliability analysis.
IOE 463 (Mfg 463). Measurement and Design of Work
Prerequisite: IOE 333 or ME 395 or BME 231 and IOE 265 or Stats 412. I (3 credits)
Design of lean manufacturing systems requires knowledge and skills for describing manual work, identifying value and non-value added work elements, designing efficient work equipment and methods, preventing fatigue and related worker health problems and predicting work performance.
IOE 465. Design and Analysis of Experiments
Prerequisite: IOE 366. II (3 credits)
Linear Models, Multi-colinearity and Robust Regression, Comparative Experiments, Randomized Blocks and Latin Squares, Factorial Designs, Confounding, Mixed Level Fractional Factorials, Random and Mixed Models, Nesting and Split Plots, Response Surface Methods, Taguchi Contributions to Experimental Design.
IOE 466 (Mfg 466) (Stats 466). Statistical Quality Control
Prerequisite: IOE 265 (Stats 265) and IOE 366 or Stats 401. I, II (3 credits)
Quality Improvement Philosophies; Modeling Process Quality, Statistical Process Control, Control Charts for Variables and Attributes, CUSUM and EWMA, Short Production Runs, Multivariate Quality Control, Auto Correlation, Engineering Process Control, Economic Design of Charts, Fill Control, Precontrol, Adaptive Schemes, Process Capability, Specifications and Tolerances, Gage Capability Studies, Acceptance Sampling by Attributes and Variables, International Quality Standards.
IOE 473 Decision Support Systems
Prerequisite: IOE 310 and IOE 373 or graduate standing. I (3 credits)
This course covers development of decision support systems for Industrial Engineering applications using two technologies: (i) spreadsheet based systems using MS Excel and VBA for Excel and (ii) web enabled systems using ASP .net. This course contains case studies of applications of decision support systems in Industrial Engineering and a student project to provide hands-on experience.
IOE 474. Simulation
Prerequisite: IOE 316, IOE 366, IOE 373. I, II (4 credits)
Simulation of complex discrete-event systems with applications in industrial and service organizations. Course topics include modeling and programming simulations in one or more high-level computer packages such as ProModel or GPSS/H; input distribution modeling; generating random numbers; statistical analysis of simulation output data. The course will contain a team simulation project.
IOE 481. Practicum in Hospital Systems
Prerequisite: Senior Standing, permission of instructor; not for graduate credit. I, II (4 credits)
Student team projects in hospital systems. Projects will be offered from areas of industrial and operations engineering, including work measurement and control, systems and procedures, management, organization and information systems. Lectures will deal with the hospital setting and project methodologies. The final report should demonstrate a mastery of the established technical communication skills. The report will be reviewed and edited to achieve the outcome.
IOE 490. Undergraduate Directed Study, Research, and Special Problems
Prerequisite: permission of instructor, not for graduate credit; maximum 4 credit hours per term. I, II, III, IIIa, IIIb (2-4 credits)
Individual or group study, design, or laboratory research in a field of interest to the student or group. Topics may be chosen from any area of industrial and operations engineering. Student(s) must register for the individual section number of the instructor/advisor.
IOE 491. Special Topics in Industrial and Operations Engineering
(to be arranged)
Selected topics of current interest in industrial and operations engineering.
IOE 499. Senior Design Projects
Prerequisite: senior standing, permission of advisor. I, II (4 credits)
Selected design projects in industrial and operations engineering to be conducted for project sponsors. The final report submitted by the students should demonstrate a mastery of the established communication skills. The final project report will be reviewed to achieve this outcome.
IOE 510 (Math 561) (OMS 518). Linear Programming I
Prerequisite: Math 217, Math 417, or Math 419. I, II, IIIa (3 credits)
Formulation of problems from the private and public sectors using the mathematical model of linear programming. Development of the simplex algorithm; duality theory and economic interpretations. Postoptimality (sensitivity) analysis application and interpretations. Introduction to transportation and assignment problems; special purpose algorithms and advance computational techniques. Students have opportunities to formulate and solve models developed from more complex case studies and to use various computer programs.
IOE 511 (Math 562). Continuous Optimization Methods
Prerequisite: Math 217, Math 417 or Math 419. I (3 credits)
Survey of continuous optimization problems. Unconstrained optimization problems: unidirectional search techniques; gradient, conjugate direction, quasi-Newton methods. Introduction to constrained optimization using techniques of unconstrained optimization through penalty transformations, augmented Lagrangians, and others. Discussion of computer programs for various algorithms.
IOE 512. Dynamic Programming
Prerequisite: IOE 510, IOE 316. (3 credits)
The techniques of recursive optimization and their use in solving multistage decision problems, applications to various types of problems, including an introduction to Markov decision processes.

IOE 515. Stochastic Processes

Prerequisite: IOE 316 or Stats 310. I (3 credits)

Introduction to non-measure theoretic stochastic processes. Poisson processes, renewal processes, and discrete time Markov chains. Applications in queuing systems, reliability, and inventory control.

IOE 516. Stochastic Processes II

Prerequisite: IOE 515. II (3 credits)

This course emphasizes the use of Markov Chains in theory and practice. General knowledge of probability theory and stochastic processes is assumed. Applications may include equipment replacement, queuing systems, and production systems. Methodologies covered include invariant measures and stationary distributions for both the discrete and continuous cases.

IOE 518. Introduction to Integer Programming

Prerequisite: IOE 510. II (1.5 credits)

Introduction to optimization problems that fall within the framework of Integer Programming, and an overview of concepts and classical methods for their analysis and solution. Integer programming formulations, relaxations, duality and bounds, branch-and-bound and cutting plane algorithms, heuristic solution methods.

IOE 519. Introduction to Nonlinear Programming

Prerequisite: Math 217/417/419 and Math 451. II (1.5 credits)

Introduction to continuous nonlinear optimization problems, and an overview of concepts and classical methods for their analysis and solution. Nonlinear programming formulations. Optimality conditions for constrained and unconstrained problems. Convexity. Algorithms: steepest descent, Newton's method, barrier and penalty methods.

IOE 522. Theories of Administration

Prerequisite: IOE 421. II (3 credits)

Provide insight into leading theories concerning the administration of research and industrial organizations. Treat the concepts needed for describing, assessing, and diagnosing organizations; processes of organizational communication, motivation, and conflict management; adaptation of organization systems to the requirements of work and information technologies.

IOE 524. Integrative Technology Management

Prerequisite: IOE 421. II (3 credits)

A technology's path from invention to market success is shaped by a variety of factors. Covering the technology cycle from basic research to product development to manufacturing systems, this course provides an introduction to the analysis of the factors on industry, firm, and functional unit levels. Integrated multiple perspectives from engineering, economics, management, and organizational behavior.

IOE 533 (Mfg 535). Human Motor Behavior and Engineering Systems

Prerequisite: IOE 333 and IOE 366. I (3 credits)

This course is designed to provide a basic perspective of the major processes of human motor behavior. Emphasis will be placed on understanding motor control and man-(machine)-environment interaction. Information processing will be presented and linked to motor behavior. Application of theories to the design of the workplace, controls and tools will be underlined and illustrated by substantial examples.

IOE 534 (BiomedE 534) (Mfg 534). Occupational Biomechanics

Prerequisite: IOE 333, IOE 334, or IOE 433. II (3 credits)

Anatomical and physiological concepts are introduced to understand and predict human motor capabilities, with particular emphasis on the evaluation and design of manual activities in various occupations. Quantitative models are developed to explain (1) muscle strength performance; (2) cumulative and acute musculoskeletal injury; (3) physical fatigue; and (4) human motion control.

IOE 536. Cognitive Ergonomics

Prerequisite: IOE 333 or IOE 433. (3 credits)

Theories and concepts of human information processing are introduced to analyze human perceptual and cognitive performance in human machine information systems such as intelligent transportation and manufacturing systems. Conceptual and quantitative models, interface design techniques, and research and evaluation methods are presented. Samples of on-going research are also discussed.

IOE 539 (Mfg 539). Occupational Safety Engineering

Prerequisite: IOE 265 or Biostat 500. I (3 credits)

Design/modification of machinery/products to eliminate or control hazards arising out of mechanical, electrical, thermal, chemical, and motion energy sources. Application of retrospective and prospective hazard analysis, systems safety, expert systems and accident reconstruction methodologies. Case examples: industrial machinery and trucks, construction and agriculture equipment, automated manufacturing systems/processes.

IOE 541 (Mfg 541). Inventory Analysis and Control

Prerequisite: IOE 310, IOE 316. (3 credits)

Models and techniques for managing inventory systems and for planning production. Topics include single item and multi-item inventory models, production planning and control, and performance evaluation of manufacturing systems.

IOE 543 (Mfg 543). Scheduling

Prerequisite: IOE 316, IOE 310. (3 credits)

The problem of scheduling several tasks over time, including the topics of measures of performance, single-machine sequencing, flow shop scheduling, the job shop problem, and priority dispatching. Integer programming, dynamic programming, and heuristic approaches to various problems are presented.

IOE 545 (Mfg 545). Queueing Networks

Prerequisite: IOE 515 or EECS 501. (3 credits)

Introduction to queueing networks. Topics include product and non-product form networks, exact results and approximations, queueing networks with blocking, and polling systems. Applications from manufacturing and service industries are given as examples.

IOE 548. Integrated Product Development
Prerequisite: Graduate Standing, co-req. I (3 credits)
Cross-disciplinary teams compete to design, manufacture, plan mass production and market a defined product. Major objectives are integration of engineering and business aspects of these issues.
IOE 549 (Mfg 549). Plant Flow Systems
Prerequisite: IOE 310, IOE 416. II, alternate years (3 credits)
Analytical models for the design and throughput performance evaluation of material handling systems used in discrete parts flow production facilities. Analysis of design and control issues for manual and automated handling systems including lift trucks, micro-load automatic storage/retrieval systems and automated guided vehicle systems.
IOE 551. Benchmarking, Productivity Analysis and Performance Measurement
Prerequisite: IOE 510. II (3 credits)
Introduction to quality engineering techniques commonly used for performance measurement, productivity analysis, and identification of best practice. Topics include balanced scorecard, activity-based costing/management, benchmarking, quality function deployment and data envelopment analysis (DEA). Significant focus of the course is on the application of DEA for identification of best practice.
IOE 552 (Math 542). Financial Engineering I
Prerequisite: IOE 453 or Math 423. Business School students: Fin 580 or Fin 618 or BA 855. II (3 credits)
Theory and applications of financial engineering. Designing, structuring and pricing financial engineering products (including options, futures, swaps and other derivative securities) and their applications to financial and investment risk management. Mathematical methodology that forms the basis of financial engineering, applied stochastic processes and numerical methods in particular.
IOE 553 (Math 543). Financial Engineering II
Prerequisite: IOE 552. I (3 credits)
Advanced issues in financial engineering: stochastic interest rate modeling and fixed income markets, derivative trading and arbitrage, international finance, risk management methodologies including Value-at-Risk and credit risk. Multivariate stochastic calculus methodology in finance: multivariate Itoís lemma, Itoís stochastic integrals, the Feynman-Kac theorem and Girsanovís theorem.
IOE 560 (Stats 550). Bayesian Decision Analysis
Prerequisite: IOE 366 or Stats 426. (3 credits)
Axiomatic foundations for, and assessment of, probability and utility; formulation of decision problems; risk functions, admissibility; likelihood functions and the likelihood principle; natural conjugate a priori distributions; Baysian regression analysis and hypothesis testing; hierarchical models; credible intervals; numerical analysis; applications to decision-making.
IOE 562 (Stats 535). Reliability
Prerequisite: IOE 316 and IOE 366 or Stats 425 and Stats 426. I (3 credits)
Reliability concepts and methodology for modeling, assessing and improving product reliability: common models for component and system reliability; analysis of field and warranty data; component reliability inference; repairable systems; accelerated stress testing for reliability assessment; reliability improvement through experimental design.
IOE 565 (ME 563) (Mfg 561). Time Series Modeling, Analysis, Forecasting
Prerequisite: IOE 366 or ME 401. I (3 credits)
Time series modeling, analysis, forecasting, and control, identifying parametric time series, autovariance, spectra, Green's function, trend and seasonality. Examples from manufacturing, quality control, ergonomics, inventory, and management.
IOE 566 (Mfg 569). Advanced Quality Control
Prerequisite: IOE 466. (3 credits)
An applied course on Quality Control including Statistical Process Control Modifications, Linear, Stepwise and Ridge Regression Applications, Quality Function Deployment, Taguchi Methods, Quality Policy Deployment, Tolerancing Systems, Process Control Methodologies and Measurement Systems and Voice of the Customer Methodologies Time Series, Experimental Design, Total Quality Management and case studies.
IOE 567. Work-Related Musculoskeletal Disorders
Prerequisite: Graduate Standing and IOE 333 or equivalent. II alternate years (3 credits)
For students with an advanced interest in the prevention and rehabilitation of occupational musculoskeletal disorders. Content includes 1) lectures, readings and discussions on biomechanical, physiological and psychological factors and on exposure assessment, 2) oral and written critiques of historical and contemporary literature, 3) job analysis and design case studies from manufacturing and service operations (site visits and archived video).
IOE 570 (Stats 570) Experimental Design
Prerequisite: Stats 500 or background in regression II (3 credits)
Basic design principles, review of analysis of variance, block designs, two-level and three-level factorial and fractional factorial experiments, designs with complex aliasing, data analysis techniques and case studies, basic response surface methodology, variation reduction and introductory robust parameter designs.
IOE 574. Simulation Analysis
Prerequisite: IOE 515. (3 credits)
Underlying probabilistic aspects of simulation experiments, statistical methodology for designing simulation experiments and interpreting output. Random number generators, variate and process generation, output analysis, efficiency improvement techniques, simulation and optimization, how commercial simulation software works. Applications from telecommunications, manufacturing statistical analysis.

IOE 583 (ME 583) (Mfg 583) (EECS 566). Scientific Basis for Reconfigurable Manufacturing
Prerequisite: Graduate Standing or permission of instructor. II alternate years (3 credits)
Principles of reconfigurable manufacturing systems (RMS). Students will be introduced to fundamental theories applicable to RMS synthesis and analysis. Concepts of customization, integrability, modularity, diagnosability, and convertibility. Reconfiguration design theory, life-cycle economics, open-architecture principles, controller configuration, system reliability, multi-sensor monitoring, and stream of variations. Term projects.

IOE 588 (ME 588) (Mfg 588). Assembly Modeling for Design and Manufacturing
Prerequisite: ME 381 and ME 401 or equivalent. I alternate years (3 credits)
Assembly on product and process. Assembly representation. Assembly sequence. Datum flow chain. Geometric Dimensioning & Tolerancing. Tolerance analysis. Tolerance synthesis. Robust design. Fixturing. Joint design and joining methods. Stream of variation. Auto body assembly case studies.

IOE 590. Masters Directed Study, Research, and Special Problems
Prerequisite: Graduate standing and permission of instructor. I, II, III, IIIa, IIIb (2-4 credits)
Individual or group study, design or laboratory research in a field of interest to the student or group. Topics may be chosen from any area of industrial and operations engineering. Student(s) must register for the section number of the instructor/advisor. Maximum of six credits of IOE 590/593 may be counted toward the IOE Masters Degree.

IOE 591. Special Topics
Prerequisite: permission of instructor. (to be arranged)
Selected topics of current interest in industrial and operations engineering.

IOE 593. Ergonomics Professional Project
Prerequisite: Graduate Standing, permission of instructor. I, II, III, IIIa, IIIb (2-4 credits)
Students work as part of a team within a production or service organization on a design project that emphasizes the application of ergonomic principles to enhance the safety, productivity, and/or quality aspects of a human-machine system. Student(s) must register for the section number of the instructor/advisor. A maximum of six credits of IOE 590/593 may be counted toward the IOE Masters Degree.

IOE 600 (EECS 600). Function Space Methods in System Theory
Prerequisite: EECS 400 or Math 419. (3 credits)
Introduction to the description and analysis of systems using function analytic methods. Metric spaces, normed linear spaces, Hilbert spaces, resolution spaces. Emphasis on using these concepts in systems problems.

IOE 610 (Math 660). Linear Programming II
Prerequisite: IOE 510 (Math 561). II (3 credits)
Primal-dual algorithm. Resolution of degeneracy, upper bounding. Variants of simplex method. Geometry of the simplex method, application of adjacent vertex methods in non-linear programs, fractional linear programming. Decomposition principle, generalized linear programs. Linear programming under uncertainty. Ranking algorithms, fixed charge problem. Integer programming. Combinatorial problems.

IOE 611 (Math 663). Nonlinear Programming
Prerequisite: IOE 510 (Math 561). I (3 credits)
Modeling, theorems of alternatives, convex sets, convex and generalized convex functions, convex inequality systems, necessary and sufficient optimality conditions, duality theory, algorithms for quadratic programming, linear complementary problems, and fixed point computing. Methods of direct search, Newton and Quasi-Newton, gradient projection, feasible direction, reduced gradient; solution methods for nonlinear equations.

IOE 612. Network Flows
Prerequisite: IOE 510 (Math 561). II (3 credits)
Flow problems on networks. Maximum flow minimum cut theorem. Labeling algorithms. Circulation and feasibility theorems. Sensitivity analysis. Incidence matrices. Shortest routes. Minimum cost flows, out-of-kilter algorithm. Critical path networks, project cost curves. Multi-commodity flow problem, biflows. Matching problems in graph theory.

IOE 614. Integer Programming
Prerequisite: IOE 510 (Math 561). (3 credits)
Modeling with integer variables, total unimodularity, cutting plane approaches, branch-and-bound methods, Lagrangian relaxation, Bender's decomposition, the knapsack, and other special problems.

IOE 615. Advanced Stochastic Processes
Prerequisite: IOE 515 and Math 451. (3 credits)
Designed for students planning to do research on stochastic models in operations research (e.g., queuing systems, stochastic scheduling, financial models, simulation, etc.) Topics covered include Martingales, Brownian motion, diffusion processes, limit theorems, and coupling.

IOE 616. Queueing Theory
Prerequisite: IOE 515. (3 credits)
Theoretical foundations, models and techniques of queuing theory. Rigorous treatment of elementary through advanced queuing systems and queuing networks. Topics include Markov Renewal and Semi-Regenerative Processes.

IOE 623 (Math 623). Computational Finance
Prerequisite: Math 316 and Math 425/525 or IOE 552. II (3 credits)
This is a course in computational methods in finance and financial modeling. Particular emphasis will be put on interest rate models and interest rate derivatives. The specific topics include: Black-Scholes theory, no arbitrage and complete markets theory, term structure models: Hull and White models and Heath Jarrow Morton models, the stochastic differential equations and martingale approach: multinomial tree and Monte Carlo methods, the partial differential equations approach: finite difference methods.

IOE 635 (BiomedE 635). Laboratory in Biomechanics and Physiology of Work
Prerequisite: IOE 534 (BiomedE 534). II (2 credits)
This laboratory is offered in conjunction with the Occupational Biomechanics lecture course (IOE 534) to enable students to examine experimentally (1) musculoskeletal reactions to volitional acts; (2) the use of electromyography (EMGs) to evaluate muscle function and fatigue; (3) biomechanical models; (4) motion analysis system; and (5) musculoskeletal reactions to vibrations.

IOE 636. Laboratory in Human Performance
Prerequisite: preceded or accompanied by IOE 533. I alternate years (2 credits)
This optional lab is offered in conjunction with IOE 533 to provide an experimental perspective on (1) the major processes of human behavior (reflexes, motor control); (2) information measurement; (3) psychophysics; and (4) controls and displays.

IOE 640. Mathematical Modeling of Operational Systems
Prerequisite: IOE 510, IOE 515. (3 credits)
The art and science of developing, using and explicating mathematical models, presented in a studio/workshop environment. Structuring of a variety of operational "situations" so they can be reasonably represented by a mathematical model. Extensive class discussion and out-of-class investigation of potential mathematical approaches to each situation. Incorporation of data analysis.

IOE 641. Supply Chain Management
Prerequisite: IOE 510, IOE 515 and IOE 541. (3 credits)
Structural analyses of production and inventory systems. Review of issues in supply chain management. Topics include inventory systems with stochastic lead time, multi-echelon supply systems, and coordination of material flows, information flows and financial flows in a supply chain.

IOE 645 (Mfg 645) (Stats 645). Topics in Reliability and Maintainability
Prerequisite: IOE 515 (Stats 526) and IOE 562 (Stats 535). (3 credits)
Advanced topics in reliability and maintainability. Examples include models for component and system reliability, probabilistic design, physics of failure models, degradation modeling and analysis, models form maintainability and availability, and maintenance and monitoring policies.

IOE 691. Special Topics
Prerequisite: permission of instructor. I, II (to be arranged)
Selected topics of current interest in industrial and operations engineering.

IOE 712. Infinite Horizon Optimization
Prerequisite: IOE 512. (3 credits)
A seminar on optimization problems with an infinite time horizon. Topics include topological properties, optimality definitions, decision/forecast horizons, regenerative models, and stopping rules. Applications discussed include capacity expansion, equipment replacement, and production/ inventory control.

IOE 800. First-Year Doctoral Seminar
Prerequisite: permission of instructor. I (1 credit)
Presentation by IOE faculty members of current and future research activities within the department. Discussion of procedural, philosophical, and professional aspects of doctoral studies in industrial and operations engineering.

IOE 801. First-Year Doctoral Directed Research
Prerequisite: IOE Ph.D. precandidacy, permission of instructor. I, II, III, IIIa, IIIb (1-3 credits)
Directed research on a topic of mutual interest to the student and the instructor. Student(s) must register for the section number of the instructor/advisor.

IOE 802. Research Presentation
Prerequisite: IOE 800, concurrent with IOE 801; mandatory satisfactory/unsatisfactory. II (1 credit)
Students present oral and written technical material, including research in IOE 801

IOE 836. Seminar in Human Performance
Prerequisite: graduate standing. I (1 credits)
Case studies of research techniques used in the human performance and safety fields. Speakers actively engaged in research will discuss their methods and results.

IOE 837. Seminar in Occupational Health and Safety Engineering
Prerequisite: graduate standing. II (1 credit)
This seminar provides an opportunity for graduate students interested in occupational health and safety engineering problems to become acquainted with various related contemporary research and professional activities, as presented by both staff and guest speakers.

IOE 899. Seminar in Industrial and Operations Engineering
Prerequisite: permission of instructor; not for master's degree; mandatory satisfactory/unsatisfactory. I, II (1 credit)
Presentation by IOE faculty members and outside speakers on current and future research activities in industrial and operations engineering.

IOE 906. Master's Thesis Project
Prerequisite: permission of department. I, II, III, IIIa, IIIb (6 credits maximum total-may be spread over several terms)

IOE 990. Dissertation Research: Pre-Candidate
Prerequisite: Completion of IOE Qualifying Exam and permission of instructor. I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student who has passed the IOE Qualifying Exam with Pass or Conditional Pass, but is not yet admitted to candidacy. Student must register for the section number of the instructor/advisor. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

IOE 995. Dissertation Research: Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate and permission of the instructor. I, II, III (8 credits); IIIa, IIIb (4 credits)
Dissertation research by a doctoral student who has been admitted to Candidacy. Student must register for the section number of the instructor/advisor. The defense of the dissertation (e.g., the final oral examination) must be held under a full-term candidacy enrollment.

Industrial and Operations Engineering Faculty

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1603 Industrial and Operations Engineering Building
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Professors

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Yavuz Bozer, Ph.D.
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Izak Duenyas, Ph.D.
Gary D. Herrin, Ph.D.; *also Associate Interim Dean for Undergraduate Education*
Barry H. Kantowitz, Ph.D.
W. Monroe Keyserling, Ph.D.
Jeffrey K. Liker, Ph.D.
Katta G. Murty, Ph.D.
Vijay Nair, Ph.D.
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Robert L. Smith, Ph.D., *Altarum/ERIM Russell D. O'Neil Professor of Engineering*

Adjunct Professor

Seth Bonder, Ph.D.

Professors Emeritus

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Luis Garcia-Guzman, Ph.D.
Patrick C. Hammett, Ph.D.
Daniel J. Reaume, Ph.D.
Omer Tsimhoni, Ph. D.

Lecturers

Robert E. Anderson, M.S. (Ind. Mgt.)
Kenneth Ludwig, M.L.S. (Lib. Stud. Tech.)
Larry F. Spiegel, M.B.A. (B.S. I.E.)
Charles Woolley, M.S. (Bio.E.)

Interdisciplinary Degree Programs

Engineering Advising Center
1001 Lurie Engineering Center (LEC)
Phone: (734) 647-7106
Fax: (734) 647-7126
http://www.engin.umich.edu/students/advising

Recent technological, economic, and social developments have significantly extended the range of problems to which engineering skills and methodologies must be applied. Problems in environmental quality, transportation systems, and urban planning, among others, challenge students to develop programs combining technical knowledge with social and political awareness. In addition, the complexity of our technological society requires that some engineers integrate studies in several technical areas.
To meet these needs, the Interdisciplinary Engineering Program — B.S. (Engineering) — allows students to combine studies in several engineering fields or to combine studies in engineering with studies in other fields. This program can prepare students for a wide variety of career and graduate school opportunities while providing a distinctive undergraduate education.
The program, however, is suited best for those students who have clearly defined career goals. Because the degree is non-departmental, the program does not provide the conventional career opportunities available to students in departmental programs.
Successful completion of the Interdisciplinary Undergraduate Degree Program results in a B.S. degree rather than a B.S.E. degree. Students who need a standard engineering background should consider a departmental B.S.E. program.

Accreditation
Students should note that this program does not meet the requirement of the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET) for Professional Engineering Certification.

Goals
For the Interdisciplinary Engineering program, students are asked to write a statement of their educational goals and career objectives, explaining how their course selections will contribute toward these goals. Goals may be modified as the student progresses. Finally, students are encouraged to explore postgraduate opportunities and alternative career paths.

Interdisciplinary Degree Programs Undergraduate Education

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Degree Program
Students with interdisciplinary goals devise a program option based on the course offerings of various departments in the College and elsewhere in the University. These programs may be one of the following:

1. A pre-professional or pre-graduate program. The student chooses, for example, a pre-law, pre-medicine, pre-dentistry, pre-public administration, pre-business administration, pre-bioengineering, or pre-public systems engineering option. Most B.S. (Engineering) students have an option in one of these areas.
2. An interdepartmental College-wide program. The student crosses traditional boundaries in technical disciplines to study in areas such as manufacturing, integrated transportation systems, or technical communication. Before considering an option in one of the areas, students should investigate the possibilities in departmental programs.
3. An interdisciplinary University-wide program. The student combines studies in the mathematical and physical sciences, the social sciences, natural resources, business administration, architecture, or industrial design with complementary studies in engineering. Most students obtain combined or dual degrees when they choose an option in one of these areas.

Students are able to pursue these goals by choosing from advanced courses in other fields and colleges as well as in engineering.

Program Design
Each student is asked to define his or her own educational goals and to design a program with the advice of the program advisor. It is very important to choose a
purposeful sequence of advanced engineering concentration courses to complement an integrated sequence of program option courses. Together these form a "major."
Such a program, however, results from the student's own decisions. Since there is no structure of prerequisite and required courses in the junior and senior years, within the constraints explained below, this program is flexible and allows considerable freedom to choose courses. The outline of studies demonstrates the well-rounded college education provided by the Interdisciplinary Engineering Program. Few degree programs in any university allow such a balanced distribution of science, mathematics, social science, humanities, and engineering courses.

Note: The combined hours for Engineering Science and Engineering Concentration courses must total at least 40 hours.

Sample Schedule
B.S. (Engineering)

	Credit Hours	Terms							
		1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engr 100, Intro to Engr	4	4	-	-	-	-	-	-	-
Engr 101, Intro to Computers	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130[1]	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241[2]	10	-	5	5	-	-	-	-	-
Humanities and Social Sciences *(include one 4-hour course in Economics)*	16	4	4	-	-	4	4	-	-
Engineering Science (18-20 hrs.)	18	-	-	3	6	6	3	-	-
Program Subjects (40-42 hrs.)									
Engineering Concentration	22	-	-	-	3	3	6	6	4
Program Option Courses	20	-	-	3	-	3	4	4	6
Unrestricted Electives (13-17 hrs.)	16	-	-	3	3	-	-	5	5
Total	128	17	17	18	16	16	17	15	15

Candidates for the Bachelor of Science degree (Engineering) - B.S.(Engineering) - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:
[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

Additional Note:
The combined hours for Engineering Science and Engineering Concentration courses must total at least 40 hours.

Interdisciplinary Degree Programs Concentrations

Program Option Courses
This group of courses is selected by students to provide a program of study oriented to their individualized educational career goals. The program option can include courses from throughout the University, including additional engineering courses. For most program options, these should be 300-, 400-, and 500-level courses. Each student is encouraged to design a curriculum that reflects his/her individual goals. Some of the possible options are identified below. (Some options involve combined or dual degree programs with other schools and colleges; although, that is not the route most students take.)

Pre-Law
Students choose this option to prepare for law school to become attorneys in a law firm or to specialize in an area such as corporate law where they use their technical training as a member of a corporate staff. However, a B.S.E. degree from any engineering department is a viable pre-law alternative. Some extra steps may be necessary after an interdisciplinary engineering degree for a concentration in Patent law since the degree is not ABET accredited.

Pre-Medicine
Students choose this option to become physicians or to go into biomedical research where they can use their technical training. However, any engineering degree is also an appropriate pre-medical degree. The interdisciplinary program is the only one in the college where a student can meet all pre-med requirements and still only take 128 credits to graduate with an engineering degree.

Pre-Bioengineering
Students choose this option to prepare for a graduate program in bioengineering, a field applied to problems in living systems and in design of new biological structures. However, graduate programs in bioengineering do not require undergraduate training in bioengineering, so several other B.S.E. degrees are also excellent preparation.

Pre-Business Administration or Business Administration
Many students combine business courses with engineering courses to prepare for a career in business. Some students earn a Master of Business Administration (M.B.A.) after completing a B.S. in Engineering. About half of all engineers who enter industry eventually assume managerial responsibilities. Students interested in this program option should consider whether or not a degree in Industrial and Operations Engineering would be more appropriate than the B.S. (Engineering) degree. Furthermore, any engineering degree provides sound preparation for an M.B.A. program.

Technical Sales and Applications Engineering
Students combine engineering, communications, and business to prepare for positions in these fields. Many companies require sales engineers to design and market products that meet the needs of other corporations and government agencies. These persons serve as liaison between their corporations' research, design, product, and manufacturing engineers and the customers' engineers and managers.

Appropriate Technology
Students interested in alternative technologies design program options in appropriate technology, alternative energy resources, or environmental systems.

Urban and Regional Planning
An increasing number of engineers become planners and administrators in urban systems because they know sophisticated technology or are trained in problem solving and systems design. Related options are in architecture, sociology, natural resources, and transportation. This option primarily is a pre-graduate school option.

Industrial Design
Some students pursue a combined degree program with the School of Art, usually in industrial design, but occasionally in graphics. The combination prepares students for careers meeting challenges in human/technology interface systems or in computer graphics.

Technical and Professional Communication
Students choose this option either to enhance their qualifications for careers as managers in industry, business, and government or to prepare themselves for careers as technical communicators. The option is distinctive in the United States because its graduates combine engineering skills while concentrating on communication skills. It is good preparation for a graduate program in technical communication. Fundamental classes are offered in fluid mechanics, combustion, and turbulent mixing. A graduate laboratory class is offered in high temperature gas dynamics. Applied propulsion classes include Rocket Propulsion and Turbojet Propulsion. Research covers the areas of laser-based flow visualization, velocity field imaging, holography, spray combustion, supersonic mixing, hydrogen combustion in a scramjet-like device, and soot formation.

Science
Students choose this option to prepare for a graduate program in mathematics, biology, or one of the physical sciences. Students choosing this option select a program of study roughly equivalent to that of a mathematics or science student in LSA. Other options for such students are the pre-Bioengineering option and the Engineering Physics option.

Engineering Concentration Courses
The engineering concentration courses complement the program option courses. The student elects a sequence of engineering courses that must have coherence with respect to subject matter and progression with respect to level of study. In environmental studies, for example, program option courses in the life sciences, natural resources, or geophysical sciences are complemented by engineering concentration courses from Civil and Environmental Engineering, Chemical Engineering, Aerospace Engineering, and Atmospheric, Oceanic and Space Sciences. In business administration, courses in systems, planning, management, operations, decision-making, and design – from several engineering fields – complement the program option. These should be 300-, 400-, and 500-level courses.

Engineering Science Courses
The Engineering Science courses provide science-based skills applicable to engineering problems. Most courses are at the 200- and 300-level and are prerequisites for many advanced engineering courses. These courses for the most part are those required in all engineering degree programs.

Each student in the program must select courses from the list in at least four of the following areas:

- *Computer Methods*
  CEE 303 (4)
- *Electrical*
  EECS 230 (4)
- *Environmental*
  CEE 260 (4)
- *Materials*
  MSE 250 (4), ME 382 (4)
- *Mechanical*
  ME 211 (4), ME 240 (4), NAME 320 (4) or ME 320 (3)
- *Systems*
  IOE 201 (2) and 202 (2), IOE 265 (4), IOE 310 (4)
- *Thermodynamics*
  ME 235 (3) or ChemE 230 (4)

Together with the engineering concentration courses, these courses provide the engineering basis of the B.S. (Engineering) degree. These requirements must be adhered to.

Materials Science and Engineering

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Materials Science and Engineering is widely recognized as one of the most promising technical fields of the 21st century.

Materials scientists and engineers specialize in the characterization, development, processing, and use of metallic, ceramic, polymeric, and electronic materials that are employed in all fields of technology.

Materials scientists and engineers are developing important new materials to meet the needs of our modern technological society. These include high-temperature superconductors; ultra-high-purity semiconductors for solid-state electronic devices; high-strength alloys for use at the extreme temperatures encountered in jet and rocket engines; strong, light alloys and composites for aerospace applications; specialized glasses and ceramics with high thermal, mechanical, and chemical stability, and a host of polymeric materials: some with unique functional characteristics and others which replace metal, glass, wood, and natural fibers in dozens of applications.

The future role of materials scientists and engineers promises to be even more important and challenging. It is widely recognized that the world is facing a critical energy shortage. Materials scientists and engineers are rising to this challenge in a variety of ways. One method is reducing the weight of automobiles and other transportation systems for fuel savings. They are also actively engaged in reducing the impact of modern society on our environment. They are at the forefront of recycling technologies and more energy-efficient ways of processing materials. New materials and processes are being developed to replace environmentally unfriendly ones currently in use. Sputtering or vapor deposition instead of plating, and biodegradable plastics are examples.

Materials science and engineering graduates are employed in research, development, and manufacturing. They support the creation of new materials and processes or the improvement of old ones with the aim of tailoring properties to applications. Often the work involves cooperating with mechanical, chemical, aeronautical, automotive and other types of engineers in selecting appropriate materials in the design of various devices; evaluating the performance of materials in service; and, particularly, determining the causes and cures for in-service failures; as well as various kinds of supervisory, research, teaching, and management activities. A tremendous range of materials science and engineering opportunities exists in metals, polymers, ceramics and electronic materials.

The undergraduate program in Materials Science and Engineering at the University of Michigan has been carefully designed to prepare students for the broad range of activities as described previously; or for continuing their academic work to acquire a master's or doctoral degree.

Introductory courses (either MSE 220 or MSE 250) and MSE 242, and a second-level course (MSE 350) provide a foundation of basic principles applicable to all classes of materials. Other courses include thermodynamics, transport phenomena and mechanical behavior.

Two required laboratory courses give our students a working knowledge of equipment used and methods practiced in the materials industry including processing that uses thermal, chemical, and mechanical methods; characterization using mechanical testing machines, microscopy and diffraction instruments; and analysis of experimental data using statistical and digital methods.

A required course in organic chemistry (Chem 210) may be used to satisfy the engineering chemistry requirement or the technical elective requirement. Introduction to Solid Mechanics (ME 211) is also required.

Students have an opportunity to tailor their program of study to their own interests. They choose three senior-level courses from a group of six. These courses cover electrical, magnetic or optical properties of materials, metals, polymers, ceramics, biomaterials, and materials characterization. They also choose one additional MSE course, plus 10 hours of technical electives and 12 hours of free electives.

All engineering students are required to take 16 credits of humanities or social sciences to broaden their education. One of the social science courses must be macro- or micro-economics (Econ 101 or 102).

Facilities

The facilities for the program in Materials Science and Engineering are housed primarily in the H. H. Dow Building. These include laboratories equipped for basic studies of the structures and properties of metals, polymers, ceramics and electronic materials; special-purpose laboratories for studies of crystal plasticity, high-temperature alloys, and structural composites; and instrument laboratories containing optical and electron microscopes, x-ray diffraction and spectroscopic apparatus, and precision mechanical-testing equipment.

In 2004 the L. H. Van Vlack Undergraduate Laboratory was opened. This facility has large, open spaces for team and group projects. It is equipped with instruments used in the characterization of materials. All undergraduate courses use this facility.

Accreditation

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Materials Science and Engineering

Mission

To provide internationally recognized leadership in education, research and service in the field of materials science and engineering. This is achieved through educational programs that produce students with a strong background in scientific and engineering problem-solving methods as well as communication and teamwork skills.

Goals

- To provide excellent, diverse students with the knowledge and engineering skills in a quality learning environment that will enable them to become flexible, effective, life-long learners and leaders in materials-related industries, government agencies, and academia.
- To have a leading undergraduate program in materials science and engineering, one that integrates a strong scientific base with engineering experience.

Objectives

The undergraduate program in the Department of Materials Science and Engineering at the University of Michigan will graduate students who:

- possess an understanding of the structure, properties, performance, and processing of materials.
- adapt to the rapidly changing scientific and technological landscape, and drive the development of future technologies.
- communicate effectively with their colleagues and the general public.
- contribute substantively to science, technology, the environment, and society.

Outcomes

All Materials Science and Engineering graduates should have :

- an ability to apply knowledge of mathematics, science, and engineering within their chosen field.
- an ability to formulate engineering problems and develop practical solutions.
- an initial ability to design products and processes applicable to their chosen field.
- an ability to design, conduct, analyze, and interpret the results of engineering experiments.
- an ability to work effectively in diverse teams and provide leadership to teams and organizations.
- an ability for effective oral, graphic and written communication.
- a broad education necessary to understand the impact of engineering decisions in a global/society/ economic/environmental context. An understanding of professional and ethical responsibility.
- a recognition of the need for and an ability to engage in life-long learning.
- a broad education necessary to contribute effectively beyond their professional careers.
- a sense of responsibility to make a contribution to society.

Materials Science and Engineering Undergraduate Education

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Degree Programs

B.S.E. in Materials Science & Engineering

Combined Degrees

Materials are critically involved in most fields of engineering; therefore, it is sometimes advantageous to obtain a B.S.E. degree in Materials Science and Engineering in combination with a B.S.E. degree in other fields such as Mechanical, Chemical, Electrical, or Aerospace Engineering. Students interested in combined degree programs should consult with the program advisors in both programs as early as possible to work out optimum combinations of courses.

Sequential Graduate/Undergraduate Education (SGUS)
B.S.E. in Materials Science and Engineering
M.S.E. in Materials Science and Engineering

Renee Hilgendorf
3062D H.H. Dow Building
Phone: (734) 763-9790
reneeh@umich.eduGraduate Program Advisor: Professor John Kieffer

Students should apply to the program in the first term of their senior year for provisional admission into the program in order to be advised appropriately regarding planning for undergraduate and graduate course selections. No dual enrollment will be required. Other requirements include a minimum undergraduate grade point average of 3.2 for provisional admission and subsequent enrollment into the SGUS program in Materials Science and Engineering. A maximum of 9 credits of prior-approved course work may be double counted. Only technical electives and/or free electives may be double counted none of the 47 required Materials Science and Engineering credits may be used for the graduate degree. A maximum of 15 credit hours that are double counted or transferred for graduate credit may be allowed. Contact the Materials Science and Engineering department for more complete program information.

B.S.E in Materials Science and Engineering
M.S. Biomedical Engineering

Susan Bitzer
sbitzer@umich.edu
Contact for B.S.E. Materials Science Engineering/M.S. Biomedical Engineering
1111 Carl A. Gerstacker
Phone: (734) 763-5290
Program Advisor: Professor David H. Kohn

This SGUS program is open to all undergraduate students from Materials Science and Engineering who have achieved senior standing (85 credit hours or more), and have an overall cumulative GPA of 3.2 or higher. A maximum of 9 credit hours may be double counted. Only technical electives and/or free electives may be double counted none of the 47 required Materials Science and Engineering credits may be used for the graduate degree. Please contact the Department of Biomedical Engineering for more complete program information.

Sample Schedule
B.S.E. (Materials Science and Engineering)

Credit Hours		Terms							
		1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4				
Engr 100, Intro to Engr	4	4							
Engr 101, Intro to Computers	4		4						
Chemistry 125/126 & 130 or Chem 210 & 211[1]	5	5							
Physics 140+141, Physics 240+241[2]	10		5	5					
Humanities and Social Sciences (Must include Econ 101 or 102)	16	3	3				5		5
Science and Technical Subjects (14 hrs.)									
ME 211, Intro to Solid Mechanics	4				4				
Science and Technical Electives	10					3	4		3
(Must include Chem 210 - if not already taken)									
Program Subjects (44 hrs.)									
MSE 250, Principles of Engr Materials or MSE 220, Intro to Mtls and Manufacturing	4			4					
MSE 242, Physics of Materials	4				4				
MSE 330, Thermodynamics of Materials	4					4			
MSE 335, Kinetics and Trans in Matls Engr	4						4		
MSE 350, Principles of Engr Materials II	4					4			
MSE 360, Materials Lab I	3					3			
MSE 365, Materials Lab II	3						3		
MSE 420, Mechanical Behavior of Materials	3							3	
MSE 480, Materials and Engineering Design	3								3
MSE 489, Materials Processing Design	3							3	
Elect 3 of the following:	9							6	3
MSE 400, EMO Matls for Modern Device Tech (3)									
MSE 410, Design and Applic of Biomatls (4)									
MSE 412, Polymeric Materials (3)									
MSE 440, Ceramic Materials (3)									
MSE 465, Structure & Chem Char of Matls (3)									
MSE 470, Physical Metallurgy (3)									
MSE Elective (3 hrs.)	3								3
Unrestricted Electives (12-15 hrs.)	12-15			3	4	2		3	
Total	**128**	**16**	**16**	**16**	**16**	**16**	**16**	**15**	**17**

Candidates for the Bachelor of Science degree in Engineering (Materials Science and Engineering) B.S.E. (Matl. Sci.& E.) must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution, you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution, you will have met the Physics Core Requirement for CoE.

Materials Science and Engineering Graduate Education

Graduate Program Coordinator
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Graduate Degrees

- Master of Science in Engineering (M.S.E.) in Materials Science and Engineering
- Doctor of Philosophy (Ph.D.) in Materials Science and Engineering

Master of Science Programs

Two different types of M.S.E. degrees are offered: one with a primary focus on coursework (the Coursework M.S.E.) and one with an emphasis on research (the Research M.S.E.) Students supported with a GSRA or research fellowship, must pursue a Research M.S.E. rather than a Coursework M.S.E.

Coursework M.S.E.

Students seeking a coursework M.S.E. degree must complete 30 credit hours of courses, which must be approved by the student's advisor. Of the 30 credit hours, up to 8 credit hours may be satisfied by MSE 690, and at least 15 credit hours of MSE department courses (excluding MSE 690) must be taken. At least 2 cognate courses (a minimum of 4 credit hours) must be taken. Students taking MSE 690 must submit a research report commensurate with the number of MSE 690 credits taken. This report must be approved by the project supervisor. It may also be used as a document for the Ph.D. oral candidacy exam.

Research M.S.E.

Students seeking a Research M.S.E. degree must complete 30 credit hours of courses, which must be approved by the student's advisor. Students must take at least 9 credits of MSE 690. Students must take at least 12 credit hours of MSE department courses. Students must take at least 2 cognate courses (a minimum of 4 credit hours).

Students must submit a master's thesis to an examining committee of three faculty members, two of which must be from MSE. This committee will include the research advisor and two other faculty selected by the advisor in consultation with the student and approved by the Graduate Committee Chair. The thesis may also be used as a document for the Ph.D. oral candidacy exam. The thesis must be defended orally before this committee and approved by a majority of the committee and the advisor. The oral defense may also serve as the Ph.D. oral exam at the committee's discretion. This thesis should contain a critical review of background information and relevant literature, a statement of objective, a results section, and a thorough scientific analysis of these results. It should have a degree of originality suitable for publication. In the event that the student is not satisfied with the results of his/her examination(s), an appeal for arbitration can be made in sequence to the graduate committee chair, the Department chair, the Rackham Graduate School or the College of Engineering Ombudsman. Graduate students who pass the Ph.D. qualifying exam but still want a Masters Degree must also satisfy the above requirements.

Ph.D. Programs

Ph.D. in Materials Science and Engineering

Advancement to candidacy in the MSE doctoral program is contingent on passing the written examination and the oral examination. A master's degree is not a prerequisite. Students must complete an additional 9 hours of formal coursework, above that required for the M.S.E. degree. Incoming students holding an M.S.E. degree (or equivalent) from another institution must complete an additional 18 hours of formal coursework to fulfill the residency and cognate requirements set forth by the Rackham Graduate School. In general, M.S. degrees from institutions outside the U.S. or Canada will be evaluated on an individual basis to determine if they meet the criteria for equivalency as set forth by the Graduate Committee of the MSE department. The criteria for such a decision will be based on the academic standards of the foreign institution, the academic performance of the student at the institution, and the fulfillment of course and research requirements similar to those required in the MSE department. Reports, a thesis and publications may be submitted to the Graduate Committee for consideration in reaching decisions in such cases.

The Department will furnish details of requirements upon request. Also, a pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School Office, 1004 Rackham Building, upon request.

Materials Science and Engineering Courses

MSE 220. Introduction to Materials and Manufacturing

Prerequisite: Chem 130 or Chem 210. I, II, iiia (4 credits)

Introduction to materials engineering and materials processing in manufacturing. The engineering properties of metals, polymers, semiconductors, ceramics, and composites are correlated with the internal structure of the materials and the service conditions.

MSE 242. Physics of Materials

Prerequisite: Physics 240 and preceded or accompanied by Math 216. II (4 credits)

Basic principles and applications of solid state physics. Mathematical and physical description of classical and quantum mechanics, crystallography and diffraction. Applications to solids, including band structure, bonding and physical properties.

MSE 250. Principles of Engineering Materials

Prerequisite: Chem 130 or Chem 210. I, II (4 credits)

A student can receive credit for only one: MSE 220 or MSE 250 Introductory course to engineering materials. Properties (mechanical, thermal and electrical) of metals, polymers, ceramics and electronic materials. Correlation of these properties with: (1) their internal structures (atomic, molecular, crystalline, micro- and macro-); (2) service conditions (mechanical, thermal, chemical, electrical, magnetic, and radiation); and (3) processing.

MSE 280. Materials Science and Engineering Undergraduate Research Opportunity

Prerequisite: Open only to 1st- or 2nd-year undergraduate students with permission of instructor. I, II, IIIa, IIIb, III (1 credit)

The UROP program enables students to work one-on-one or with a small group of students with faculty members conducting research. Students receive 1 credit per 3 hours of work per week. Students participating in the program are required to attend biweekly research peer group meetings, meet monthly with a peer advisor, and keep a research journal.

MSE 330. Thermodynamics of Materials

Prerequisites: Chem 130 or 210, Phys 140/141, Math 215, and MSE 220 or 250. I (4 credits)

The laws of thermodynamics and their consequences. Applications to solid and liquid materials. Mass and energy balances. Gas reactions. Phase diagrams. Ellingham, Pourbaix and stability diagrams. Defects in solids. Interfaces. Statistical thermodynamics.

MSE 335. Kinetics and Transport in Materials Engineering

Prerequisite: Math 215 and 216 and MSE 220 or 250. II (4 credits)

Application of basic principles of molecular transport and mass, energy, and momentum balance to the solution of heat, diffusion, and fluid flow problems relevant to materials processing. Introduction to radiative heat transfer. Empirical approaches to and dimensional analysis of complex transport problems including convection, turbulence, and non-Newtonian flow.

MSE 350. Principles of Engineering Materials II

Prerequisite: MSE 220 or MSE 250. I (4 credits)

Basic principles and fundamental tools of Materials Science & Engineering; including bonding, structure, microstructure, thermodynamics, and kinetics.

MSE 360. Materials Laboratory I

Prerequisite: accompanied or preceded by MSE 350. I (3 credits)

Laboratory experiences based on principles emphasized in Fundamentals of Materials Science including processing, properties, and structure with a focus on micro structural analysis and structure-property relationships. Continued as MSE 365.

MSE 365. Materials Laboratory II

Prerequisite: MSE 360 and preceded or accompanied by MSE 242. II (3 credits)

Laboratory experiences based on principles emphasized in Physics of Materials and Fundamentals of Materials. Processing, properties, and microstructure with a focus on electronic and magnetic phenomena.

MSE 400. Electronic, Magnetic and Optical Materials for Modern Device Technology

Prerequisites: MSE 242 and either MSE 220 or 250 or equivalents. I (3 credits)

Application of solid-state phenomena in engineering structures such as microelectronic, magnetic and optical devices. Review of quantum mechanical descriptions of crystalline solids. Microelectronic, magnetic and optical properties of devices, fabrication and process methods.

MSE 410 (BiomedE 410). Design and Applications of Biomaterials

Prerequisite: MSE 220 or 250 or permission of instructor. I (4 credits)

Biomaterials and their physiological interactions. Materials used in medicine/ dentistry: metals, ceramics, polymers, composites, resorbable smart, natural materials. Material response/degradation: mechanical breakdown, corrosion, dissolution, leaching, chemical degradation, wear. Host responses: foreign body reactions, inflammation, wound healing, carcinogenicity, immunogenicity, cytotoxicity, infection, local/systemic effects.

MSE 412 (ChemE 412) (MacroSE 412). Polymeric Materials

Prerequisites: MSE 220 or 250 and CHEM 210. I (3 credits)

The synthesis, characterization, microstructure, rheology, and processing of polymeric materials. Polymers in solution and in the liquid, liquid-crystalline, crystalline, and glassy states. Engineering and design properties, including viscoelasticity, yielding, and fracture. Forming and processing methods. Recycling and environmental issues.

MSE 414 (ChemE 414) (MacroSE 414) (Mfg 414). Applied Polymer Processing

Prerequisites: MSE 412 or equivalent. II (3 credits)

Theory and practice of polymer processing. Non-Newtonian flow, extrusion, injection molding, fiber, film, and rubber processing. Kinetics of and structural development during solidification. Physical characterization of microstructure and macroscopic properties. Component manufacturing and recycling issues, compounding and blending.

MSE 420. Mechanical Behavior of Materials
Prerequisite: ME 211, MSE 350. I (3 credits)
Macroscopic and microscopic aspects of deformation and fracture. Plasticity, general continuum approach. Microscopic hardening mechanisms. Rate and temperature dependent deformation. Deformation and fracture mechanism maps. Fracture mechanics. Fatigue behavior.
MSE 440. Ceramic Materials
Prerequisites: MSE 350. II (3 credits)
Chemistry, structure, processing, microstructure and property relationships and their applications in design and production of ceramic materials.
MSE 465. Structural and Chemical Characterization of Materials
Prerequisites: MSE 220 or 250, MSE 242, and MSE 360. II (3 credits)
Study of the basic structural and chemical characterization techniques that are commonly used in materials science and engineering. X-ray, electron and neutron diffraction, a wide range of spectroscopies, microscopies, and scanning probe methods will be covered. Lectures will be integrated with a laboratory where the techniques will be demonstrated and/or used by the student to study a material. Techniques will be presented in terms of the underlying physics and chemistry.
MSE 470. Physical Metallurgy
Prerequisite: MSE 350. II (3 credits)
Phase transformations and hardening mechanisms in metallic systems. Nucleation, diffusion-controlled growth, spinodal decomposition and martensitic reactions. Strengthening mechanisms based on two-phase microstructure thermal stability.
MSE 480. Materials and Engineering Design
Prerequisite: Senior Standing. II (3 credits)
Design concepts. Engineering economics. Various design criteria, processes, and process control. Materials substitution. Competitive design. Case histories. Professional and ethical considerations. Written and oral presentations of solutions to design problems.
MSE 485 (Mfg 458). Design Problems in Materials Science and Engineering
Prerequisite: MSE 480. I, II (1-4 credits) (to be arranged)
Design problem supervised by a faculty member. Individual or group work in a particular field of materials of particular interest to the student. The design problem is arranged at the beginning of each term by mutual agreement between the student and a faculty member. Written and oral reports are required.
MSE 489. Materials Processing Design
Prerequisites: MSE 330 and MSE 335. I (3 credits)
The design of production and refining systems for engineering materials. Design of problems for the extraction and refining of metals, production and processing of ceramics, polymeric materials, and electronic materials. Written and oral presentation of solutions to processing design problems.
MSE 490. Research Problems in Materials Science and Engineering
Prerequisite: not open to graduate students. I, II, III, IIIa, IIIb (to be arranged)
Individual or group work in a particular field or on a problem of special interest to the student. The program of work is arranged at the beginning of each term by mutual agreement between the student and a faculty member. Written and oral reports are required. Laboratory and conferences.
MSE 493. Special Topics in Materials Science and Engineering
Prerequisite: MSE 350. (to be arranged)
Selected topics of current interest for students entering industry.
MSE 500. Materials Physics and Chemistry
Prerequisite: Senior level or Graduate Standing. II (3 credits)
Physical properties of a wide range of materials, including crystalline and organic materials from the electronic and atomic point of view. The bonding and structure of materials will be placed in context of quantum mechanics and band theory; and the electrical, optical, thermal, mechanical, and magnetic properties will be emphasized.
MSE 501. Structure and Processing of Electrical Materials
Prerequisite: MSE 440 or EECS 314. (2 credits)
The role of chemistry, structure, and processing in determining the properties of electrical materials.
MSE 502. Materials Issues in Electronics
Prerequisites: MSE 242 and MSE 400 or equivalent. II (3 credits)
This course covers the key materials issues, including defects, diffusion, and oxidation relevant to the conversion of a material into an electronic device.
MSE 505. Materials Science of Thin Films
Prerequisites: MSE 242 and MSE 400 or equivalent. I (3 credits)
Thermodynamics and kinetics of film nucleation, growth, structure and stability for a single crystal, polycrystalline, and amorphous thin films.
MSE 510 (CHEM 511). Materials Chemistry
(3 credits)
This course presents concepts in materials chemistry. The main topics covered include structure and characterization, macroscopic properties, and synthesis and processing.
MSE 511 (ChemE 511) (MacroSE 511). Rheology of Polymeric Materials
Prerequisite: a course in fluid mechanics or permission from instructor. I (3 credits)
An introduction to the relationships between the chemical structure of polymer chains and their rheological behavior. The course will make frequent reference to synthesis, processing, characterization, and use of polymers for high technology applications.

MSE 512 (ChemE 512) (MacroSE 512). Polymer Physics
Prerequisite: Senior or Graduate Standing in engineering or physical science. II (3 credits)
Structure and properties of polymers as related to their composition, annealing and mechanical treatments. Topics include creep, stress relaxation, dynamic mechanical properties, viscoelasticity, transitions, fracture, impact response, dielectric properties, permeation, and morphology.

MSE 514 (MacroSE 514) (Mfg 514). Composite Materials
Prerequisite: MSE 350. I even years (3 credits)
Behavior, processing, and design of composite materials, especially fiber composites. Emphasis is on the chemical and physical processes currently employed and expected to guide the future development of the technology.

MSE 515 (MacroSE 515). Mechanical Behavior of Solid Polymeric Materials
Prerequisite: ME 211, MSE 412. II even years (3 credits)
The mechanical behavior of polymers from linear viscoelastic to yield and fracture are covered. Specific topics include dynamic-mechanical relaxations, creep, yielding, craz-ing, fatigue, and fracture mechanics. The materials include toughened plastics, polymer alloys and blends, and composite materials. Structured design with plastics is also considered.

MSE 516 (ME 516). Mechanics of Thin Films and Layered Materials
Prerequisite: ME 311 or Graduate Standing. I alternate years (3 credits)
Stresses and deformations in layered materials; energy-release rates and delamination; fracture mechanics of layered materials; spalling; interfacial fracture mechanics; mixed-mode fracture; buckling-driven delamination; cracking of thin films; effects of plasticity on fracture; stress-relaxation mechanisms in multi-layered materials; adhesion and fracture tests.

MSE 520. Advanced Mechanical Behavior
Prerequisite: Graduate Standing. II (3 credits)
Advanced studies of deformation and failure in materials. Macroscopic and microscopic aspects of deformation. Elasticity and plasticity theories and problems in deformation processing. Fracture mechanics and composite toughening mechanisms. Mechanisms of creep deformation.

MSE 523 (Mfg 582) (ME 582). Metal-Forming Plasticity
Prerequisite: ME 211. II (3 credits)
Elastic and plastic stress-strain relations; yield criteria and flow rules; analyses of various plastic forming operations. Effects of work hardening and friction, temperature, strain rate, and anisotropy.

MSE 525. Dislocations and Plastic Flow of Materials
Prerequisite: MSE 420 or Graduate Standing in engineering or physical science. II (3 credits)
Fundamentals of dislocation theory. Applications to the understanding of physical and mechanical behavior of materials. Dislocation bases for alloy design.

MSE 526. Micromechanisms of Strengthening and Flow
Prerequisite: MSE 420 or MSE 470. II (3 credits)
Micromechanisms responsible for strengthening and deformation in structural materials. Quantitative analyses of microscopic processes. Theories of work hardening, polycrystalline strengthening, dislocation-precipitate interactions, kinetics of slip and climb processes, diffusion-assisted flow, grain boundary sliding and migration processes, physical basis for constitutive equation.

MSE 532. Advanced Thermodynamics of Materials
Prerequisite: MSE 430 or equivalent. I (3 credits)
Classical and statistical thermochemistry with emphasis on topics important in materials science and engineering, including thermodynamics of solids, solution thermochemistry, heterogeneous equilibria of stable and metastable phases, multicomponent systems, coherent equilibria and strain effects interfaces and adsorption, polymer alloys and solutions.

MSE 535. Kinetics, Phase Transformations, and Transport
Prerequisite: MSE 430 or equivalent. II (3 credits)
Fundamentals of phase change, diffusion, heat transport, nucleation, and growth applied to solidification, ordering, spinodal decomposition, coarsening, reactions, massive transformations, diffusion-limited transformations and glass transitions.

MSE 542 (Mfg 542). Reactions in Ceramic Processes
Prerequisite: MSE 440 or graduate standing. I, II (3 credits)
Dissociation, sintering, vitrification, devitrification, and thermochemical reactions in ceramic processing.

MSE 543. Structures of Ceramic Compounds
Prerequisite: MSE 440 or graduate standing. (3 credits)
Structures and crystal chemistry of ceramic compounds.

MSE 544. Properties of Ceramic Compounds
Prerequisite: MSE 440 or graduate standing. (3 credits)
Consideration of mechanical, thermal, dielectric, ferroelectric, magnetic, and semiconducting properties of ceramic compounds.

MSE 550. Fundamentals of Materials Science and Engineering
Prerequisite: senior or graduate standing or permission of instructor. I (3 credits)
An advanced level survey of the fundamental principles underlying the structures, properties, processing, and uses of engineering materials.

MSE 554 (ChemE 554). Computational Methods in MSE and ChemE
Prerequisite: Senior level or Graduate Standing. I (3 credits)
Broad introduction to the methods of numerical problem solving in Materials Science and Chemical Engineering. Topics include numerical techniques, computer algorithms, and the formulation and use of computational approaches for the modeling and analysis of phenomena peculiar to these disciplines.

MSE 556. Molecular Simulation of Materials
Prerequisite: Senior level or graduate standing. I (3 credits)
Practical and theoretical consideration in the simulation of materials on the molecular level. Molecular dynamics and Monte Carlo techniques. Empirical interaction potentials for metals, ceramics, and polymers. Statistical mechanics and thermodynamics of simulated systems.

MSE 557 (ChemE 557). Computational Nanoscience of Soft Matter
Prerequisites: Differential equations course, and a statistical thermodynamics or statistical mechanics course. I (3 credits)
Provides an understanding of strategies, methods, capabilities, and limitations of computer simulation as it pertains to the modeling and simulation of soft materials at the nanoscale. The course consists of lectures and hands-on, interactive simulation labs using research codes and commercial codes. Ab initio, molecular dynamics, Monte Carlo and mesoscale methods.

MSE 560. Structure of Materials
Prerequisite: MSE 550. II (3 credits)
Atomic arrangements in crystalline and noncrystalline materials. Crystallography, kinematic and dynamical theories of diffraction, applications to x-rays, electrons and neutrons. Interpretation of diffraction patterns and intensity distributions, applications to scattering in perfect and imperfect crystals, and amorphous materials. Continuum description of structure emphasizing the tensor analysis of distortions in solids.

MSE 562. Electron Microscopy I
Prerequisite: MSE 460 II (4 credits)
An introduction to electron optics, vacuum techniques, and the operation of electron optical instruments. The theory and applications of transmission and scanning electron microscopy and electron microprobe analysis in the study of nonbiological materials.

MSE 574. High-Temperature Materials
Prerequisite: MSE 350. (3 credits)
Principles of behavior of materials at high temperatures. Microstructure-property relationships including phase stability and corrosion resistance to high temperature materials. Fracture and fatigue at elevated temperatures. Damage accumulation behavior and engineering applications of service life techniques.

MSE 577 (Mfg 577). Failure Analysis of Materials
Prerequisite: MSE 350. II (3 credits)
Analysis of failed structures due to tensile overload, creep, fatigue, stress corrosion, wear and abrasion, with extensive use of scanning electron microscope. Identification and role of processing defects in failure.

MSE 583 (BiomedE 583) (ChemE 583). Biocompatibility of Materials
Prerequisite: undergraduate course in biology and/or physiology; undergraduate course in biochemistry, organic chemistry, or molecular biology. II (2 credits)
This course describes the interactions between tissue and materials and the biologic/pathologic processes involved. In addition, specifications which govern biocompatibility testing, various strengths and weaknesses of a number of approaches to testing, and future directions are discussed.

MSE 585. Materials or Metallurgical Design Problem
Prerequisite: MSE 480. I (2 credits)
Engineering design and economic evaluation of a specific process and/or materials application. Original and individual work and excellence of reporting emphasized. Written and oral presentation of design required.

MSE 590. Materials Science and Engineering Research Survey
(1 credit)
Research activities and opportunities in the Materials Science and Engineering programs. Lecture by faculty and guest lecturers. Brief weekly reports.

MSE 621 (NERS 621). Nuclear Waste Forms
Prerequisites: NERS 531 (recommended). I even years (3 credits)
This interdisciplinary course will review the materials science of radioactive waste remediation and disposal strategies. The main focus will be on corrosion mechanisms, radiation effects, and the long-term durability of glasses and crystalline ceramics proposed for the immobilization and disposal of nuclear waste.

MSE 622 (Mfg 622) (NERS 622). Ion Beam Modification and Analysis of Materials
Prerequisite: NERS 421, NERS 521 or MSE 350 or permission of instructor. II alternate years (3 credits)
Ion-solid interactions, ion beam mixing, compositional changes, phase changes, micro-structural changes; alteration of physical and mechanical properties such as corrosion, wear, fatigue, hardness; ion beam analysis techniques such as RBS, NRA, PIXE, ion channeling, ion microprobe; accelerator system design and operation as it relates to implantation and analysis.

MSE 662. Electron Microscopy II
Prerequisite: MSE 562. II (3 credits)
Advanced methods in electron microscopy such as high resolution bright field and dark field imaging, micro and convergent beam diffraction, analysis of thin film specimens, and electron energy loss spectroscopy. Two lectures and one three-hour laboratory-discussion session per week.

MSE 690. Research Problems in Materials Science and Engineering
Prerequisite: I, II, III (to be arranged)
Laboratory and conferences. Individual or group work in a particular field or on a problem of special interest to the students. The program of work is arranged at the beginning of each term by mutual agreement between the student and a member of the faculty. Any problem in the field of materials and metallurgy may be selected. The student writes a final report on this project.

MSE 693. Special Topics in Materials Science and Engineering
(to be arranged)
MSE 751 (ChemE 751) (Chem 751) (MacroSE 751) (Physics 751). Special Topics in Macromolecular Science
Prerequisite: permission of instructor. (2 credits)
Advanced topics of current interest will be stressed. The specific topics will vary with the instructor.
MSE 890. Seminar in Materials Science and Engineering
(to be arranged)
Selected seminar topics in metallurgy, ceramics, polymers, or electronic materials.
MSE 990. Dissertation/Pre-Candidate
I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
MSE 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate I, II, III (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Department of Materials Science and Engineering Faculty

Materials Science and Engineering (Subject=MATSCIE)
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Professors

Peter F. Green, Ph.D.; *Chair, also Macromolecular Science and Engineering*
Rodney C. Ewing, Ph.D.; *Donald R. Peacor Collegiate Professor of Geological Sciences; also Chair, Geological Sciences; also Nuclear Engineering and Radiological Sciences.*
Frank E. Filisko, Ph.D.; P.E.; *also Macromolecular Science and Engineering*
Stephen R. Forrest, Ph.D.; *Vice President for Research; also Electrical Engineering and Computer Science; also Physics*
Amit K. Ghosh, Ph.D.
Sharon C. Glotzer, Ph.D.; *also Chemical Engineering*
John W. Halloran, Ph.D.; *Alfred Holmes White Collegiate Professor of Materials Science and Engineering*
J. Wayne Jones, Ph.D.; *Arthur F. Thurnau Professor*
John Kieffer, Ph.D.
Richard M. Laine, Ph.D.; *also Director, Macromolecular Science and Engineering*
Victor Li, Ph.D.; *also Civil and Environmental Engineering*
David C. Martin, Ph.D.; *also Biomedical Engineering.*
Jyotirmoy Mazumder, Ph.D.; D.I.C.; *Robert H. Lurie Professor of Engineering; also Mechanical Engineering*
Xiaoqing Pan, Ph.D.
Tresa M. Pollock, Ph.D.; *L.H. and F.E. Van Vlack Professor of Materials Science and Engineering*
Richard E. Robertson, Ph.D.; *also Macromolecular Science and Engineering*
Ann Marie Sastry, Ph.D.; *also Mechanical Engineering; also Biomedical Engineering*
Michael Thouless, Ph.D.; *also Mechanical Engineering*
Lumin Wang, Ph.D.; *also Nuclear Engineering and Radiological Sciences; also Research Scientist, Geological Sciences*
Gary S. Was, Sc.D.; *also Nuclear Engineering and Radiological Sciences*

Professors Emeritus

John C. Bilello, Ph.D.
Wilbur C. Bigelow, Ph.D.
Ronald Gibala, Ph.D.
William F. Hosford, Jr., Sc.D.
Edward E. Hucke, Sc.D.
Robert D. Pehlke, Sc.D., P.E.
Albert F. Yee, Ph.D.
Edwin Harold Young, M.S.E., P.E.; *also Chemical Engineering*

Associate Professors

Michael Atzmon, Ph.D.; *also Nuclear Engineering and Radiological Sciences*
Rachel S. Goldman, Ph.D.
Nicholas Kotov, Ph.D.; *also Chemical Engineering*
Joanna Mirecki-Millunchick, Ph.D.
Steven M. Yalisove, Ph.D.

Assistant Professors

Michael L. Falk, Ph.D.; *also Applied Physics*
Jinsang Kim, Ph.D.; *also Chemical Engineering; also Macromolecular Science and Engineering; also Biomedical Engineering*
Joerg Lahann, Ph.D.; *also Chemical Engineering; also Biomedical Engineering*
Max Shtein, Ph.D.
Katsuyo Thornton, Ph.D.
Anton Van der Ven, Ph.D.

Associate Research Scientist

John F. Mansfield

Assistant Research Scientist

Kai Sun

Lecturer

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Mechanical Engineering

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Fax: (734) 647-7303

The Department of Mechanical Engineering at the University of Michigan reflects the broad aspects of the mechanical engineering field. As exhibited by our internationally recognized leadership in traditional fields such as manufacturing and automotive, to new enabling technologies of micro- and nanotechnology, biomechanics and biomaterials, and environmentally friendly product design, mechanical engineers are well positioned for the research, design, development and manufacture of a diverse set of systems and products.

The Mechanical Engineering program provides students with an excellent foundation in the core technical competencies of the discipline: thermal and fluid sciences, solid mechanics and materials, and dynamics and control. Built upon these strengths is a very strong focus on application of these technical abilities through our design and manufacturing sequence. In addition, an array of technical electives is offered to enable students to tailor their mechanical engineering education to best suit their career goals.
There are numerous programs offered to enrich your education, such as dual-degrees (ME degree and a second degree from another Engineering Honors program), Sequential Graduate/Undergraduate Studies (SGUS), the Engineering Global Leadership Honors Program (EGL), study abroad, and independent study opportunities with ME faculty. Students interested in any of these programs should contact the Mechanical Engineering Academic Services Office.

Students who do well in their undergraduate program are encouraged to consider graduate work and may take some of their electives in preparation for graduate study.

Information and assistance regarding fellowships and assistantships for graduate study may be obtained in the Academic Services Office of the Department of Mechanical Engineering.

Facilities
The laboratories of the Department of Mechanical Engineering, located in the George Granger Brown Laboratories, Walter E. Lay Automotive Laboratory, and H. H. Dow buildings on the North Campus provide facilities for both instruction and research.

The George Granger Brown Laboratories Building contains thermodynamics, heat transfer, and fluid mechanics laboratories; holographic measurements laboratory; and thermal systems research. Also located in this building are the biomechanics laboratory, the manufacturing processes and integrated manufacturing laboratories, and the materials laboratories, which provide facilities for investigations in such areas as adaptive controls, welding, acoustic emission, brittle fracture, heat treating, plasticity, surface phenomena, and mechanical properties.

The Walter E. Lay Automotive Laboratory houses the mechanical analysis laboratory with a wide variety of electromechanical instrumentation and computers for the experimental analysis of dynamics of mechanical systems; the cavitation and multiphase flow laboratory for theoretical and experimental investigations into many aspects of such phenomena; the automatic controls laboratory for demonstrating and investigating principles and applications of control systems; the combustion laboratory with a gas chromatograph and an infrared spectrometer; and the facilities for automotive engineering, which include a number of well-instrumented test cells for reciprocating engines, a test cell for a small aircraft gas turbine, and a number of single cylinder engines, including optical engines.

The Integrated Manufacturing Systems Laboratory (IMSL) in the H.H. Dow Building is one of the premiere manufacturing research laboratories in the U.S., with facilities to support machining, computer aided manufacturing, and precision engineering.

An up-to-date description of all facilities and procedures can be found on the departmental webpage.

Accreditation
This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Mission
To prepare the graduates for diverse careers in both mechanical engineering and non-mechanical engineering fields.

Goals
To have students graduate with outstanding problem solving skills and a superb knowledge of mechanical engineering that allow them to continue their education throughout their careers and to become leaders in their fields.

Objectives
The mission and goal of the Mechanical Engineering program lead to three program educational objectives (PEOs):
Upon graduation, our students are

1. Prepared for professional practice in entry-level engineering positions or to enroll in further engineering degree programs through rigorous instruction in the engineering sciences and extensive laboratory and design experience.
2. Prepared for successful careers and leadership positions because of their integrated introduction to teamwork, communications, and problem-solving.
3. Prepared for a variety of careers resulting from the opportunity to deepen their technical understanding in a particular subject by a program of related technical electives or to obtain a broader education in engineering by a flexible choice of technical and free electives.

Outcomes
The outcomes we desire are that our graduates demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering to mechanical engineering problems.
- An ability to design and conduct experiments, as well as to analyze and interpret data.
- An ability to design thermal and mechanical systems, components, or processes to meet desired needs.
- An ability to function on multi-disciplinary teams.
- An ability to identify, formulate, and solve engineering problems.
- An understanding of professional and ethical responsibility.
- An ability to communicate effectively with written, oral, and visual means.
- The broad education necessary to understand the impact of engineering solutions in a global and societal context.
- A recognition of the need for and an ability to engage in life-long learning.
- A knowledge of contemporary issues.
- An ability to use modern engineering techniques, skills, and computing tools necessary for engineering practice.
- A familiarity with chemistry, calculus-based physics, and advanced mathematics.
- Familiarity with statistics and linear algebra.

Mechanical Engineering Undergraduate Education

Undergraduate Program Director
Professor Gregory M. Hulbert
2212 G.G. Brown Bldg.
Ann Arbor, MI 48109
Phone: (734) 763-4456

Undergraduate Student Advisor
Susan J. Gow
Academic Services Office
2206 G.G. Brown
2350 Hayward St.
Ann Arbor, MI 48109-2125
Phone: (734) 763-4276/Fax: (734) 647-7303

Degree Program
BSE in Mechanical Engineering

Sequential Graduate/Undergraduate Study (SGUS)
BSE in Mechanical Engineering /
MSE in Mechanical Engineering
Student Advisor:
Susan Gow
sgow@umich.edu
2206 G.G. Brown Bldg.
Phone: (734) 763-4276
Faculty Advisor: Professor TBD

The master's degree is rapidly becoming the leading technical level at which engineers practice their profession. The Sequential Graduate/Undergraduate Program (SGUS) in Mechanical Engineering affords students the opportunity to begin graduate studies during their Senior year. By double counting 9 credit hours, students can earn their Master of Science in Engineering degree with only 21 additional credits over two terms. This program is available only to students enrolled at the University of Michigan Ann Arbor campus in the College of Engineering.

Admission Process

During their junior year, students will work with the Undergraduate Program Advisor to fill out the Intent to Enroll Form for provisional admission into the Program. The purpose of the Intent to Enroll Form is to outline a preliminary course of study enabling the student to make appropriate course selections.

At the time of application into the SGUS Program, students must have a minimum 3.6 cumulative GPA. They must be within 6 credits of completing their undergraduate degree to enroll in the MSE Program (Fall or Winter Terms only). They must submit a completed Rackham Graduate School application, which includes the SGUS Intent to Enroll Form, 3 reference letters, a transcript, statement of purpose and an application fee. SGUS applicants are not required to take the Graduate Record Exam (GRE). Approval for enrollment in the MSE program is required from the Graduate Program Chair.

SGUS

Sequential Graduate Undergraduate Study.

Program Coordinator:
Nonna Hamilton
macromolecular@umich.edu
2541 Chemistry
930 N. University
Faculty Advisor: Professor

SGUS is an integrated program that facilitates the completion of a Master's Degree with two semesters of study beyond that required for the Bachelor's Degree. Macromolecular Science and Engineering presently offers the SGUS degree option in conjunction with the undergraduate departments of Biomedical Engineering, Mechanical Engineering, Chemistry, Chemical Engineering, Materials Science and Engineering, and Physics.

Course Requirements

SGUS students are allowed to satisfy some of the requirements for an M.S. degree while completing the requirements for the B.S. degree. A maximum of nine hours of credit can be double counted for both degrees.

Students may substitute any course that meets the requirements of both programs. In general, this will correspond to any senior level courses or above (courses numbered 400 or higher) taken in the undergraduate department.

Eligibility:

Students who are interested in the SGUS program can begin to follow the recommended curriculum for their particular area of study as early as their sophomore year. There are also seminar courses and a research symposium that a student can become involved in before they are officially in the program.

Students must have a GPA of 3.2 or higher and must have obtained

Senior standing (85+ hours) by the time of entry.

Application Requirements: Interested applicants should contact the Macromolecular Science and Engineering Coordinator for details.

BSE in Mechanical Engineering /
M.Eng in Automotive Engineering

Program Coordinator:
Henia Kamil
hek@umich.edu
273B Chrysler Center
Phone: (734) 763-1134
Program Advisor: Huei Peng

A sequential Graduate/Undergraduate Study Program (SGUS) is offered through the Automotive Engineering Program. This program leads to the Master of Engineering in Automotive (M. Eng. in Auto.) sequentially with a Bachelor of Science in Engineering (B.S.E.) through the Mechanical Engineering Department (MECHENGR).

The SGUS program follows the standard SGUS template approved by the College of Engineering. In addition, SGUS applicants must:

- Have completed 80 or more credits of course work with a 3.6 GPA or better.

BSE in Mechanical Engineering/M. Eng in Manufacturing

Program Coordinator:
Henia Kamil
hek@umich.edu
1542 H.H. Dow
Phone: (734) 764-3312
Faculty Advisor: S. Jack Hu

A sequential Graduate/Undergraduate Study program (SGUS) is offered through the Program in manufacturing (PIM). This program leads to the Master of Engineering in Manufacturing (M.Eng. in Mfg.) sequentially with a bachelor of Science in Engineering (BSE) through the Mechanical Engineering Department.

The SGUS program follows the standard SGUS template approved by the College of Engineering. In addition, SGUS applicants must:

- Have completed 80 or more credits of course work with a 3.6 GPA or better

BSE in Mechanical Engineering /
MS in Biomedical Engineering

Student Advisor:
Susan Bitzer
sbitzer@umich.edu
1111 Carl A. Gerstacker Bldg.
Phone: (734) 763-5290
Faculty Advisor: Professor David H. Kohn

This SGUS program is open to all undergraduate students from Mechanical Engineering who have achieved senior standing (85 credit hours or more) and have an overall cumulative GPA of 3.2 or higher. Please contact the Department of Biomedical Engineering for more complete program information.

Engineering Global Leadership (EGL)
Honors Program
The Engineering Global Leadership Program (EGL), is an exciting honors program for those students with strong GPAs who enjoy learning foreign languages, and studying other cultures. This honors program is designed to maximize and focus free electives, language, humanities, and social science courses around a region of economic importance to the US. In addition, EGL students are required to take business courses and complete a practical experience to place technical knowledge in an industrial context. This honors program is very rigorous (full class loads every semester and maintenance of a high GPA) but EGL students graduate with both a BSE and a Master's degree and tend to have higher starting salaries than other engineering undergrads. For more details please see page 60.

Sample Schedule

B.S.E. (Mechanical Engineering)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 216+	16	4	4	4	4	–	–	–	–
Engr 100, Intro to Engr+	4	4	–	–	–	–	–	–	–
Engr 101, Intro to Computers+	4	–	4	–	–	–	–	–	–
Chemistry 125/126 and 130 or Chemistry 210 and 211+[1]	5	5	–	–	–	–	–	–	–
Physics 140 with Lab 141; Physics 240 with Lab 241+[2]	10	–	5	5	–	–	–	–	–
Humanities and Social Sciences *(including one course in micro- or macro- economics)*	16	4	4	–	–	–	4	–	4
Advanced Mathematics (3 hrs.)[3]	3	–	–	–	–	3	–	–	–
Related Program Subjects (4 hrs.)									
EECS 314, Cct Analy and Electronics	4	–	–	–	–	–	–	4	–
Program Subjects (45 hrs.)									
ME 211, Intro to Solid Mechanics+	4	–	–	4	–	–	–	–	–
ME 235, Thermodynamics I+	3	–	–	–	3	–	–	–	–
ME 240, Intro to Dynamics and Vibrations+	4	–	–	–	4	–	–	–	–
ME 250, Design and Manufacturing I+	4	–	–	–	4	–	–	–	–
ME 320, Fluids I+	3	–	–	–	–	3	–	–	–
ME 335, Heat Transfer	3	–	–	–	–	–	3	–	–
ME 350, Design and Manufacturing II+	4	–	–	–	–	4	–	–	–
ME 360, Systems and Controls+	4	–	–	–	–	–	4	–	–
ME 382, Engineering Materials+	4	–	–	–	–	4	–	–	–
ME 395, Laboratory I+	4	–	–	–	–	–	4	–	–
ME 450, Design and Manufacturing III	4	–	–	–	–	–	–	–	4
ME 495, Laboratory II	4	–	–	–	–	–	–	4	–
Technical Electives (12 hrs.)[3]	12	–	–	–	–	–	–	6	6
Unrestricted Electives (9-12 hrs.)	9-12	–	–	3	–	3	–	3	–
Total	128	17	17	16	15	17	15	17	14

Candidates for the Bachelor of Science degree in Engineering (Mechanical Engineering) — B.S.E.(M.E.) — must complete the program listed above. This is an example schedule that will lead to graduation in eight terms.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

[3]Advanced Mathematics and Technical Electives: A list of approved courses is available in the Academic Services Office (ASO), 2206 GGB.

(+) "D+" rule: Students must earn a "C-" or better in prerequisite courses indicated by the (+) symbol; anything less must be repeated prior to taking a subsequent class for which this class is required.

"D-" rule: No grade less than "D" shall be earned in any course used for degree credit.

The Mechanical Engineering program offers several dual and joint degree programs.* A 3.0 cumulative and core grade point average is required for admission to one of these programs. As well, minors through LS&A (see page 63 of the CoE *Bulletin*), and a Concentration in Manufacturing are available. Look at the ME Web site or consult with staff in the ASO.

*There are dual degree programs with other Engineering Departments and Joint (combined) degrees with other Schools such as Music and LS&A.

Mechanical Engineering Graduate Education

Program Coordinator:
Cynthia Quann-White
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2350 Hayward
Ann Arbor, Michigan
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cynthiaq@umich.edu

Graduate Degrees

- Master of Science in Engineering (M.S.E.) in Mechanical Engineering
- Doctor of Philosophy (Ph.D.) in Mechanical Engineering

M.S.E. in Mechanical Engineering

The requirement for this degree is 30 credit hours of approved graduate course work. At least 18 hours must be taken in mechanical engineering, 6 hours in mathematics, and 6 cognate credits. Up to 6 credit hours of research or 9 credit hours of thesis can be taken as part of a 30-credit-hour requirement. Research can be done in an industrial environment ('practicum'). Details of course requirements and fields of specialization will be furnished by the department upon request.

Ph.D. in Mechanical Engineering

A doctoral committee is appointed for each applicant to supervise the investigative work of the student and election of graduate courses of instruction and passing the qualifying examination. Candidacy is achieved when the student demonstrates competence in his/her field of knowledge through completion of courses and passing the preliminary examination.

The doctoral degree is conferred after the student presents the result of their investigation in the form of a dissertation, and in recognition of marked ability and scholarship in a relatively broad field of knowledge.

The Department will furnish details of requirements upon request. Also, a pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School Office, 1004 Rackham Building, upon request.

Mechanical Engineering Courses

ME 211. Introduction to Solid Mechanics
Prerequisite: Physics 140, Math 116. I, II, IIIa (4 credits)
Statics: moment and force resultants, equilibrium. Mechanics of deformable bodies: stress/strain, classification of material behavior, generalized Hooke's law. Engineering applications: axial loads, torsion of circular rods and tubes, bending and shear stresses in beams, deflection of beams, combined stresses, stress and strain transformation. Four lecture classes per week.

ME 235. Thermodynamics I
Prerequisite: Chem 130, 125 or Chem 210, 211, and Math 116. I, II, IIIa (3 credits)
Introduction to engineering thermodynamics. First law, second law system and control volume analyses; properties and behavior of pure substances; application to thermodynamic systems operating in a steady state and transient processes. Heat transfer mechanisms. Typical power producing cycles and refrigerators. Ideal gas mixtures and moist air applications.

ME 240. Introduction to Dynamics and Vibrations
Prerequisite: Physics 140, preceded or accompanied by Math 216. I, II, IIIa (4 credits)
Vector description of force, position, velocity and acceleration in fixed and moving reference frames. Kinetics of particles, of assemblies of particles and of rigid bodies. Energy and momentum concepts. Euler's equations. Moment of inertia properties. The simple oscillator and its applications.

ME 250. Design and Manufacturing I
Prerequisite: Math 116, Eng 101 or equivalent. I, II (4 credits)
Basics of mechanical design: visual thinking, engineering drawing, and machine anatomy. Basics of manufacturing: processes, materials, and thermofluid aspects. Use of computers in various phases of design and manufacturing. Exposure to CAD systems and basic machine shop techniques. Design/manufacturing project. Three hours lecture and two hours laboratory.

ME 305. Introduction to Finite Elements in Mechanical Engineering
Prerequisite: ME 311. I, II (3 credits)
Rod element stiffness matrix. The assembly process. Solution techniques, gaussian elimination. Truss examples. Beam elements. Frame examples. Plate bending. Heat conduction. Triangular and quadrilateral elements. The Isoparametric formulation. Plane stress applications. The course is project oriented with a substantial design content. A commercial finite element package is used extensively.

ME 311. Strength of Materials
Prerequisite: ME 211, Math 216. I, II, IIIa (3 credits)
Energy methods; buckling of columns, including approximate methods; bending of beams of asymmetrical cross-section; shear center and torsion of thin-walled sections; membrane stresses in axisymmetric shells; elastic-plastic bending and torsion; axisymmetric bending of circular plates.

ME 320. Fluid Mechanics I
Prerequisite: ME 235, ME 240, and Math 216. I, II (3 credits)
Fluid statics; conservation of mass, momentum ,and energy in fixed and moving control volumes; steady and unsteady Bernoulli's equation; differential analysis of fluid flow; dimensional analysis and similitude; laminar and turbulent flow; boundary layers; lift and drag; introduction to commercial CFD packages; applications to mechanical, biological, environmental, and micro-fluidic systems.

ME 335. Heat Transfer
Prerequisite: ME 320. I, II (3 credits)
Heat transfer by conduction, convection, radiation; heat storage, energy conservation; steady-state/transient conduction heat transfer; thermal circuit modeling; multidimensional conduction; surface radiation properties, enclosure radiation exchange; surface convection/fluid streams over objects, nondimensional numbers, laminar, turbulent, thermobuoyant flow, boiling and condensation; heat exchangers; design of thermal systems, solvers for problem solving/ design.

ME 336. Thermodynamics II
Prerequisite: ME 235. I, II (3 credits)
Thermodynamic power and refrigeration systems; availability and evaluation of thermodynamic properties; general thermodynamic relations, equations of state, and compressibility factors; chemical reactions; combustion; gaseous dissociation; phase equilibrium. Design and optimization of thermal systems.

ME 350. Design and Manufacturing II
Prerequisite: ME 211, ME 240, ME 250, preceded or accompanied by ME 382. I, II (4 credits)
Principles of mechanical design; synthesis and selection of machine components. Design project. Three hours of lecture and one lab.

ME 360. Modeling, Analysis and Control of Dynamic Systems
Prerequisite: ME 240. I, II (4 credits)
Unified approach to abstracting real mechanical, fluid, and electrical systems into proper models in graphical and state equation form to meet engineering design and control system objectives. Introduction to system analysis (eigen values, time and frequency response) and linear feedback control. Synthesis and analysis by analytical and computer methods. Four lectures per week.

ME 382. Mechanical Behavior of Materials
Prerequisite: ME 211. I, II (4 credits)
Material microstructures, dislocations and defects; processing and mechanical properties of metals, polymers, and composites; heat treatment of metals; elastic, plastic, and viscoelastic behavior of materials, strain hardening; fracture, fracture mechanics, fatigue and multiaxis loading; creep and stress relaxation; materials-related design issues, materials selection, corrosion and environmental degradation of materials.

ME 395. Laboratory I

Prerequisite: Phys 240, Phys 241, ME 211, ME 235, and ME 240; preceded or accompanied by ME 320, and ME 382. I, II (4 credits)
Weekly lectures and experiments designed to introduce the student to the basics of experimentation, instrumentation, data collection and analysis, error analysis, and reporting. Topics will include fluid mechanics, thermodynamics, mechanics, materials, and dynamical systems. Emphasis is placed on report writing and team-building skills.

ME 400. Mechanical Engineering Analysis

Prerequisite: ME 211, ME 240, Math 216. I (3 credits)
Exact and approximate techniques for the analysis of problems in mechanical engineering including structures, vibrations, control systems, fluids, and design. Emphasis is on application

ME 401. (Mfg 402) Statistical Methods for Manufacturing Systems

Prerequisite: senior or graduate standing. II (3 credits)
Evolution of quality methods. Fundamentals of statistics. Process behavior over time. Concept of statistical process control (SPC). Design and interpretation of control charts. Process capability study. Tolerance. Measurement system analysis. Correlation. Regression analysis. Independent t-test and paired t-test. Design and analysis of two-level factorial experiments. Fractional factorial experiments. Response model building. Taguchi methods. Case studies.

ME 403. Instrumentation

Prerequisite: ME 395 or graduate standing. I (3 credits)
General considerations for selection and evaluation of measurement equipment, signal and data processing methods. Operation principles of sensors, e.g., for force, pressure, flow and temperature measurements. Uncertainty Analysis of complete measurement systems to allow appropriate selection and use of measurement instrumentation including digital signal processing.

ME 404. Coherent Optical Measurement Techniques

Prerequisite: senior or graduate standing. I (3 credits)
Modern optical techniques using lasers in measurements of mechanical phenomena. Introduction to the nature of laser light and Fourier optics; use of holography and laser speckle as measurement techniques; laser doppler velocimetry.

ME 406. Biomechanics for Engineering Students.

Prerequisites: ME 320 and 382. II (3 credits)
Fundamental properties of biological systems, followed by a quantitative, mechanical analysis. Topics include mechanics of the cytoskeleton, biological motor molecules, cell motility, muscle, tissue, and bio-fluid mechanics, blood rheology, bio-viscoelasticity, biological ceramics, animal mechanics and locomotion, biomimetics, and effects of scaling. Individual topics will be covered on a case by case study basis.

ME 412. Advanced Strength of Materials

Prerequisite: ME 311. II (3 credits)
Review of energy methods, Betti's reciprocal theorem; elastic, thermoelastic and elastoplastic analysis of axisymmetric thick cylinders and rotating discs; bending of rectangular and circular plates, including asymmetric problems; beams on elastic foundations; axisymmetric bending of cylindrical shells; torsion of prismatic bars.

ME 420. Fluid Mechanics II

Prerequisite: ME 320. II (3 credits)
Control volume and streamline analysis for steady and unsteady flows. Incompressible and compressible flow. Hydraulic systems. Design of components. Losses and efficiency. Applications to centrifugal and axial flow machinery, e.g., fans, pumps, and torque converters.

ME 424 (BME 424). Engineering Acoustics

Prerequisite: Math 216 or Physics 240. I (3 credits)
Vibrating systems; acoustic wave equation; plane and spherical waves in fluid media; reflection and transmission at interfaces; propagation in lossy media; radiation and reception of acoustic waves; pipes, cavities, and waveguides; resonators and filters; noise; selected topics in physiological, environmental and architectural acoustics.

ME 432. Combustion

Prerequisite: ME 336, preceded or accompanied by ME 320. II (3 credits)
Introduction to combustion processes; combustion thermodynamics, reaction kinetics and combustion transport. Chain reactions, ignition, quenching, and flammability limits, detonations, deflagrations, and flame stability. Introduction to turbulent premixed combustion. Applications in IC engines, furnaces, gas turbines, and rocket engines.

ME 437. Applied Energy Conversion

Prerequisites: ME 235 and Math 216. I (3 credits)
Quantitative treatment of energy resources, conversion processes, and energy economics. Consideration of fuel supplies, thermodynamics, environmental impact, capital and operating costs. Emphasis is placed on issues of climate change and the role of energy usage. In-depth analysis of automobiles to examine the potential of efficiency improvement and fuel change.

ME 438. Internal Combustion Engines

Prerequisite: preceded or accompanied by ME 336 or permission of instructor. I (4 credits)
Analytical approach to the engineering problem and performance analysis of internal combustion engines. Study of thermodynamics, combustion, heat transfer, friction and other factors affecting engine power, efficiency, and emissions. Design and operating characteristics of different types of engines. Computer assignments. Engine laboratories.

ME 440. Intermediate Dynamics and Vibrations

Prerequisite: ME 240. II (4 credits)
Newton/Euler and Lagrangian formulations for three-dimensional motion of particles and rigid bodies. Linear free and forced responses of one and two degree of freedom systems and simple continuous systems. Applications to engineering systems involving vibration isolation, rotating imbalance and vibration absorption.

ME 450. Design and Manufacturing III
Prerequisite: ME 350, ME 360, and ME 395. May not be taken concurrently with ME495. I, II (4 credits)
A mechanical engineering design project by which the student is exposed to the design process from concept through analysis to layout and report. Projects are proposed from the different areas of study within mechanical engineering and reflect the expertise of instructing faculty. Two hours of lecture and two laboratories.
ME 451 (Mfg 453). Properties of Advanced Materials for Design Engineers
Prerequisite: ME 382. II (3 credits)
Mechanical behavior and environmental degradation of polymeric-, metal-, and ceramic-matrix composites; manufacturability of advanced engineering materials; use of composite materials in novel engineering designs.
ME 452 (Mfg 452). Design for Manufacturability
Prerequisite: ME 350. II (3 credits)
Conceptual design. Design for economical production, Taguchi methods, design for assembly; case studies. Product design using advanced polymeric materials and composites; part consolidation, snap-fit assemblies; novel applications. Design projects.
ME 453. Electronic Circuits Laboratory-Self-Paced
Prerequisite: EECS 314. I, II, IIIa, IIIb (1-3 credits)
Students will design, build, and test useful electronic circuits and come to understand how most simple electronic circuits function. This will enable them to find resources to improve their circuit design skills. Topics include basic circuit design and assembly techniques; analog & digital circuits and embedded microcontrollers; data acquisition and electromechanical systems.
ME 454. (Mfg 454) Computer Aided Mechanical Design
Prerequisite: Eng 101, ME 360. II (3 credits)
Introduction to the use of the digital computer as a tool in engineering design and analysis of mechanical components and systems. Simulation of static, kinematic and dynamic behavior. Optimal synthesis and selection of elements. Discussion and use of associated numerical methods and application software. Individual projects.
ME 455. Analytical Product Design
Prerequisite: ME 350, ME 360, ME 395 for ME majors. PI for all others. I (3-4 credits)
Design of artifacts is addressed from a multidisciplinary perspective that includes engineering, art, psychology, marketing, and economics. Using a decision-making framework, emphasis is placed on quantitative methods. Building mathematical models and accounting for interdisciplinary interactions. Students work in team design projects from concept generation to prototyping and design verification. Four credit-hour election requires prototyping of project.
ME 456 (BiomedE 456). Tissue Mechanics
Prerequisite: ME 211, ME 240. II (3 credits)
Definition of biological tissue and orthopedic device mechanics including elastic, viscoelastic and non-linear elastic behavior. Emphasis on structure function relationships. Overview of tissue adaptation and the interaction between tissue mechanics and physiology.
ME 458. Automotive Engineering
Prerequisite: ME 350. I, II (3 credits)
Emphasizes systems approach to automotive design. Specific topics include automotive structures, suspension steering, brakes, and driveline. Basic vehicle dynamics in the performance and handling modes are discussed. A semester team-based design project is required.
ME 461. Automatic Control
Prerequisite: ME 360. I (3 credits)
Feedback control design and analysis for linear dynamic systems with emphasis on mechanical engineering applications; transient and frequency response; stability; system performance; control modes; state space techniques; digital control systems.
ME 471. Computational Heat Transfer
Prerequisite: ME 320. II (3 credits)
Enclosure and gas radiation. Parallel flow and boundary layer convection. Variable property and odd geometry conduction. Technological applications. Individual term projects. Use of elementary spectral, similarity, local similarity, local (finite) difference and global difference (finite element) solution techniques.
ME 476 (BiomedE 476). Biofluid Mechanics
Prerequisite: ME 320. II (4 credits)
This is an intermediate level fluid mechanics course which uses examples from biotechnology processes and physiologic applications including the cardiovascular, respiratory, ocular, renal, musculo-skeletal and gastrointestinal systems.
ME 481. Manufacturing Processes
Prerequisite: ME 382. I,(3 credits)
Modeling and quantitative analysis of manufacturing processes used in industry to manufacture mechanical systems: machining, deformation, welding assembly, surface treatment, and solidification. Process costs and limits; influence of processes on the final mechanical properties of the product. Reconfigurable manufacturing. Three recitations. *Undergraduate credit only.*
ME 482 (Mfg 492). Machining Processes
Prerequisite: II (3 credits)
Introduction to machining operations. Cutting tools and tool wear mechanisms. Cutting forces and mechanics of machining. Machining process simulation. Surface generation. Temperatures of the tool and workpiece. Machining dynamics. Non-traditional machining. Two hours lecture and one laboratory session.
ME 487 (Mfg 488). Welding
Prerequisite: ME 382. II (3 credits)
Study of the mechanism of surface bonding, welding metallurgy, effect of rate of heat input on resulting microstructures, residual stresses and distortion, economics and capabilities of the various processes.

ME 490. Experimental Research in Mechanical Engineering
Prerequisite: senior standing. I, II, IIIa, IIIb (3 credits)
Individual or group experimental or theoretical research in the area of mechanical engineering. A topic in mechanical engineering under the direction of a member of the department. The student will submit a final report. Two four-hour laboratories per week. For undergraduates only.

ME 491. Independent Study
Prerequisite: ME 490, permission of instructor; mandatory pass/fail. I, II, IIIa, IIIb (1-3 credits)
Individual or group experimental or theoretical research in the area of mechanical engineering. A topic in mechanical engineering under the direction of a member of the department. The student will submit a final report. Two four-hour laboratories per week. For undergraduates only.

ME 495. Laboratory II
Prerequisite: ME 360, ME 395, preceded or accompanied by ME 350. ME 450 not be taken concurrently. I, II (4 credits)
Weekly lectures and extended experimental projects designed to demonstrate experimental and analytical methods as applied to complex mechanical systems. Topics will include controls, heat transfer, fluid mechanics, thermodynamics, mechanics, materials, and dynamical systems. Emphasis on laboratory

ME 499. Special Topics in Mechanical Engineering
Prerequisite: permission of instructor. I, II, IIIa, IIIb (to be arranged)
Selected topics pertinent to mechanical engineering.

ME 501. Analytical Methods in Mechanics
Prerequisite: ME 211, ME 240, Math 216. II (3 credits)
An introduction to the notation and techniques of vectors, tensors, and matrices as they apply to mechanics. Emphasis is on physical motivation of definitions and operations, and on their application to problems in mechanics. Extensive use is made of examples from mechanics.

ME 502. Methods of Differential Equations in Mechanics
Prerequisite: Math 454. I (3 credits)
Applications of differential equation methods of particular use in mechanics. Boundary value and eigenvalue problems are particularly stressed for linear and nonlinear elasticity, analytical dynamics, vibration of structures, wave propagation, fluid mechanics, and other applied mechanic topics.

ME 503. Mathematical Methods in Applied Mechanics
Prerequisite: one 500-level course in mechanics. I (3 credits)
Matrix methods applied to the stiffness matrix, vibration analysis, and hydrodynamic stability. Solution of integral equations by collocation, variational methods, successive approximations; applications to elasticity, plates, slow viscous flow, and inviscid flow. Finite difference and finite increment methods; application to wave propagation, structural stability, plasticity, free-surface flows and wakes.

ME 504. Principles and Applications of Variational Methods
Prerequisite: ME 440. I (3 credits)
Fundamental processes of the calculus of variations; derivation of the Euler-Lagrange equations; proof of the fundamental lemma; applications of the direct method; Lagrange multipliers; "natural" boundary conditions; variable end points; Hamilton's canonical equation of motion; Hamilton-Jacobi equations. Descriptions of fields by variational principles. Applications to mechanics. Approximate methods.

ME 505. Finite Element Methods in Mechanical Engineering
Prerequisite: ME 501 (ME 311 or ME 320). I, II (3 credits)
Theoretical and computational aspects of finite element methods. Examples from areas of thermal diffusion, potential/irrotational flows, lubrication, structural mechanics, design of machine components, linear elasticity, and Navier-Stokes flows problems. Program development and modification are expected as well as learning the use of existing codes.

ME 506 (BiomedE 506). Computational Modeling of Biological Tissues
I, II (3 credits)
Biological tissues have multiple scales and can adapt to their physical environment. This course focuses on visualization and modeling of tissue physics and adaptation. Examples include electrical conductivity of heart muscle and mechanics of hard and soft tissues. Homogenization theory is used for multiple scale modeling.

ME 507. Approximate Methods in Mechanical Engineering
Prerequisite: senior standing. II (3 credits)
Orthogonal and non-orthogonal expansions. Matrix algebra and algebraic eigenvalue problems. Finite difference formulation and solution. Integral and variational approaches to finite element formulation. Solution by electronic calculator and digital computer. Application to conduction, convection, radiation heat transfer, and fluid and solid mechanics.

ME 508. Product Liability
Prerequisite: senior or graduate standing. I (3 credits)
Introduction and background to areas of law that affect engineering practice with main emphasis on product liability. Additional topics include torts, law and economics, engineering ethics and professional responsibility. The Socratic method of instruction is used in conjunction with relevant case law.

ME 509. Patents, Trademarks, Copyrights
Prerequisite: senior or graduate standing. II (3 credits)
The course surveys the area of intellectual property law for engineers. Topics include: 1) patents: requirements, statutory bars, infringement, remedies; 2) trademarks: registrability requirements, scope of rights, abandonment, remedies; 3) copyrights: requirements, scope of rights, fair use doctrine, remedies. Unfair competition and public access policy issues are also covered.

ME 511. Theory of Solid Continua
Prerequisite: ME 211, Math 450. I (3 credits)
The general theory of a continuous medium. Kinematics of large motions and deformations; stress tensors; conservation of mass, momentum and energy; constitutive equations for elasticity, viscoelasticity and plasticity; applications to simple boundary value problems.

ME 512 (CEE 509). Theory of Elasticity
Prerequisite: ME 311 or ME 412, or ME 511 or equivalent. II (3 credits)
Stress, strain and displacement, equilibrium and compatibility. Use of airy stress function in rectangular and polar coordinates, asymptotic fields at discontinuities, forces and dislocations, contact and crack problems, rotating and accelerating bodies. Galerkin and Papcovich-Neuber solutions, singular solutions, spherical harmonics. Thermoelasticity. Axisymmetric contact and crack problem. Axisymmetric torsion.

ME 513. Automotive Body Structures
Prerequisite: ME 311. II (3 credits)
Emphasis is on body concept for design using first order modeling of thin walled structural elements. Practical application of solid/structural mechanics is considered to design automotive bodies for global bending, torsion, vibration, crashworthiness, topology, material selection, packaging, and manufacturing constraints.

ME 514. Nonlinear Fracture Mechanics
Prerequisite: ME 412. II (3 credits)
Elements of solid mechanics, historical development of fracture mechanics, energy release rate of cracked solids, linear elastic fracture mechanics, and elastic-plastic fracture mechanics.

ME 515. Contact Mechanics
Prerequisite: ME 311 or ME 350. I alternate and odd years (3 credits)
Hertzian elastic contact; elastic-plastic behavior under repeated loading; shakedown. Friction; transmission of frictional tractions in rolling; fretting; normal and oblique impact. Dynamic loading. Surface durability in rolling. Surface roughness effects. Conduction of heat and electricity across interfaces. Thermal and thermoelastic effects in sliding and static contact.

ME 516. (MSE 516) Mechanics of Thin Films and Layered Materials
Prerequisite: ME 311 or graduate standing. I alternate years (3 credits)
Stresses and deformations in layered materials; energy-release rates and delamination; fracture mechanics of layered materials; spalling; interfacial fracture mechanics; mixed-mode fracture; buckling-driven delamination; cracking of thin films; effects of plasticity on fracture; stress-relaxation mechanisms in multi-layered materials; adhesion and fracture tests.

ME 517. Mechanics of Polymers I
Prerequisite: ME 511 or permission of instructor. II (3 credits)
Constitutive equation for linear small strain viscoelastic response; constant rate and sinusoidal responses; time and frequency dependent material properties; energy dissipation; structural applications including axial loading, bending, torsion; three dimensional response, thermo-viscoelasticity, correspondence principle, Laplace transform and numerical solution methods.

ME 518 (Mfg 518). Composite Materials: Mechanics, Manufacturing, and Design
Prerequisite: senior or graduate standing. II alternate years (3 credits)
Composite materials, including naturally occurring substances such as wood and bone, and engineered materials from concrete to carbon-fiber reinforced epoxies. Development of micromechanical models for a variety of constitutive laws. Link between processing and as-manufactured properties through coupled fluid and structural analyses.

ME 519. Theory of Plasticity I
Prerequisite: ME 511. II (3 credits)
Fundamentals of plasticity; stress-strain relations, yield criteria and the general behavior of metals and nonmetals beyond proportional limit in the light of experimental evidence. Various approximate theories with emphasis on the theory of plastic flow. Application to problems of bending, torsion, plane strain and plane stress, technological problems.

ME 520. Advanced Fluid Mechanics I
Prerequisite: ME 320. I (3 credits)
Fundamental concepts and methods of fluid mechanics; inviscid flow and Bernoulli theorems; potential flow and its application; Navier-Stokes equations and constitutive theory; exact solutions of the Navier-Stokes equations; boundary layer theory; integral momentum methods; introduction to turbulence.

ME 521. Advanced Fluid Mechanics II
Prerequisite: ME 520. II (3 credits)
Viscous flow fundamentals; vorticity dynamics; solution of the Navier-Stokes equations in their approximate forms; thin shear layers and free surface flows; hydrodynamic stability and transition to turbulence; fundamental concepts of turbulence; the turbulent boundary layer; introduction to turbulence modeling.

ME 523 (Aero 523). Computational Fluid Dynamics I
Prerequisite: Aero 325 or preceded or accompanied by ME 520. I (3 credits)
Physical and mathematical foundations of computational fluid mechanics with emphasis on applications. Solution methods for model equations and the Euler and the Navier-Stokes equations. The finite volume formulation of the equations. Classification of partial differential equations and solution techniques. Truncation errors, stability, conservation, and monotonicity. Computer projects and homework.

ME 524. Advanced Engineering Acoustics
Prerequisite: ME 424, (BME 424). II (3 credits)
Derivation of the acoustic wave equation and development of solution techniques. Transmission and reflection from solids, plates and impedance boundaries. Radiation and scattering from non-simple geometries. Green's functions; boundary element and finite element methods. Sound in ducts and enclosures. Introduction to structural-acoustic coupling. Automotive and other applications considered.

ME 527. Multiphase Flow
Prerequisite: ME 520. II (3 credits)
Selected topics in multiphase flow including nucleation and cavitation, dynamics of stationary and translating particles and bubbles, basic equations of homogeneous two-phase gas/liquid, gas/solid, and vapor/liquid flows, kinematics and acoustics of bubbly flows, instabilities and shock waves in bubbly flows, stratified, annular, and granular flow.
ME 530. Advanced Heat Transfer
Prerequisite: ME 320 or equivalent background in fluid mechanics and heat transfer. I (3 credits)
Advanced topics in conduction and convection including the presentation of several solution methods (semi-quantitative analysis, finite difference methods, superposition, separation of variables) and analysis of multi-mode heat transfer systems. Fundamentals of radiation heat transfer including; blackbody radiation, radiative properties, view factors, radiative exchange between ideal and non-ideal surfaces.
ME 531. Conduction Heat Transfer
Prerequisite: ME 335. I (3 credits)
Lumped, differential, and integral formulations of conduction. Product solutions in terms of orthogonal functions or approximate profiles. Periodic conduction, computational conduction: finite difference versus finite element. Technological applications.
ME 532. Convection Heat Transfer
Prerequisite: ME 335. II (3 credits)
Differential and integral formulations of convection. Parallel and nearly parallel laminar (boundary layer) flows. Similarity solutions. Periodic convection. Computational convection. Instability and turbulence. Kinetic and thermal scales and spectra. Flow prediction. Heat transfer prediction. Multiple scale dimensional analysis. Technological applications.
ME 533. Radiative Heat Transfer
Prerequisite: ME 335. I (3 credits)
Electromagnetic, optical and quantum aspects of radiative equilibrium. Enclosure radiation including spatial, specular, and spectral distributions. Gas radiation including boundary affected thin gas and thick gas approximations. Averaged and spectral properties. Technological applications.
ME 535. Thermodynamics III
Prerequisite: ME 336. II (3 credits)
Definitions and scope of thermodynamics; first and second laws. Maxwell's relations. Clapeyron relation, equation of state, thermodynamics of chemical reactions, availability.
ME 536. Phase Change Dynamics
Prerequisite: ME 336; ME 335. II (3 credits)
Heat and mass transfer and fluid dynamics of phase change and two-phase flow. Basic laws, mechanisms and correlations for evaporation, boiling, condensation and pressure drop. Applications in areas of power plant boilers and condensers (conventional and nuclear), internal combustion engines (carburetion, diesel injection), freeze drying, bubble lift pumps, humidification/ dehumidification.
ME 537. Advanced Combustion
Prerequisite: ME 432 or equivalent. II (3 credits)
Advanced treatment of fundamental combustion processes. Conservation equations for reacting gas mixtures. The structure of one-dimensional diffusion and premixed flames; introduction to activation energy asymptotics. Two-dimensional Burke-Schumann flames and boundary layer combustion. Flame instabilities and flame stretch; turbulent combustion.
ME 538. Advanced Internal Combustion Engines
Prerequisite: ME 438. II (3 credits)
Modern analytical approach to the design and performance analysis of advanced internal combustion engines. Study of thermodynamics, fluid flow, combustion, heat transfer, and other factors affecting the design, operating and emissions characteristics of different engine types. Application of course techniques to engine research projects.
ME 539. Heat Transfer in Porous Media
Prerequisite: ME 335 or equivalent. II (3 credits)
Heat transfer and fluid flow in porous media are examined based on conservation principles. Local volume-averaging is developed and applied to conduction, convection, mass transfer, radiation, and two-phase flows. Several single-phase and two-phase problems are examined.
ME 540 (Aero 540). Intermediate Dynamics
Prerequisite: ME 240. I or II (3 credits)
Newton/Euler and Lagrangian formulations for three dimensional motion of particles and rigid bodies. Principles of dynamics applied to various rigid-body and multi-body dynamics problems that arise in aerospace and mechanical engineering.
ME 541. Mechanical Vibrations
Prerequisite: ME 440. I (3 credits)
Time and frequency domain mathematical techniques for linear system vibrations. Equations of motion of discrete non-conservative systems. Vibration of multi-degree-of-freedom systems. Small oscillation theory. Free vibration eigenvalue problem. Undamped system response. Viscously damped systems. Vibration of continuous systems. Modes of vibration of bars, beams, membranes, plates.
ME 542. Vehicle Dynamics
Prerequisite: ME 440. II (3 credits)
Dynamics of the motor vehicle. Static and dynamic properties of the pneumatic tire. Mechanical models of single and double-track vehicles enabling prediction of their response to control forces/moments and external disturbances. Directional response and stability in small disturbance maneuvers. The closed-loop driving process. Behavior of the motor vehicle in large perturbation maneuvers. Ride phenomena treated as a random process.

ME 543. Analytical and Computational Dynamics I
Prerequisite: ME 440. I (3 credits)
Modern analytical rigid body dynamics equation formulation and computational solution techniques applied to mechanical multibody systems. Kinematics of motion generalized coordinates and speeds, analytical and computational determination of inertia properties, generalized forces, Gibb's function, Routhian, Kanes's equations, Hamilton's principle, Lagrange's equations holonomic and nonholonomic constraints, constraint processing, computational simulation.
ME 551 (Mfg 560). Mechanisms Design
Prerequisite: ME 350. II (3 credits)
Basic concepts. Type synthesis - creative design of mechanisms; graph theory. Precision-point Burmester theory for dimensional synthesis of linkages. Applications. Cam and follower system synthesis. Joint force analysis and dynamic analysis formulations. Analytical synthesis of programmable and compliant mechanisms. Use of software for synthesis and analysis. Design projects.
ME 552 (Mfg 552). Electromechanical System Design
Prerequisite: EECS 314 or equivalent. II (3 credits)
Design of electromechanical systems with emphasis placed on the integration of mechanical and electrical principles. Topics include: electromechanical device design: generators/alternators, electrical motors, measurement/sensing devices; digital control: microprocessors, AD/DA converters, data transmission and acquisition; electromechanical system design: mixed domain modeling, real time control and mechatronic systems.
ME 553 (Mfg 553). Microelectromechanical Systems
Prerequisite: senior or graduate standing. II alternate years (3 credits)
Basic integrated circuit (IC) manufacturing processes; electronics devices fundamentals; microelectromechanical systems fabrications including surface micromachining, bulk micromachining, LIGA and others. Introduction to micro-actuators and microsensors such as micromotors, grippers, accelerometers and pressure sensors. Mechanical and electrical issues in micromachining. IC CAD tools to design microelectromechanical structures using MCNC MUMPs service. Design projects.
ME 554 (Mfg 554). Computer Aided Design Methods
Prerequisite: ME 454. (Mfg 454) or ME 501. I (3 credits)
Generalized mathematical modeling of engineering systems, methods of solution and simulation languages. Analysis methods in design; load, deformation, stress and finite element considerations; nonlinear programming. Computational geometry; definition and generation of curves and surfaces. Computer graphics; transformations; clipping and windowing; graphics systems; data structures; command languages; display processors.
ME 555 (Mfg 555). Design Optimization
Prerequisite: Math 451 and Math 217 or equivalent. II (3 credits)
Mathematical modeling of engineering design problems for optimization. Boundedness and monotonicity analysis of models. Differential optimization theory and selected numerical algorithms for continuous nonlinear models. Emphasis on the interaction between proper modeling and computation. Students propose design term projects from various disciplines and apply course methodology to optimize designs.
ME 558 (Mfg 558). Discrete Design Optimization
Prerequisite: senior or graduate standing. I alternate years (3 credits)
Fundamentals of discrete optimization for engineering design problems. Mathematical modeling of engineering design problems as discrete optimization problems, integer programming, dynamic programming, graph search algorithms, and introduction to NP completeness. A term project emphasizes applications to realistic engineering design problems.
ME 559 (Mfg 559). Smart Materials and Structures
Prerequisite: EECS 314 or equivalent. I alternate years (3 credits)
This course will cover theoretical aspects of smart materials, sensors and actuator technologies. It will also cover design, modeling and manufacturing issues involved in integrating smart materials and components with control capabilities to engineering smart structures.
ME 560 (Mfg 562). Modeling Dynamic Systems
Prerequisite: ME 360. II (3 credits)
A unified approach to the modeling, analysis and simulation of energetic dynamic systems. Emphasis on analytical and graphical descriptions of state-determined systems using Bond Graph language. Analysis using interactive computer simulation programs. Applications to the control and design of dynamic systems such as robots, machine tools and artificial limbs.
ME 561 (EECS 561). Design of Digital Control Systems
Prerequisite: EECS 460 or ME 461. I, II (3 credits)
Sampling and data reconstruction. Z-transforms and state variable descriptions of discrete-time systems. Modeling and identification. Analysis and design using root locus, frequency response, and state space techniques. Linear quadratic optimal control and state estimation. Quantization and other nonlinearities.
ME 562. Dynamic Behavior of Thermal-Fluid Processes
Prerequisite: ME 335. II alternate years (3 credits)
Principles of transport processes and automatic control. Techniques for dynamic analysis; dynamic behavior of lumped- and distributed-parameter systems, nonlinear systems, and time-varying systems; measurement of response; plant dynamics. Experimental demonstration for dynamic behavior and feedback control of several thermal and fluid systems.
ME 563 (IOE 565) (Mfg 561). Time Series Modeling, Analysis, Forecasting
Prerequisite: IOE 366 or ME 401. I (3 credits)
Time series modeling, analysis, forecasting, and control, identifying parametric time series, autovariance, spectra, Green's function, trend and seasonality. Examples from manufacturing, quality control, ergonomics, inventory, and management.

ME 564 (Aero 550) (EECS 560). Linear Systems Theory
Prerequisite: graduate standing. I (4 credits)
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability.

ME 567 (EECS 567) (Mfg 567). Introduction to Robotics: Theory and Practice
Prerequisite: EECS 281. II (3 credits)
Introduction to robots considered as electro-mechanical computational systems performing work on the physical world. Data structures representing kinematics and dynamics of rigid body motions and forces and controllers for achieving them. Emphasis on building and programming real robotic systems and on representing the work they are to perform.

ME 568. Vehicle Control Systems
Prerequisite: ME 461 or equivalent. I (3 credits)
Design and analysis of vehicle control systems such as cruise control, traction control, active suspensions and advanced vehicle control systems for Intelligent Vehicle-Highway Systems (IVHS). Human factor considerations such as driver interfaces. This course may be used as part of the IVHS certification program.

ME 569. Control of Advanced Powertrain Systems
Prerequisite: ME 360; preceded or accompanied by ME 461. II (3 credits)
Will cover essential aspects of electronic engine control for spark ignition (gasoline) and compression ignition (diesel) engines followed by recent control developments for direct injection, camless actuation, active boosting technologies, hybrid-electric, and fuel cell power generation. Will review system identification, averaging, feedforward, feedback, multivariable (multiple SISO and MIMO), estimation, dynamic programming, and optimal control techniques.

ME 572 (Mfg 580). Rheology and Fracture
Prerequisite: ME 382. I (3 credits)
Mechanisms of deformation, cohesion, and fracture of matter. Unified approach to the atomic-scale origins of plastic, viscous, viscoelastic, elastic, and anelastic behavior. The influences of time and temperature on behavior. Stress field of edge and screw dislocations, dislocation interactions, and cross slip. Ductile, creep, brittle, and fatigue failure mechanisms.

ME 573 (Mfg 581). Friction and Wear
Prerequisite: background in materials and mechanics desirable. II (3 credits)
The nature of solid surfaces, contact between solid surfaces, rolling friction, sliding friction, and surface heating due to sliding; wear and other types of surface attrition are considered with reference to practical combinations of sliding materials, effect of absorbed gases, surface contaminants and other lubricants on friction, adhesion, and wear; tire and brake performance.

ME 576 (Mfg 556). Fatigue in Mechanical Design
Prerequisite: 382 or equivalent. I (3 credits)
A broad treatment of stress, strain, and strength with reference to engineering design and analysis. Major emphasis is placed on the analytical and experimental determination of stresses in relationship to the fatigue strength properties of machine and structural components. Also considered are deflection, post-yield behavior, residual stresses, temperature and corrosion effects.

ME 577 (Mfg 557). Materials in Manufacturing and Design
Prerequisite: senior or graduate standing. I (3 credits)
Material selection on the basis of cost, strength, formability and machinability. Advanced strength analysis of heat-treated and cold-formed parts including axial, bending, shear and cyclic deformation. Correlations of functional specifications and process capabilities. Problems in redesign for productability and reliability.

ME 581 (Mfg 574). Global Product Development
Prerequisite: graduate standing. I (3 credits)
A project-based course in which each (global) student team comprising students from three universities will be responsible for development of a product for the global market. Teams will use collaboration technology tools extensively. Several case studies on global product developement will be presented and follow-up lectures will focus on the issues highlighted.

ME 582 (Mfg 582) (MSE 523). Metal-Forming Plasticity
Prerequisite: ME 211. II (3 credits)
Elastic and plastic stress-strain relations; yield criteria and flow rules; analyses of various plastic forming operations. Effects of hardening and friction, temperature, strain rate, and anisotropy.

ME 583 (IOE 583) (Mfg 583). Scientific Basis for Reconfigurable Manufacturing
Prerequisite: graduate standing or permission of instructor. II alternate years (3 credits)
Principles of reconfigurable manufacturing systems (RMS). Students will be introduced to fundamental theories applicable to RMS synthesis and analysis. Concepts of customization, integrability, modularity, diagnosability, and convertibility. Reconfiguration design theory, life-cycle economics, open-architecture principles, controller configuration, system reliability, multi-sensor monitoring, and stream of variations. Term projects.

ME 584 (Mfg 584). Control of Machining Systems
Prerequisite: ME 461 or equivalent. II (3 credits)
Advanced control and sensing methodologies for machining processes: milling, turning, drilling, grinding and laser cutting: machine tool structure; CNC programming; drive components; trajectory interpolators; selection of control parameters; software compensation and adaptive control. The design process of a comprehensive machining system. (Two-hour lecture and two-hour lab per week.)

ME 585 (Mfg 585). Machining Dynamics and Mechanics
Prerequisite: graduate standing or permission of instructor. I even years (3 credits)
Dynamic cutting process models and process stability issues. Advanced cutting process mechanics and modeling including cutting process damping, thermal energy and cutting temperature, and wear evolution. Single and multi-DOF stability analysis techniques, stability margins and stability charts. Modeling approximations for industrial applications.
ME 586 (Mfg 591). Laser Materials Processing
Prerequisite: senior or graduate standing. I (3 credits)
Application of lasers in materials processing and manufacturing. Laser principles and optics. Fundamental concepts of laser/material interaction. Laser welding, cutting, surface modification, forming, and rapid prototyping. Modeling of processes, microstructure and mechanical properties of processed materials. Transport phenomena. Process monitoring.
ME 587 (Mfg 587). Reconfigurable Manufacturing for Market Responsiveness
Prerequisite: one 500-level MFG, DES or BUS class. II (3 credits)
Product-process-business relationships. Manufacturing paradigms and the market. Product design for customization. Paradoxial products. Mass-production model. Mass-customization principles. Reconfigurable manufacturing systems-design and principles. Reconfigurable machine tools. Impact of system configurations on productivity, quality, scalability, and convertibility. IT for market responsiveness. Business models. Reconfigurable enterprises. Introduction to financial planning and business plans.
ME 588 (IOE 588) (Mfg 588). Assembly Modeling for Design and Manufacturing
Prerequisites: ME 481 and ME 401 or equivalent. I alternate years (3 credits)
Assembly on product and process. Assembly representation. Assembly sequence. Datum flow chain. Geometric Dimensioning and Tolerancing. Tolerance analysis. Tolerance synthesis. Robust design. Fixturing. Joint design and joining methods. Stream of variation. Auto body assembly case studies.
ME 589. Ecological Sustainability in Design and Manufacturing.
Prerequisite: senior or graduate standing. I (3 credits)
A scientific basis for understanding and reducing the environmental impact of engineering design and manufacturing decisions from a life cycle perspective. Environmental impact principles: air/water pollution, ozone depletion, global warming, resource sustainability. Life cycle assessment and environmentally conscious manufacturing of metals, plastics, and electronics products. Systems design metrics, disassembly, remanufacturing, recycling, policy considerations. Case studies include: sustainable mobility, alternative energy sources, tooling and machining, refrigeration, electronics remanufacturing.
ME 590. Study or Research in Selected Mechanical Engineering Topics
Prerequisite: graduate standing; permission of the instructor who will guide the work; mandatory satisfactory/unsatisfactory. I, II, III, IIIa, IIIb (3 credits)
Individual or group study, design, or laboratory research in a field of interest to the student. Topics may be chosen from any of the areas of mechanical engineering. The student will submit a report on the project and give an oral presentation to a panel of faculty members at the close of the term.
ME 595. Master's Thesis Proposal
Prerequisite: graduate standing in Mechanical Engineering. I, II, III, IIIa, IIIb (3 credits); Not for credit until 6 hrs of ME 695 is satisfactorily completed.
A course devoted to literature search, analysis, design of experiments, and other related matters prior to completion of a master's degree thesis. A thesis proposal clearly delineating the proposed research and including the above items is required at the conclusion of the course.
ME 599. Special Topics in Mechanical Engineering
Prerequisite: permission of instructor I, II, IIIa, IIIb (to be arranged)
Selected topics pertinent to mechanical engineering.
ME 605. Advanced Finite Element Methods in Mechanics
Prerequisite: ME 505 or CEE 510, (NA 512). I (3 credits)
Recent developments in finite element methods; mixed, hybrid, mixed-hybrid, reduced integration penalty, singular, boundary integral elements. Emphasis on the methodology for developing elements by using calculus of variations. Applications selected from various branches of solid and fluid mechanics.
ME 617. Mechanics of Polymers II
Prerequisite: ME 511, ME 517, (MacroSE 517), or permission of instructor. II alternate years (3 credits)
Selected advanced topics in the mechanics of polymeric solids and fluids, including nonlinear elasticity, nonlinear viscoelastic solids, viscoplasticity in amorphous and crystalline polymer solids, constitutive models and associated flow properties for polymer fluids, temperature dependence and solidification, applications.
ME 619. Theory of Plasticity II
Prerequisite: ME 519. II (3 credits)
Plastic theory for materials with isotropic hardening, kinematic hardening, and time dependence. Theories based on crystal slip; variational theorems; range of validity of total deformation theories. Theory of generalized stresses applied to circular plates; behavior at finite deflection; limit analysis of shells. Plane stress, plane strain, and axial symmetry. Plastic response to impact loads. Minimum weight design.
ME 622. Inviscid Fluids
Prerequisite: ME 520. II (3 credits)
Vorticity theorems of Helmholtz and Kelvin. Potential Flow; the complex potential; flow around bodies. Conformal mapping and free streamline theory. Rotational flow; Stability, Kelvin-Helmholtz and Rayleigh-Taylor instabilities. Motion of point vortices and vortex regions. Chaotic vortex motions. Vortex filaments and vortex sheets.

ME 623. Hydrodynamic Stability
Prerequisite: ME 520. I (3 credits)
An introduction to the theory of hydrodynamic stability with applications to stability of thermal flows, rotating and curved flows, wallbounded and free shear flows. Development of the asymptotic theory of the Orr-Sommerfeld equation. Review of the fundamental concepts and current work in nonlinear theory of hydrodynamic stability.

ME 624. Turbulent Flow
Prerequisite: ME 520. II (3 credits)
Fundamentals of turbulent flows; the basic equations and the characteristic scales, statistical description of turbulence. Review of experimental results on the statistics and structure of turbulent flows. Methods for calculation of turbulent flows; the problem of closure, semi-empirical, phenomenological and analytical theories of turbulence, large-eddy and direct simulations of turbulence.

ME 625. Nonhomogeneous Fluids
Prerequisite: ME 520. I, II (3 credits)
Motion of fluids of variable density and entropy in gravitational field, including the phenomenon of blocking and selective withdrawal; waves of small finite amplitudes, including waves in the lee of mountains; stability of stratified flows; flow of Nonhomogeneous fluids in porous media. Analogy with rotating fluids.

ME 626. Perturbation Methods for Fluids
Prerequisite: ME 520. II (3 credits)
Application of asymptotic methods to fluid mechanics, with special emphasis on the method of matched expansions. Regular perturbation solutions; suppression of secular terms; method of multiple scales; boundary layer and low Reynolds number flows by inner and outer expansions; phenomena in rotating flows. Applications to computational fluid mechanics.

ME 627 (NA 627). Wave Motion in Fluids
Prerequisite: ME 520 or NA 520 or equivalent. I (3 credits)
Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to a moving body; Korteweg de Vries equation; conoidal and solitary waves in water; wave reflection and diffraction; shallow-water waves by the method of characteristics; statistical approach and spectral analysis; wave generation.

ME 631. Statistical Thermodynamics
Prerequisite: ME 230 or ME 336. II (3 credits)
Introduction to statistical methods for evaluating thermodynamic and transport properties. Elements of quantum mechanics, statistical mechanics, and kinetic theory, as applied to engineering thermodynamics.

ME 635. Thermodynamics IV
Prerequisite: ME 535. II (3 credits)
Discussion of thermodynamic systems including surface phenomena, external fields, and relativistic effects. Study of complex equilibrium calculations including effect of heterogeneous reactions and real substance behavior. Introduction to the thermo-dynamics of irreversible processes with applications to heat and mass transfer, relaxation phenomena and chemical reactions.

ME 641. Advanced Vibrations of Structures
Prerequisite: ME 541. II (3 credits)
Energy formulation for nonconservative gyroscopic systems. Spectral methods for free and forced vibrations. Eigenvalue and boundary value problems. Non self-adjoint systems. Variational methods of approximation: Bubnov-Galerkin. Perturbation theory for the eigenvalue problem. Dynamics of rotating systems. Dynamics of constrained dynamical systems.

ME 643. Analytical and Computational Dynamics II
Prerequisite: ME 543. II alternate years (3 credits)
Kinematical and dynamical equation formulation for rigid and flexible mechanical multi-body systems undergoing large overall motion and small elastic deformation. Energy principles, higher and lower pair joint parameterizations, space and dense equation formulation and solution techniques, numerical integration, generalized impulse and momentum, collisions, and computational elastodynamics. Course project.

ME 645. Wave Propagation in Elastic Solids
Prerequisite: ME 541. II alternate years (3 credits)
Elastodynamic equations, isotropic and anisotropic materials; vector/scalar potentials, reflection and transmission at interfaces, mode conversion, surface waves, Rayleigh-Lamb equation. Green's tensor; variational, Galerkin and Hamilton's equations. Kirchhoff-Love and Reissner-Mindlin kinematic hypotheses for beam, plate and shell theories. Fourier and Laplace transform, modal and state-vector solution techniques.

ME 646 (BiomedE 646). Mechanics of Human Movement
Prerequisite: ME 540, (Aero 540) or ME 543, or equivalent. II alternate years (3 credits)
Dynamics of muscle and tendon, models of muscle contraction. Kinematics and dynamics of the human body, methods for generating equations of motion. Mechanics of proprioceptors and other sensors. Analysis of human movement, including gait, running, and balance. Computer simulations and discussion of experimental measurement techniques.

ME 648. Nonlinear Oscillations and Stability of Mechanical Systems
Prerequisite: ME 541. II (3 credits)
Large amplitude mechanical vibrations; phase-plane analysis and stability; global stability, theorems of Liapunov and Chetayev; asymptotic and perturbation methods of Lindstedt-Poincare, multiple scales, Krylov-Bogoliubov-Mitropolsky; external excitation, primary and secondary resonances; parametric excitation, Mathieu/Hill equations, Floquet theory; multi-degree of freedom systems and modal interaction.

ME 649 (Aero 615) (CEE 617). Random Vibrations
Prerequisite: Math 425 or equivalent, CEE 513 or ME 541, or Aero 543 or equivalent. II alternate years (3 credits)
Introduction to concepts of random vibration with applications in civil, mechanical, and aerospace engineering. Topics include: characterization of random processes and random fields, calculus of random processes, applications of random vibrations to linear dynamical systems, brief discussion on applications to nonlinear dynamical systems.

ME 661. Adaptive Control Systems
Prerequisite: ME 561. I (3 credits)
Introduction to control of systems with undetermined or time varying parameters. Theory and application of self-tuning and model reference adaptive control for continuous and discrete-time deterministic systems. Model based methods for estimation and control, stability of nonlinear systems, adaptation laws, and design and application of adaptive control systems.

ME 662 (Aero 672) (EECS 662). Advanced Nonlinear Control
Prerequisite: EECS 562 or ME 548. I (3 credits)
Geometric and algebraic approaches to the analysis and design of nonlinear control systems. Nonlinear controllability and observability, feedback stabilization and linearization, asymptotic observers, tracking problems, trajectory generation, zero dynamics and inverse systems, singular perturbations, and vibrational control.

ME 663. Estimation of Stochastic Signals and Systems
Prerequisite: ME 563 or IOE 565 or Mfg. 561 equivalent. I alternate years (3 credits)
Estimation and prediction methods for vector stochastic signals and systems. Topics include characteristics of stochastic signals and systems; principles of estimation theory; linear regression models; description of signals and systems within a time series frame-work; prediction, prediction-error, and correlation-type estimation methods; recursive estimation methods; asymptotic properties; model validation.

ME 672. Turbulent Transport of Momentum, Heat and Mass
Prerequisite: ME 532. I (3 credits)
Introduction to laminar flow stability. Statistical and phenomenological theories of turbulence. Turbulent transport of momentum, heat and mass in steady and unsteady internal, boundary layer, and free flows. Skin friction, heat and mass transfer coefficients. Discussion of experimental results.

ME 695. Master's Thesis Research
Prerequisite: ME 595; mandatory satisfactory/unsatisfactory. I, II, IIIa, IIIb (3 credits)
Student must elect 2 terms of 3 hrs/term. No credit without ME 595. Student is required to present a seminar at the conclusion of the second election as well as prepare a written thesis.

ME 699. Advanced Special Topics in Mechanical Engineering
Prerequisite: permission of instructor. I, II, IIIa, IIIb (to be arranged)
Advanced selected topics pertinent to mechanical engineering.

ME 790. Mechanical Sciences Seminar
Prerequisite: candidate status in the mechanical sciences. I (1 credit)
Every Ph.D. student in the field of mechanical sciences is asked to present a one-hour seminar about his/her research, and lead a one-hour follow-up discussion. Active participation in the discussions that follow all presentations is also required for a grade. In addition, each student will participate as a panelist in a panel discussion of the future trends in his/her field. Graded S-U.

ME 990. Dissertation/Pre-Candidate
I, II, III (1-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

ME 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, III (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Mechanical Engineering Faculty

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Dragan Djurdjanovic
Wenkao Hou
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Naval Architecture and Marine Engineering

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More than 70 percent of our planet is covered by water. Engineering for the marine environment covers the design and production of all types of systems to operate successfully in this often harsh and demanding environment. In addition to traditional naval architecture and marine engineering, instruction is offered in offshore engineering, coastal engineering, and marine environmental engineering. Recent graduates are active in design and research related to offshore oil and gas exploration and production platforms. Others are involved in overcoming water-borne pollution transport in the Great Lakes and the oceans, and coastal erosion predictions, as well as the design of traditional ships, submersibles, high-speed vessels and recreational craft. A number of our alumni have leading roles in the design of America's Cup racing yachts.
Since the design of modern marine systems encompasses many engineering fields, graduates of this department are called upon to handle diverse professional responsibilities; therefore, the program includes study in the fundamentals of the physical sciences and mathematics as well as a broad range of engineering aspects that constitute design for the marine environment. To provide the appropriate educational breadth, it is also desirable that as many courses in the humanities and social sciences be elected as can be accommodated. It is recognized that the undergraduate program cannot, in the time available, treat all important aspects of engineering for the marine environment that may be desired by the student; therefore, graduate work is encouraged.

Ship and offshore platform analysis and design require knowledge of hull geometry, vessel arrangements, hydrostatic stability, structures, resistance, propulsion, maneuvering, and seakeeping. Other areas of concern are the economic aspects of design and operation, production, model testing, propeller and control theory, vibration problems, and piping and electrical system analysis and design.

The undergraduate degree program is arranged to give the student a broad engineering mechanics education by requiring basic courses in the areas of structural mechanics, hydrodynamics, marine power systems, and marine dynamics. These courses cover engineering fundamentals and their application to the design and construction of marine vehicles and systems. Courses in marine structures deal with the design and analysis of marine vehicles and platforms including static strength, fatigue, dynamic response, safety, and production. Resistance, maneuvering, and seakeeping characteristics of bodies in the marine environment are the subject matter for courses in marine hydrodynamics. Marine power systems involve all the mechanical systems on a marine vehicle with particular emphasis on the selection and arrangement of the main propulsion system. In marine dynamics, the student studies the vibrations of marine structures and engines and the rigid body responses of the vessel to wind and waves. Through the use of technical and free electives, students may decide to focus their education in areas such as:

- Marine Structures
- Ship Production and Management
- Sailing Yachts
- High Speed Craft
- Marine Power Systems

An integration of the material covered in earlier courses takes place in the two-semester, final design sequence. In the first course of this sequence, the student works on a class design project using state-of-the-art computer-aided design tools. In the second semester, the students form design teams and work on projects of their choosing. Recent final design projects included a Volvo 70 Around the World racing yacht, a ferry, a drillship, a mini–cruise ship, a trimaran ferry, a landing ship dock, and a mega yacht.

The department works closely with the marine industry and is able to assist graduates in obtaining positions in the field. The department is in constant touch with the country's marine design offices, shipyards, ship operators, government agencies, and other organizations concerned with ocean development. A summer internship program allows students to work in the marine field and receive academic credit. Academic credit is earned by successful completion of a job-related project; the final written report is formally presented to faculty and students the following semester.

Students who meet the academic requirements of both departments may earn an additional B.S.E. degree in another engineering program, or in combined programs with other engineering departments. The combined programs allow substantial substitution of courses required in one regular program for those required in the other, and typically can be completed in one extra term.

Facilities
The Marine Hydrodynamics Laboratories (MHL) are part of the Department of Naval Architecture and Marine Engineering, and are located on the first floor of West Hall on Central Campus. They consist of a physical modeling basin, a 110 x 6.7 x 3.2 meter towing tank, a low turbulence, free surface water channel, a 35-meter-long gravity-capillary wind wave facility, a 35-meter-long gravity circulating water channel, a specialized circulating water channel for drag reduction investigations, and the Ocean Engineering Laboratory. In addition, there are complete support facilities, including a woodworking shop, a machine shop, a welding fabrication area, several assembly areas, and an electronics shop (see: http://www.engin.umich.edu/dept/name/facilities/mhl/mhl.html). In addition to research in all areas of the marine environment, the MHL is also used in several group courses and for individual directed studies. MHL also hires students on a part-time basis to help with ongoing research.

The department provides the Undergraduate Marine Design Laboratory (UMDL) to support student design work in sophomore through senior classes. Teams of seniors work in this laboratory to develop and present their final design projects. The laboratory contains 15 team work areas, each with a Windows workstation, small drawing layout table, and work desk. This laboratory also contains major Michigan-developed and industrial ship design software needed in the design activities. The laboratory also supports digitizing, scanning, and printing needs. The department's Ocean Engineering Laboratory (OEL) is involved in full-scale field measurements such as beach erosion, thermal fronts and pollution transport on the Great Lakes, predicting the response of engineering structures in the coastal zone, and active remote sensing of the ocean surface from satellites and aircraft. In addition, the OEL is the home of the University's underwater Remote Operated Vehicles for Education and Research (M-ROVER and Mini-ROVER). M-ROVER and Mini-ROVER are used for submerged vehicle/ dynamics studies in the undergraduate curriculum and for exploration and research of the Great Lakes and the oceans. The OEL also operates the University's coastal survey vessel S/V Blue Traveler. This vessel is outfitted with precise navigation and acoustic survey gear to provide detailed maps and searches of underwater regions.

The Virtual Reality Laboratory (VRL) is a leading university facility that investigates the use of immersive display technologies in a variety of applications, especially in virtual prototyping of marine and other designs and in the simulation of manufacturing processes. The VRL is equipped with state-of-the-art graphics computers as well as with Head Mounted Display devices, BOOM devices, data gloves, motion sensors and other related technologies.

The department also houses the Computational Marine Mechanics Laboratory and the Fluid Physics and Air-Sea Interaction Facility. The Computational Marine Mechanics Laboratory (CMML) supports research and education in computational marine mechanics, computational fluid dynamics (CFD), computational methods in structural acoustics, and computational methods in fluid/structure interaction (among other areas). The laboratory utilizes two state-of-the-art supercomputers, and nine workstations. In the Fluid Physics and Air-Sea Interaction Facility, high-speed imaging, particle imaging and particle-tracking velocimetry, and flow visualization techniques are employed to better understand fluid control in microgravity environments. Research in this facility investigates flow physics associated with oscillating thin disks and similarly shaped bodies used in offshore structures, e.g., tension-leg platforms and spar buoys. The facility contains a glass-walled wave basin, a computer-controlled precision wavemaker, specially designed capacitance-type wave probes, and an intensified high-speed video system with attendant Argon-ion laser.

Accreditation
This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Department of Naval Architecture and Engineering

Mission
To be a world leader in the education of naval architects, marine and ocean engineers in the application of engineering principles in the marine environment by:

- Providing the leading bachelor's program in naval architecture and marine engineering, with emphasis on the design, manufacture, and management of marine vehicles, structures, and systems;
- Providing the leading graduate education and research program in engineering for the marine environment; one which spans a broad range of inquiry;
- Providing leadership and service to the state, national and international marine community.

Goals

- To recruit, educate, and support excellent, diverse students and prepare them for a life-long career of engineering leadership in the marine related industries, government service, and academia.
- To have the leading undergraduate program in the world in Naval Architecture and Marine Engineering; one which provides a rigorous and effective preparation for a life-long career of engineering leadership.

Objectives

- Prepare engineers for professional practice in the design and manufacture of vehicles to operate in the marine environment. Primary emphasis is on the scientific, engineering, and design aspects of ships, small boats, and craft, and also submersibles, platforms, and other marine systems. The program also emphasizes the ability to work effectively in teams and culminates with a major team design experience.
- Prepare students for professional practice in the marine industries, for further graduate study, and for life-long learning.
- To serve the people of Michigan and the world through preeminence in creating, communicating, preserving and applying knowledge, art, and academic values, and in developing leaders and citizens who will challenge the present and enrich the future.

Outcomes

The outcomes we desire are that graduates of the Naval Architecture and Marine Engineering Program demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering within naval architecture and marine engineering;
- An ability to formulate engineering problems and develop practical solutions;
- An ability to design products and processes applicable to naval architecture and marine engineering;
- An ability to design, conduct, analyze, and interpret the results of engineering experiments;
- An ability to work effectively in diverse teams and provide leadership to teams and organizations;
- An ability for effective oral, graphic, and written communication;
- A broad education necessary to understand the impact of engineering decisions in a global/societal/economic/environmental context;
- An understanding of professional and ethical responsibility;
- A recognition of the need for and an ability to engage in life-long learning;
- A broad education necessary to contribute effectively beyond their professional careers;
- A sense of responsibility to make a contribution to society;
- An ability to apply probability and statistical methods to naval architecture and marine engineering problems;
- An ability to apply basic knowledge in fluid mechanics, dynamics, structural mechanics, material properties, hydrostatics, stochastic mechanics, and energy/propulsion systems in the context of marine vehicles, and/or ocean structures;
- A familiarity and experience with instrumentation appropriate to naval architecture and marine engineering including experiment design, data collection, data analysis, and formal laboratory report writing;
- An understanding of the organization, methods and techniques of marine system manufacture and the use of concurrent marine design;
- An understanding of and experience in marine system conceptual and preliminary design using industrial capability design software, including a team design experience with formal written and oral presentation.

Naval Architecture and Marine Engineering Undergraduate Education

Program Advisor
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Degree Programs

The undergraduate degree program is arranged to give the student a broad engineering mechanics education by requiring basic courses in the areas of structural mechanics, hydrodynamics, marine power systems, and marine dynamics. These courses cover engineering fundamentals and their application to the design and construction of marine vehicles and systems. Courses in marine structures deal with the design and analysis of marine vehicles and platforms including static strength, fatigue, dynamic response, safety, and production. Resistance, maneuvering, and seakeeping characteristics of bodies in the marine environment are the subject matter for courses in marine hydrodynamics. Marine power systems involve all the mechanical systems on a marine vehicle with particular emphasis on the selection and arrangement of the main propulsion system. In marine dynamics, the student studies the vibrations of marine structures and engines and the rigid body responses of the vessel to the wind and waves.

Combined Degrees

For students with special interests, dual degree programs leading to two bachelor's degrees are available. Favorite second degree areas of concentration among Naval Architecture and Marine Engineering students are Aerospace Engineering and Mechanical Engineering. Combined degrees with other departments can also be arranged. As early as possible, students interested in such dual degree programs should consult with the program advisors in both programs to work out optimum combinations of courses.

Sequential Graduate/Undergraduate Education (SGUS)
BSE/MSE in Naval Architecture and Marine Engineering
BSE/MEng in Concurrent Marine Design

This program permits outstanding Naval Architecture and Marine Engineering students to receive the BSE and MSE (or the BSE and MEng) degrees after completing a minimum of 149 credit hours. The student benefits from the continuity of study, and the inefficiencies of transferring from an undergraduate to a graduate program are eliminated. The program allows students with a 3.2 or better GPA, to apply early in the first semester of their senior year (once 85 credit hours have been completed), for a Sequential Graduate/Undergraduate program, which allows them to double count up to 9 credits of technical or free electives. In consultation with their advisor, students select technical electives that will be relevant to the master's program of study. Students are admitted using the normal department graduate admission process, with the admission standards required for expected successful completion of the program. Recommendation from the Undergraduate Program Advisor is required. Please contact the Naval Architecture and Marine Engineering department for more complete program information.

Sample Schedule
B.S.E. (Naval Architecture and Marine Engineering)

	Credit Hours	Terms 1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	–	–	–	–
Engr 100, Intro to Engr	4	4	–	–	–	–	–	–	–
Engr 101, Intro to Computers	4	–	4	–	–	–	–	–	–
Chemistry 125/126 and 130 or Chemistry 210/211[1]	5	5	–	–	–	–	–	–	–
Physics 140 with Lab 141 and Physics 240 with Lab 241 [2]	10	–	5	5	–	–	–	–	–
Humanities and Social Sciences	16	4	4	–	–	–	–	4	4
Related Technical Core Subjects (11 hrs.)									
ME 211, Intro to Solid Mechanics	4	–	–	4	–	–	–	–	–
ME 240, Intro to Dynamics	4	–	–	–	4	–	–	–	–
ME 235, Thermodynamics I	3	–	–	–	3	–	–	–	–
Program Subjects (44 hrs.)									
NA 270, Marine Design	4	–	–	4	–	–	–	–	–
NA 260, Marine Systems Manufacturing	3	–	–	–	3	–	–	–	–
NA 310, Marine Structures I	4	–	–	–	–	4	–	–	–
NA 320, Marine Hydrodynamics I	4	–	–	–	–	4	–	–	–
NA 321, Marine Hydrodynamics II	4	–	–	–	–	–	4	–	–
NA 331, Marine Engineering I	3	–	–	–	–	3	–	–	–
NA 332, Marine Electrical Engineering	3	–	–	–	–	–	3	–	–
NA 340, Marine Dynamics I	4	–	–	–	–	–	4	–	–
NA 387, Probability and Statistics for Marine Engineers	3	–	–	–	–	–	3	–	–
NA 470, Foundations of Ship Design	4	–	–	–	–	–	–	4	–
NA 475, Marine Design Team Project	4	–	–	–	–	–	–	–	4
NA 491, Marine Engr Laboratory	4	–	–	–	–	–	–	4	–
Technical Electives (7-8 hrs.)	7-8	–	–	–	–	–	–	4	4
Choose two from the following list. At least one must come from the first four on the list:									
NA 410, Marine Structures II									
NA 420, Environmental Ocean Dynamics									
NA 431, Marine Engineering II									
NA 440, Marine Dynamics II									
NA 401, Small Craft Design									
NA 403, Sailing Craft Design Principles									
NA 416, Theory of Plates and Shells									
NA 455, Nearshore Environmental Dynamics									
NA 562, Marine Systems Production Strategy Operations Management									
Advanced Mathematics: Math 450, Math 454, or Math 471									
Unrestricted Electives (10-13)	10-13	–	–	–	2	3	2	–	3
Total	**128**	**17**	**17**	**17**	**16**	**14**	**16**	**16**	**15**

Candidates for the Bachelor of Science degree in Engineering (Naval Architecture and Marine Engineering)—B.S.E. (Nav. Arch. & Marine E.)—must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE.

Department of Naval Architecture and Marine Engineering

In the fourth year, students are required to select two four-credit technical electives from a prescribed list. These electives allow students to focus their education in specific areas. Example focus areas and possible courses are as follows:

Marine Structures: NA 410 and NA 440
High Speed Craft Design: NA 401 and NA 431 or NA 440
Marine Power Systems: NA 431 and NA 401 or NA 410
Marine Manufacturing: NA 410 and NA 562
Sailing Yachts: NA 403 and NA 410, NA 431, or NA 440

These and other combinations of free and technical electives should be selected in consultation with the Undergraduate Program Advisor. Students are strongly encouraged to review the possible options prior to their senior year.

Naval Architecture and Marine Engineering Graduate Education

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Graduate Degrees

- Master of Science (M.S.) in Naval Architecture and Marine Engineering
- Master of Science in Engineering (M.S.E.) in Naval Architecture and Marine Engineering
- Joint Master of Science in Engineering (M.S.E.)/Master of Business Administration (M.B.A.) in Naval Architecture and Marine Engineering
- Master of Engineering (M.Eng.) in Concurrent Marine Design
- Professional Degrees: Naval Architect (N.A.) and Marine Engineer (M.E.)
- Doctor of Philosophy (Ph.D.) in Naval Architecture and Marine Engineering

Masters Programs

M.S. and M.S.E. in Naval Architecture and Marine Engineering

The applicant should have a bachelor's degree in a mechanics-oriented engineering discipline, such as naval architecture and marine engineering, aerospace, mechanical, applied mechanics, or civil engineering. Applicants with bachelor's degrees in other engineering disciplines, mathematics, or physics may have to take additional courses beyond the 30-credit-hour minimum.

A minimum of 30 credit hours is required for the degree, of which at least 18 hours are Naval Architecture and Marine Engineering Department credits. A student is required to take NA 500, plus at least two of five core courses. Half of the program must consist of 500-level (or higher) courses. Three or more hours must be in graduate-level mathematics courses. Two courses of a minimum of 2 credit hours each must be taken outside the department. One of these cognate courses may be a graduate level mathematics course.

The student is free to set up his/her own program of course work that meets the above requirements. The two primary areas of graduate study and research are marine mechanics and marine systems design. In each of these broad areas of focus there are a number of sub-areas of specialization possible through the choice of electives. Examples of such areas are hydrodynamics, structures, coastal processes, marine systems design, concurrent marine design, marine structures, marine systems management and offshore engineering.

Joint M.S.E./M.B.A. in Naval Architecture and Marine Engineering

The Department of Naval Architecture and Marine Engineering and the School of Business Administration offer a joint degree program for qualified persons to pursue concurrent work in business administration and naval architecture and marine engineering studies leading to the M.B.A. and M.S.E. degrees. The program is arranged so that all requirements for both degrees can be completed in two years of enrollment, depending on undergraduate NAME background and the specialty area of the NAME master's program. The degrees are awarded simultaneously.

The program can begin with studies in either school. However, because of the sequential nature of the core courses in the M.B.A. program, most students will find it advantageous to start with year one in the Business School. During the remainder of the program, courses might be taken in both schools. Students who wish to begin in NAME should consult a counselor in the Business School to formulate an appropriate plan of study. Students admitted to this joint program must satisfy the following degree requirements:

- Roughly 30 credit hours M.B.A. core
- Roughly 15 elective hours in business administration
- MBA communication requirement
- 18 hours of graduate-level NAME courses, including NA 500 and any two of NA 510, NA 520, NA 540, NA 570, and NA 580.
- 3 or more credit hours of mathematics
- Up to 9 hours acceptable to the NAME program advisor, some of which could be part of the business electives.
- Interested students must file separate applications and be admitted to both schools.

M.Eng. in Concurrent Marine Design

The M.Eng. in Concurrent Marine Design is a professionally-oriented graduate degree program designed to meet the needs of the marine industry. It focuses on providing entry- and mid-level marine professionals with knowledge and practical experience dealing with the product development for marine vehicles, structures, and systems for both performance and production. The integrating philosophy for this degree is that of concurrent engineering—the simultaneous consideration of the design of both the product and the production methods considering the full life-cycle costs and operation of the product.

World competitiveness demands that performance and production are considered concurrently with the goal of an associated reduction in the design/build time. This approach requires the integrating support of a product model-based computer environment with simulation of both product and process performance. This degree program deals with the linkages within early marine design among life-cycle economics, performance, and manufacturing processes.

A prerequisite for this program of study is the equivalent of a Bachelor of Science in Engineering degree in naval architecture and marine engineering, naval architecture, mechanical engineering, civil engineering, aerospace engineering, or an equivalent field. Relevant marine industrial experience totaling at least two years is preferred. Significant internship and co-op assignments will be considered as a substitute. Prerequisite courses are Foundations of Ship Design (NA 470) and Probability and Statistics for Marine Engineers (NA 387), or their equivalents.

The degree requires 30 credit hours of graduate courses beyond the prerequisites, of which 24 must be graded (not pass/fail), 15 must be at the 500-level and above, and 15 of the 24 graded credits must be in engineering courses. The minimum grade point average for graduation is 5.0/9.0 ("B" average).
In addition to the prerequisite courses, each student is required to meet the following course distribution requirements:

- At least twelve (12) credits of naval architecture courses including: Marine Systems Production Business Strategy and Operations Management (NA 562), Advanced Marine Design (NA 570), and Reliability and Safety of Marine Systems (NA 582).
- At least six (6) credits from a list of advanced engineering courses in related fields.
- At least 6 credits of relevant, non-engineering courses; however, one may be Optimization, Market Forecasts and Management of Marine Systems (NA 580).
- Six (6) credits of industrial-based Concurrent Marine Design Team Project (NA 579).

The above requirements are intended to provide the student with the educational background demanded by an engineering design environment capable of integrating basic engineering principles with consideration of manufacturing and life-cycle costs. The program helps prepare the student for participation and leadership in cross-functional design teams involved in marine systems product development.

Professional Degrees: Naval Architect (N.A.) or Marine Engineer (M.E.)

The professional degree programs require a minimum of 30 credit hours of work beyond the master's level, or its equivalent, taken at the University of Michigan with an average grade of "B" or better. A minimum of 20 credits must be in formal course work. Requirements for the professional degree include:

- At least 24 credits beyond the master of science in engineering degree requirements in the area of the program.
- Of the 24 credits in the program, at least six (6) credits devoted to a professional degree thesis involving a research, design, or development study. In general, the thesis project is intended to provide results which are immediately and directly applicable to design practice in naval architecture or marine engineering in the context of concurrent marine design. The thesis project must include a prospectus presentation and a written report. A committee of faculty members will supervise the work, evaluate the report, and conduct a final oral examination of the work.
- At least three (3) graduate-level courses in cognate fields other than mathematics.
- At least nine (9) credits in mathematics beyond the bachelor of science in engineering mathematics requirement of the department.
- Successful completion of a comprehensive 3-hour, open-book, written examination is required. This normally takes place near the end of the course work. It emphasizes the application of engineering science in practice, and the student should demonstrate maturity in formulating and solving problems at the level of advanced engineering practice. The professional degree comprehensive examination, owing to its different level and emphasis, may not be substituted for part I of the Ph.D. preliminary qualifying examination.

Ph.D. Programs

Doctor of Philosophy (Ph.D.) in Naval Architecture and Marine Engineering

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must conduct an independent investigation in a subdivision of the selected field, and must present the results of the investigation in the form of a dissertation.

A student becomes a pre-candidate for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. Candidacy is achieved when the student demonstrates competence in her/his broad field of knowledge through the completion of course work, passing comprehensive exams, and successful presentation of a Ph.D. prospectus.

There is no general course requirement for the doctorate. However, during the course of a student's graduate study, nine (9) credit hours of math and 50 total classroom credit hours are expected as a minimum. The comprehensive exam consists of a Part I written exam covering general mechanics, and a Part II oral exam and prospectus presentation describing the proposed Ph.D. dissertation. A special doctoral committee is appointed for each applicant to supervise the work of the student both in election of courses and in the preparation of the dissertation.

A pamphlet describing the general procedure leading to the doctorate is available from the Rackham Graduate School upon request.

Naval Architecture and Engineering Courses

NA 102 (NS 201). Introduction to Ship Systems
Prerequisite: none. II (3 credits) (Not open for credit to students in NAME.)
Types, structures, and purposes of ships. Ship compartmentation, propulsion systems, auxiliary power systems, interior communications, and ship control. Elements of ship design to achieve safe operations, and ship stability characteristics.
NA 260. Marine Systems Manufacturing
Prerequisite: NA 270 or concurrent with NA 270. II (3 credits)
Overview of the marine industry and its environment as it relates to all aspects of naval architecture and engineering, including industry characteristics; organization; product types and components; materials used; joining methods; design; production engineering; planning; contracts and specifications; cost estimating; production and material control.
NA 270. Marine Design
Prerequisite: Math 116. I, II (4 credits)
Introduction to the marine industries, ships, and platforms. Engineering economics as applied in marine design decision making. Overview of preliminary ship design with brief team design project. Hydrostatics, stability, and trim of ships, boats, and marine platforms.
NA 310. Marine Structures I
Prerequisite: ME 211, NA 270. I (4 credits)
Structural analysis of ship hulls and offshore structures. Loading, material and fabrication considerations. Hull primary bending and midship section analysis. Framing systems. Secondary and tertiary stresses in stiffened plate components. Energy methods. Introduction to Finite Element Analysis. Failure theories for buckling; combined stress states; brittle fracture and fatigue.
NA 320. Marine Hydrodynamics I
Prerequisite: Math 215 and ME 211 or ME 240, or permission of instructor. I (4 credits)
Concepts and basic equations of marine hydrodynamics. Similitude and dimensional analysis, basic equations in integral form, continuity, and Navier-Stokes equations. Ideal fluid flow, Euler's equations, Bernoulli equation, free surface boundary value problems. Laminar and turbulent flows in pipes and around bodies.
NA 321. Marine Hydrodynamics II
Prerequisite: NA 320. II (4 credits)
Ideal and viscous fluid theory applied to marine systems. Ship resistance components. Resistance prediction from model testing and standard series. Two-dimensional and three-dimensional airfoil theory. Propeller geometry, design and matching. Hull-propeller interaction, propeller charts, powering prediction. Unsteady marine hydrodynamics: wave loads, seakeeping and transport of pollutants.
NA 331. Marine Engineering I
Prerequisites: ME 235, co-requisite NA 320. I (3 credits)
Diesel engines, steam turbines and gas turbines as marine prime movers. Thermodynamic cycles, ratings, matching to loads. Engine-propeller matching. Mechanical transmission of power to marine loads. Principles of fluid system design. Introduction to heat transfer and heat exchangers.
NA 332. Marine Electrical Engineering
Prerequisites: NA 331, Phys 240. II (3 credits)
Electrical circuit analysis. Electromagnetic interactions. Principles, characteristics, and properties of transformers, and DC and AC motors. Power electronics, integrated marine electrical plants. Electrical power distribution and control. Circuit protection. Introduction to fuel cells.
NA 340. Marine Dynamics I
Corequisites: NA 277, NA 321, ME 240. Co-requisite: NA 387. II (4 credits)
Structural vibration; one and multi-degree of freedom models. Forced steady state response. Fourier series; definition and application to frequency response. Introduction to random processes and applications in linear systems. Rigid body motion of floating structures. Sea wave excitation. Hydrodynamic added mass and damping; anti-roll tanks. Ship maneuvering; directional stability and steady turning.
NA 387. Introduction to Probability and Statistics for Marine Engineers
Prerequisites: MTH 116 (C-). II (3 credits)
Fundamentals of probability theory, with marine engineering applications. An introduction to statistics, estimation, goodness of fit, regression, correlation, engineering applications.
NA 401. Small Craft Design
Prerequisite: preceded or accompanied by NA 321 and NA 340. I (4 credits)
Hydrodynamics of small high-speed craft including planing hulls, air cushion vehicles, surface effect ships, and catamarans. Theoretical and empirical methods for resistance propulsion and attitude prediction. Nonlinear dynamics and stability of high-speed marine vehicles. Effect of hull form on resistance and dynamic performance. Structural design considerations including bottom plating strength and frame loading. Discussion of various types of framing. Material choices.
NA 403. Sailing Craft Design Principles
Prerequisite: preceded or accompanied by NA 321. II (4 credits)
Forces and moments acting on a sailing yacht. Speed polar diagrams. Two- and three-dimensional airfoil theory. Application to keel and rudder design. Yacht model testing. Delft Standard Series for prediction of hydrodynamic performance. Aerodynamics of yacht sails. Sail force coefficients. Velocity Prediction Program. Rigging design and analysis. Yacht racing rules.
NA 410 (Mfg 410). Marine Structures II
Prerequisite: NA 310. I (4 credits)
Structural modeling and analysis techniques applied to ship and marine structure components. Equilibrium and energy methods applied to elastic beam theory; static bending, torsion and buckling. Shear flow and warping of multicell cross sections. Stiffened and composite plates. Plastic analysis of beams. Thick walled pressure vessels. Course project using finite element analysis.

NA 416 (AERO 416). Theory of Plates and Shells

Prerequisite: NA 310 or AERO 315. II (3 credits)

Linear elastic plates. Membrane and bending theory of axisymmetric and non-axisymmetric shells. Variational formulation of governing equations boundary conditions. Finite element techniques for plate and shell problems.

NA 420 (AOSS 420). Environmental Ocean Dynamics

Prerequisites: NA 320 or AOSS 305 or CEE 325. I (4 credits)

Physical conditions and physical processes of the oceans; integration of observations into comprehensive descriptions and explanations of oceanic phenomena. Emphasis on wave and current prediction, optical and acoustical properties of sea water, currents, tides, waves and pollutant transport.

NA 421. Ship Model Testing

Prerequisite: undergraduates only and permission of instructor. I, II, IIIa (to be arranged)

Individual or team project, experimental work, research or directed study of selected advanced topics in ship model testing.

NA 431. Marine Engineering II

Prerequisite: NA 310, NA 331, NA 332, NA 340. II (3 credits)

Integrated treatment of the statics and dynamics of marine power transmission systems. Shafting design and alignment. Bearing selection and lubrication. Propeller excitation, added mass, and damping. Vibration modeling, analysis and evaluations of shafting systems: torsional, longitudinal, and lateral vibrations.

NA 440. Marine Dynamics II

Prerequisite: NA 321, NA 340. II (4 credits)

Dynamic analysis in a fluid environment. Rayleigh's principle for continuous systems. Equations of motion for ship rigid body dynamics. Wave excitation. Response Amplitude Operator (RAO). Random processes and probability. Motion in irregular seas. Introduction to time series analysis.

NA 455. Environmental Nearshore Dynamics

Prerequisite: NA 320. offered alternate years II (4 credits)

Shallow water waves and currents are investigated in nearshore processes including tides and long-term sea-level changes, longshore current and prediction of sediment and pollutant transport. Beach response to these processes is examined; coastal structures and effects on the nearshore environmentally conscious coastal design is emphasized. Interpretation of aerial photography is investigated.

NA 470 (Mfg 470). Foundations of Ship Design

Prerequisite: NA 321, NA 332, NA 340. Co-requisites: NA 310. I (4 credits)

Organization of ship design. Preliminary design methods for sizing and form; powering, maneuvering, seakeeping estimation; arranging; propulsion; structural synthesis; and safety and environmental risk of ships. Extensive use of design computer environment. Given owner's requirements, students individually create and report the conceptual/preliminary design for a displacement ship.

NA 475. Marine Design Team Project

Prerequisite: NA 470. II (4 credits)

Small teams of up to 4 students create, develop, and document original marine designs to contract design level. Projects typically involve a ship, yacht, submersible, or offshore system. Involves extensive project planning and weekly progress reporting. Extensive written and oral presentation of the project. Significant design CAD effort.

NA 477 (Eng 477). Principles of Virtual Reality

Prerequisite: Senior standing or permission of instructor. I (4 credits)

Enabling technologies (display systems, motion trackers, interactive devices, others), applications, human factors and perception, computer graphics and geometric modeling principles, creation of virtual environments, existing tools, special topics. Interdisciplinary group projects will develop VR applications using the facilities in the Media Union. http://www-VRL.umich.edu/Eng477/

NA 490. Directed Study, Research and Special Problems

Prerequisite: undergraduate only and permission. I, II, IIIa (to be arranged)

Individual or team project, experimental work or study of selected topics in naval architecture or marine engineering. Intended primarily for students with senior standing.

NA 491. Marine Engineering Laboratory

Prerequisite: NA 310, NA 320, NA 321, NA 331, NA 332, NA 340. I (4 credits)

Instruction in laboratory techniques and instrumentation. Use of computers in data analysis. Technical report writing. Investigation of fluid concepts, hydro-elasticity, marine dynamics, propeller forces, wave mechanics, ship hydrodynamics, and extrapolation of model tests to full scale.

NA 500. Engineering Analysis in the Marine Environment

Prerequisite: Graduate Standing. I (4 credits)

Formulation of hydrodynamic, rigid body dynamics, and structural problems in the marine environment. Multiple scales, problem decoupling. Direct, energy, and stochastic modeling methods. Solution methods: linear systems, linear stochastic systems, linear ODE and PDE boundary and initial value problems, stability concepts, perturbation methods, dominant balance in nonlinear differential equations. Applications in ship motions, viscous flows, vibrations, structures, elasticity, structural dynamics, stochastic loading.

NA 510. Marine Structural Mechanics

Prerequisite: NA 500. II (4 credits)

Failure modes encountered in ship and offshore structures. Von Karman plate equations. Geometric and material nonlinear analyses of beams and stiffened plates. Calculus of variations. Effective width and breadth of stiffened plates. Introduction to structural reliability theory with applications to marine structural design.

NA 511. Special Topics in Ship Structure

Prerequisite: prior arrangement with instructor. (to be arranged)

Individual or team project, experimental work, research or directed study of selected advanced topics in ship structure. Primarily for graduate students.

NA 512 (CEE 510). Finite Element Methods in Solid and Structural Mechanics

Prerequisite: Graduate Standing. II (3 credits)

Basic equations of three dimensional elasticity. Derivation of relevant variational principles. Finite element approximation. Convergence requirements. Isoparametric elements in two and three dimensions. Implementational considerations. Locking phenomena. Problems involving non-linear material behavior.

NA 518. Strength Reliability of Ship and Offshore Structures

Prerequisite: NA 410, Aero 452. I (3 credits)

Stress versus strength analysis. Deterministic stress analysis, safety factor approach. Random nature of loads, geometry material and construction. Random variables and random functions. Reliability of structures described by one or more random variables. Introduction to random vibration of discrete and continuous structural systems.

NA 520. Wave Loads on Ships and Offshore Structures

Prerequisite: NA 500. II (4 credits)

Computation of wave loads on marine vehicles and offshore structures including resistance, diffraction, viscous and radiation forces. Linear theory using panel methods and Green functions. Forces on cylindrical bodies. Morison's Equation. Nonlinear computation using desingularized method for inviscid flow and Reynold's averaged Navier-Stokes equation (RANS) for viscous flow.

NA 521. Directed Study and Research in Marine Hydrodynamics

Prerequisite: permission of instructor. (to be arranged)

Individual or team project, experimental work, research or directed study of selected advanced topics in marine hydrodynamics. Primarily for graduate students.

NA 522. Experimental Marine Engineering

Prerequisite: NA 410 and NA 440 or third-term Graduate Standing. IIIa (3 credits)

Advanced experiments in mechanics, vibrations, dynamics, and hydrodynamics illustrating concepts of 400 and introductory 500 level NA courses. Typical experiments include full scale experiments using Remote Operated Vehicle; vessel dynamic stability; offshore tower strength and vibrations; high speed planing; Tension Leg Platform hydrodynamic damping.

NA 528 (AOSS 528). Remote Sensing of Ocean Dynamics

Prerequisite: NA 420 (AOSS 420) or permission of instructor. II (3 credits)

The dynamics of ocean wave motion, both surface and internal waves, and ocean circulation are explored utilizing active and passive remote sensing techniques. Emphasis is placed upon the synoptic perspective of ocean dynamics provided by remote sensing which is not obtainable by conventional means.

NA 531. Adaptive Control

Prerequisite: Graduate standing or permission of instructor. I (3 credits)

Models of systems with unknown or time-varying parameters. Theory and algorithm for online parameter identification. Adaptive observers. Direct and indirect adaptive control. Model reference systems. Design and analysis of nonlinear adaptive control. Application and implementation of adaptive systems.

NA 540. Marine Dynamics III

Prerequisite: NA 340 or equivalent, preceded or accompanied by NA 500. I (4 credits)

Fundamental analysis of marine dynamical systems. Normal mode analysis. Matrix representation of frequency domain seakeeping equations. Properties of linear gravity waves. Wave forces on marine structures. Linear and non-linear time domain seakeeping, and maneuvering simulations. Nonlinear stability and bifurcation theory applied to mooring and capsizing. Shock mitigation.

NA 550 (AOSS 550). Offshore Engineering Analysis II

Prerequisite: NA 420 (AOSS 420). II (3 credits)

Design and analysis requirements of off-shore facilities. Derivation of hydrodynamic loads on rigid bodies. Loads on long rigid and flexible cylinders. Viscous forces on cylinders, experimental data, Morison's equation, Stokes wave theories. Shallow water waves. Selection of appropriate wave theory. Diffraction of waves by currents. Hydrodynamic loads on risers, cables, pipelines and TLP's.

NA 561 (Mfg 573). Marine Product Modeling

Prerequisite: NA 570. II (3 credits)

Fundamental aspects of marine product modeling, data exchange, and visualization. Simulation Based Design. Introduction to activity modeling and information modeling. Overview of Object Oriented Programming. Geometric modeling of solids and surfaces. Simulation and visualization. Virtual prototyping.

NA 562 (Mfg 563). Marine Systems Production Business Strategy and Operations Management

Prerequisite: NA 260 or graduate standing. I (4 credits)

Examination of business strategy development, operations management principles and methods, and design-production integration methods applied to the production of complex marine systems such as ships, offshore structures, and yachts. Addresses shipyard and boat yard business and product strategy definition, operations planning and scheduling, performance measurement, process control and improvement.

NA 570 (Mfg 572). Advanced Marine Design

Prerequisite: Graduate Standing required. II (4 credits)

Organization of marine product development; concurrent marine design. Shipbuilding policy and build strategy development. Group behaviors; leadership and facilitation of design teams. General theories and approaches to design. Conceptual design of ships and offshore projects. Nonlinear programming, multicriteria optimization, and genetic algorithms applied to marine design. Graduate standing required.

NA 571 (Mfg 571). Ship Design Project
Prerequisite: prior arrangement with instructor. I, II, IIIa (to be arranged)
Individual (or team) project, experimental work, research or directed study of selected advanced topics in ship design. Primarily for graduate students.
NA 575 (Mfg 575). Computer-Aided Marine Design Project
I, II, IIIa, IIIb, III (2-6 credits), (to be arranged)
Development of computer-aided design tools. Projects consisting of formulation, design, programming, testing, and documentation of programs for marine design and constructional use.
NA 579. Concurrent Marine Design Team Project
Prerequisite: NA 460, NA 570, and NA 580. II, IIIa (2-4 credits)
Industrial related team project for Master's of Engineering in Concurrent Marine Design degree program. Student teams will conduct concurrent design project for and in conjunction with industrial or government customer.
NA 580 (Mfg 578). Optimization, Market Forecast and Management of Marine Systems
Prerequisite: NA 500. I (4 credits)
Optimization methods (linear, integer, nonlinear, sequential) concepts and applications in the operations of marine systems. Forecasting methods (ARMA, Fuzzy sets, Neural nets) concepts and applications to shipping and shipbuilding decisions. Economics of merchant shipbuilding and ship scrapping. Elements of maritime management: risk and utility theory. Deployment optimization.
NA 582 (Mfg 579). Reliability and Safety of Marine Systems
Prerequisite: EECS 401 or Math 425 or Stat 412. II (3 credits)
Brief review of probability, statistics, trade-off analysis, and elements of financial management. Thorough presentation of the methods and techniques of reliability analysis. Marine reliability, availability, maintenance, replacement, and repair decisions. Safety and risk analysis. FMEA, fault-tree and event-tree analysis. Marine applications.
NA 590. Reading and Seminar
Prerequisite: permission. I, II, IIIa, IIIb (to be arranged)
A graduate level individual study and seminar. Topic and scope to be arranged by discussion with instructor.
NA 592. Master's Thesis
Prerequisite: Graduate Standing. I, II, III, IIIa, IIIb (1-6 credits)
To be elected by Naval Architecture and Marine Engineering students pursuing the master's thesis option. May be taken more than once up to a total of 6 credit hours.
NA 615. Special Topics in Ship Structure Analysis II
Prerequisite: NA 510, prior arrangement with instructor. I, II (to be arranged)
Advances in specific areas of ship structure analysis as revealed by recent research. Lectures, discussions, and assigned readings.
NA 620. Computational Fluid Dynamics for Ship Design
Prerequisite: NA 500. I alternate years (3 credits)
Development of the necessary skills for the hydrodynamic design of hull shapes based on available Computational Fluid Dynamic (CFD) tools. Topics: Potential Flows (Deeply submerged, Free-surface treatment, Status of CFD solvers), Viscous flows (Basics, Turbulence modeling, Grid generation, Discretization, Numerical techniques, Free-surface, Status of CFD solvers), Design methodologies (Strategies for Wave Resistance, Viscous flows, Total resistance and Optimization work).
NA 625. Special Topics in Marine Hydrodynamics
Prerequisite: permission. I, II (to be arranged)
Advances in specific areas of marine hydrodynamics as revealed by recent research.
NA 627 (ME 627). Wave Motion in Fluids
Prerequisite: ME 520 or NA 520 or equivalent. I (3 credits)
Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to a moving body; Korteweg-deVries equation; conoidal and solitary waves in water; wave reflection and diffraction; shallow-water waves by the method of characteristics; statistical approach and spectral analysis; wave generation.
NA 635. Special Topics in Marine Engineering
Prerequisite: permission. I, II (to be arranged)
Advances in specific areas of marine engineering as revealed by recent research. Lectures, discussions, and assigned readings.
NA 644. Numerical Methods for Vibro-Acoustic Modeling of Complex Systems
Prerequisite: NA 340 or ME 440. II alternate years (3 credits)
Theoretical development, numerical formulation, and practical modeling aspects of the Statistical Energy Analysis (SEA) and the Energy Finite Element Analysis (EFEA). Numerical evaluation of vibration and acoustic characteristics of complex structural/acoustic systems, such as ship structure, airframe, or trimmed car body.
NA 650. Dynamics of Offshore Facilities
Prerequisite: NA 410, NA 440. II (3 credits)
Dynamics and stability of single point mooring systems. Marine cable statics and dynamics. Dynamics and stability of multilegged mooring systems. Dynamics and stability of towing systems. Dynamics of offshore towers. Structural redesign. Correlation of finite element model and physical structure. Dynamics and stability of marine risers; bundles of risers. Statics and dynamics of pipelines.
NA 655. Special Topics in Offshore Engineering
Prerequisite: NA 410, NA 440, NA 550 or NA 650. II (to be arranged)
Advances in specific areas of offshore engineering as revealed by recent research. Lectures by doctoral students. Projects and presentations by M.S. students. Discussion, assigned readings.

NA 685. Special Topics in Marine Systems
Prerequisite: permission of instructor; mandatory pass/fail. I, II (to be arranged)
Advances in specific areas of marine systems engineering as revealed by recent research. Lectures, discussions, and assigned readings.
NA 792. Professional Degree Thesis
I, II, III (2-8 credits); IIIa, IIIb (1-6 credits)
NA 990. Dissertation/Pre-Candidate
I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
NA 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, III (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Naval Architecture and Marine Engineering Faculty

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Professors

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Nuclear Engineering and Radiological Sciences

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Nuclear engineering and radiological sciences are concerned with the direct technological use of atomic and subatomic particles. These applications have become an inseparable part of much of modern technological life: smoke detectors, nuclear power reactors, nondestructive evaluation of turbine blades, hardening of artificial hip joints, treatment of radioactive waste, medical CT and PET imaging, treatment of cancer using radiotherapy—all of these rely on the direct manipulation and measurements of parts of atoms or their emitted energy. These are the kinds of technologies that nuclear engineering and radiological sciences encompasses.

The Undergraduate Program in Nuclear Engineering and Radiological Sciences is divided into two tracks (the nuclear engineering track and the radiological science track) both leading to the Bachelor of Science in Engineering degree—B.S.E.(N.E.R.S.).

Nuclear Engineering

The nuclear engineering track is intended for students interested in nuclear power and nuclear reactors. Students following this track are generally interested in:

- Radiation transport and reactor physics: Study of neutron and photon interactions with matter and ways to control the processes.
- Advanced nuclear reactors: Development of Generation IV nuclear energy systems for the 21st century.
- Fuel cycle and safety analysis: Evaluation of safety of nuclear power plants and the development of environmentally sustainable fuel cycles for nuclear energy systems.

Radiological Sciences

The radiological sciences track is designed for students who are interested in applying radiation and subatomic particles in environmental, biomedical, industrial and scientific fields. Students pursuing this track have options to work in:

- Radiation safety: Health physics, the protection of people and the environment from radiation in medical, industrial, and nuclear power applications.
- Environmental sciences: Environmental impact of the nuclear fuel cycle, nuclear waste disposal, and decommissioning of nuclear facilities.
- Medical physics: Radiation diagnosis (nuclear medicine and diagnostic radiology) and treatment of cancer and other diseases (radiation therapy).
- Radiation measurements: Development of advanced radiation detectors and medical and industrial imaging systems.
- Radiation effects on materials: Study of the deleterious effects of radiation on engineering materials and applications of radiation to enhance material properties.
- Plasma materials processing: Utilization of plasmas (charged gases of separated electrons and ions) in industrial settings, such as in the etching of computer chips.

Students interested in Biomedical Engineering should consider the radiological sciences track as one with sufficient flexibility to ready them for their graduate studies. The program is designed to provide a basic common core, and then allow a wide range of choices, from Nuclear Engineering and Radiological Sciences, other College of Engineering departments, the School of Public Health, and the University of Michigan Hospitals so that students can develop their interests.

Students in either track learn the fundamentals of modern physics and the fundamentals of radiation measurement on which these nuclear and radiation technologies are based. In the senior year the tracks branch apart into more specialized courses and design studies.

Research Opportunities and Scholarships

Programs have been established in the Nuclear Engineering and Radiological Sciences Department which allow students to interact with faculty and graduate students on different research projects. These include the Fermi Scholar Program specifically for first- and second-year students and the Research Opportunity Program for junior- and senior-level students. In addition to the research opportunities, scholarships are also available for all levels (first-year through completion of a B.S.E.) for those students interested in this program of study.

Facilities

The Department of Nuclear Engineering and Radiological Sciences occupies the Mortimer E. Cooley Laboratory, which contains departmental offices, faculty offices, classrooms, and several of the labs listed below.

Departmental Laboratories

Other laboratories of the department are housed in the Phoenix Memorial Laboratory and the Naval Architecture and Marine Engineering (NAME) Building. The Department of Nuclear Engineering and Radiological Sciences has a number of special facilities and laboratories that allow students to get hands-on experience with systems that manipulate matter at a fundamental level. These include:

- Bioelectromagnetism Laboratory
- High Temperature Corrosion Laboratory
- Intense Energy Beam Interaction Laboratory
- Irradiated Materials Testing Laboratory
- Materials Preparation Laboratory
- Metastable Materials Laboratory
- Michigan Ion Beam Laboratory
- Nuclear Imaging and Measurements Laboratory
- Radiation Detection Laboratory
- Radiation Effects and Nanomaterials Laboratory
- Radiological Health Engineering Laboratory

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET), 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, telephone (410) 347-7700.

Nuclear Engineering and Radiological Sciences Mission

To provide a superior education for engineers and scientists in nuclear engineering and radiological sciences and to develop future leaders in industry, government, and education.

Goals

The program provides students with:

- skills and tools necessary for industrial, medical, governmental and environmental applications of nuclear processes and radiation; and
- insights and skills that will prepare them to be leaders in research and the practice of nuclear engineering and radiological sciences.

Objectives

Upon graduation, our students are:

- prepared for entry-level professional practice in industry, government or health care practice, where they will be performing analysis and measurements related to radiation and radiation interactions with matter, including nuclear power system and health physics design and analysis;
- prepared to pursue graduate studies and earn M.S. or Ph.D. degrees in nuclear engineering and related fields;
- prepared for successful careers and eventual leadership roles because of their strong background in fundamental engineering analysis, teamwork and communications skills, and ability to engage in life-long learning and the continual improvement of their skills and knowledge.

Outcomes

Graduates of the program will have:

- an ability to apply mathematics, engineering, and science, including atomic and nuclear physics, to the study of radiation interactions with matter and nuclear processes;
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice;
- an ability to formulate engineering problems and develop practical solutions;
- an ability to design products and processes applicable to nuclear engineering and radiological sciences, including realistic constraints;
- an ability to design, conduct, analyze, and interpret the results of engineering experiments, including characteristic attributes of nuclear processes and radiation;
- an ability to work effectively in diverse multidisciplinary teams and provide leadership to teams and organizations;
- an ability for effective oral, graphic, and written communication;
- a broad education necessary to understand the global impact of engineering decisions and biological effects of radiation in a societal and environmental context;
- an understanding of professional and ethical responsibility;
- a recognition of the need for and an ability to engage in life-long learning, and;
- a knowledge of contemporary issues;

Sequential Graduate/Undergraduate Education (SGUS)

B.S.E in Nuclear Engineering and Radiological Sciences/M.S. in Nuclear Engineering and Radiological Sciences

This program is open to all Nuclear Engineering and Radiological Sciences (NERS) undergraduate students who have completed 85 or more credit hours. All NERS undergraduates are eligible to apply for admission to this program during the first semester of their senior year. Recommendation of the Undergraduate Program Advisor is required, and the standard Rackham graduate application process is followed. All undergraduate students with a minimum cumulative GPA of 3.2 would be automatically accepted into the simultaneous degree program. Applications of students who do not meet the required GPA will be reviewed by the NERS Graduate Admission Committee.

B.S.E in Nuclear Engineering and Radiological Sciences/M.S. Biomedical Engineering

This SGUS program is open to all undergraduate students from Nuclear Engineering and Radiological Sciences who have achieved senior standing (85 credit hours or more), and have an overall cumulative GPA of 3.2 or higher. Please contact the Department of Biomedical Engineering for more complete program information.

Sample Schedule

B.S.E. Nuclear Engineering and Radiological Sciences

	Credit Hours	Terms							
		1	2	3	4	5	6	7	8
Subjects required by all programs (52-55 hrs.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	–	–	–	–
Engr 100, Intro to Engr	4	4	–	–	–	–	–	–	–
Engr 101, Intro to Computers	4	–	4	–	–	–	–	–	–
Chemistry 125/126 and 130 or Chemistry 210 and 211 [1]	5	5	–	–	–	–	–	–	–
Physics 140 with 141; Physics 240 with 241 [2]	10	–	5	5	–	–	–	–	–
Humanities and Social Sciences	16	4	4	–	4	–	–	4	–
Advanced Mathematics (4 hrs.)	4								
Math 450, Adv Math for Eng I	4	–	–	–	–	4	–	–	–
Related Technical Subjects (19 hrs.)	19								
MSE 250, Princ of Eng Materials or MSE 220, Intro to Materials and Manf	4	–	–	4	–	–	–	–	–
CEE 211, Statics and Dynamics	4	–	–	–	4	–	–	–	–
EECS 215, Intro to Circuits or EECS 314, Electrical Circuits, Systems, and Applications	4	–	–	–	–	4	–	–	–
CEE 325, Fluid Mechanics or ME 320, Fluid Mechanics I[3]	4	–	–	–	–	–	4	–	–
ME 235, Thermodynamics I	3	–	–	–	–	3	–	–	–
Program Subjects (37 hrs.)									
NERS 250, Fundamentals of Nuclear Eng and Rad Sci	4	–	–	–	4	–	–	–	–
NERS 311, Ele of Nuc Eng & Rad Sci I	4	–	–	–	–	4	–	–	–
NERS 312, Ele of Nuc Eng & Rad Sci II	4	–	–	–	–	–	4	–	–
NERS 315, Nuclear Instr Lab	4	–	–	–	–	–	4	–	–
NERS 441, Nuclear Reactor Theory I or NERS 484, Rad Hlth Eng Fundamentals	4	–	–		–	–	–	4	–
Laboratory Course (above NERS 315)[4]	4	–	–	–	–	–	–	–	4
Design Course[5]	4	–	–	–	–	–	–	–	4
NERS Electives	9	–	–	–	–	–	–	6	3
Technical Electives (3 hrs.)	3	–	–	–	–	–	–	3	–
Unrestricted Electives (10-13 hrs.)	10-13	–	–	3	–	–	3	–	4
Total	128	17	17	16	16	15	15	17	15

Candidates for the Bachelor of Science degree in Engineering (Nuclear Engineering and Radiological Sciences) — B.S.E. (N.E.R.S.) —must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

[1]If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.

[2]If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or 240/241 you will have met the Physics Core Requirement for CoE

[3]If ME 320 (3 hrs) is elected, students will have an additional hour of unrestricted electives.

[4]Laboratory Course (above NERS 315) select one from the following: NERS 445, 575, 586. (NERS 575 and NERS 586 need program advisor's consent.)

[5]Design Course select one: NERS 442, 554.

Nuclear Engineering and Radiological Sciences Graduate Education

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Graduate Degrees

- Master of Science (M.S.) in Nuclear Science
- Master of Science in Engineering (M.S.E.) in Nuclear Engineering and Radiological Sciences
- Doctor of Philosophy (Ph.D.) in Nuclear Science
- Doctor of Philosophy (Ph.D.) in Nuclear Engineering and Radiological Sciences
- Doctor of Philosophy (Ph.D.) with Scientific Computing Option

Programs of Study

Master of Science Programs/M.S. in Nuclear Science and M.S.E. in Nuclear Engineering and Radiological Sciences

Students entering the program in Nuclear Engineering and Radiological Sciences must have a bachelor's degree from an accredited engineering program. The nuclear science program is available to those with bachelor's degrees from recognized programs in physics, chemistry, or mathematics who wish to work in the field of nuclear engineering and radiological sciences.

Students planning to enter the M.S. degree program who do not have an undergraduate degree in Nuclear Engineering and Radiological Sciences should take courses in atomic and nuclear physics and in advanced mathematics for engineers (Math 450 or equivalent). Students without these prerequisites will be requested to make up the deficiencies in addition to the 30 hours required for the M.S. degree. An upper-level course in electronic circuits (EECS 314 and Physics 455 or equivalent), a course in fluid mechanics (CEE 325 or equivalent), a course in computer programming (Eng 101, EECS 283, or equivalent) are recommended as desirable preparation.

The requirements for the master's degree are 30 hours of course work at the graduate level, including 20 hours from nuclear engineering and radiological sciences and four credits outside the department. At least four of the nuclear engineering and radiological sciences courses, excluding NERS 599 and NERS 799, must be at the 500-level or higher. All M.S. degree students must take a formal 400-level or higher lab course while enrolled as a graduate student. The student, with approval of the program advisor, may substitute a master's project report for 2 to 6 credit hours of graduate course work. In this case, the student will be required to make a seminar presentation of the master's project, in addition to a written final report. Additional courses are selected with the help of the program advisor from courses in nuclear engineering and radiological sciences, cognate fields of engineering, mathematics, physics, chemistry, and others.

Ph.D. Programs

Ph.D. in Nuclear Engineering and Radiological Sciences and Ph.D. in Nuclear Science

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the result of the investigation in the form of a dissertation. The selected fields (options) are:

- Fission Systems and Radiation Transport
- Materials
- Plasma and Fusion
- Radiation Measurements and Imaging
- Radiation Safety, Environmental Sciences and Medical Physics

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. Candidacy is achieved when the student demonstrates competence in her/his broad field of knowledge through completion of a prescribed set of courses and passing a comprehensive examination. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation. All Ph.D. students must take NERS 515, Nuclear Measurements Laboratory and 6 credit hours of NERS courses selected from outside the student's option, and obtain a grade of B or better for each of these courses.

Candidate Status: Candidacy requirements are described in requirements for Achieving Candidacy section of the Rackham Graduate Student Handbook. For information on the dissertation committee, final oral examination, and publication of dissertation, see the Rackham Graduate Student Handbook.

Note: The Graduate Record Exam (GRE) is required for financial consideration and fellowship nominations.

UM URLs of Interest:
UM NERS Department:
http://www.ners.engin.umich.edu
Rackham Graduate School Home Page:
http://www.rackham.umich.edu
Rackham Publications: Graduate Student Handbook:
http://www.rackham.umich.edu/StudentInfo/Publications/
Online Application:
https://apply.embark.com/Grad/Umich/Rackham/ProgramA/

Ph.D. in Scientific Computing

The Ph.D. program in scientific computing is a joint degree program—students pursue their doctoral studies in a home department such as Nuclear Engineering and Radiological Sciences and take additional courses in areas such as numerical analysis, scientific computation, and the study of algorithms for advanced computer architectures. This interdisciplinary program is intended for students who will make extensive use of large-scale computation, computational methods, or algorithms for advanced computer architectures in their doctoral studies. Students are expected to complete the normal doctoral requirements of their home department as well as additional requirements in the area of scientific computation.

NERS 211 (ENSCEN 211). Introduction to Nuclear Engineering and Radiological Sciences

Prerequisite: preceded or accompanied by Math 216. II (4 credits)

This course will discuss different forms of energy, the history of nuclear energy, the fundamentals of fission and fusion nuclear power, radiological health applications, and electromagnetic radiation in the environment. Current topics in the media such as radon, radioactive waste, and nuclear proliferation will also be covered.

NERS 250. Fundamentals of Nuclear Engineering and Radiological Sciences

Prerequisite: preceded or accompanied by Math 216 and Physics 240 . II (4 credits)

Technological, industrial and medical applications of radiation, radioactive materials and fundamental particles. Basic nuclear physics, interactions of radiation with matter. Fission reactors and the fuel cycle. Additional topics and guest lectures.

NERS 311. Elements of Nuclear Engineering and Radiological Sciences I

Prerequisite: NERS 250, Physics 240, preceded or accompanied by Math 450. I (4 credits)

Photons, electrons, neutrons, and protons. Particle and wave properties of radiation. Introduction to quantum mechanics and special relativity. Properties and structure of atoms and nuclei. Introduction to interactions of radiation with matter.

NERS 312. Elements of Nuclear Engineering and Radiological Sciences II

Prerequisite: NERS 311. II (4 credits)

Production and use of nuclear radiation. Alpha-, beta- and gamma-decay of nuclei. Neutrons. Nuclear Reactions. Elementary radiation interactions and transport.

NERS 315. Nuclear Instrumentation Laboratory

Prerequisites: EECS 215 or EECS 314, preceded or accompanied by NERS 312. II (4 credits)

An introduction to the devices and techniques most common in nuclear measurements. Topics include the principles of operation of gas-filled, solid state, and scintillation detectors for charged particle, gamma ray, and neutron radiations. Techniques of pulse shaping, counting, and analysis for radiation spectroscopy. Timing and coincidence measurements.

NERS 421. Nuclear Engineering Materials

Prerequisites: MSE220 or MSE 250, NERS 312. I (3 credits)

An introduction to materials used in nuclear systems and radiation effects in materials (metals, ceramics, semiconductors, organics) due to neutrons, charged particles, electrons and photons.

NERS 425. Application of Radiation

Prerequisite: NERS 312. II (4 credits)

Applications of radiation interaction with matter using various forms (neutrons, ions, electrons, photons) of radiation, including activation analysis, neutron radiography, nuclear reaction analysis, Rutherford backscattering analysis, proton-induced x-ray emission, plasma-solid interactions and wave-solid interactions. Lectures and laboratory.

NERS 441. Nuclear Reactor Theory I

Prerequisite: NERS 312, Math 450. I (4 credits)

An introduction to the theory of nuclear fission reactors including neutron transport theory, the P1 approximation, diffusion theory, criticality calculations, reactor kinetics, neutron slowing down theory, and numerical solution of the diffusion equation.

NERS 442. Nuclear Power Reactors

Prerequisite: NERS 441, CEE 325 or ME 320. II (4 credits)

Analysis of nuclear fission power systems including an introduction to nuclear reactor design, reactivity control, steady-state thermal-hydraulics and reactivity feedback, fuel cycle analysis and fuel management, environmental impact and plant siting, and transient analysis of nuclear systems. A semester-long design project of the student's choice.

NERS 462. Reactor Safety Analysis

Prerequisite: preceded or accompanied by NERS 441. I (3 credits)

Analysis of those design and operational features of nuclear reactor systems that are relevant to safety. Reactor containment, engineered safety features, transient behavior and accident analysis for representative reactor types. NRC regulations and procedures. Typical reactor safety analyses.

NERS 471. Introduction to Plasmas

Prerequisite: preceded or accompanied by Physics 240 or equivalent. I (3 credits)

Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Wave phenomena in plasmas. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory.

NERS 472. Fusion Reactor Technology
Prerequisite: NERS 471. II (2 credits)
Study of technological topics relevant to the engineering feasibility of fusion reactors as power sources. Energy and particle balances in fusion reactors; neutronics and tritium breeding, various approaches to plasma heating, heat removal and environmental aspects.

NERS 481. (BiomedE 481) Engineering Principles of Radiation Imaging
II (2 credits)
Analytic description of radiation production, transport and detection in radiation imaging systems. Measurements methods for image quality and statistical performance of observers. Systems for radiographic and radioisotope imaging, including film/screen, storage phosphor, and electronic radiography, fluoroscopy, computed tomography, Anger camera, and PET systems. Emphasis on impact of random process on observer detection.

NERS 484. (BiomedE 484, ENSCEN 484) Radiological Health Engineering Fundamentals

Prerequisite: NERS 312 or equivalent or permission of instructor. I (4 credits)

Fundamental physics behind radiological health engineering and topics in quantitative radiation protection. Radiation quantities and measurement, regulations and enforcement, external and internal dose estimation, radiation biology, radioactive waste issues, radon gas, emergencies, and wide variety of radiation sources from health physics perspective.

NERS 490. Special Topics in Nuclear Engineering and Radiological Sciences

Prerequisite: permission of instructor. (to be arranged)

Selected topics offered at the senior or first-year graduate level. The subject matter may change from term to term.

NERS 499. Research in Nuclear Engineering and Radiological Sciences

Prerequisite: permission of instructor. (1-3 credits)

Individual or group research in a field of interest to the student under the direction of a faculty member of the Nuclear Engineering and Radiological Sciences department.

NERS 511. Quantum Mechanics in Neutron-Nuclear Reactions

Prerequisite: NERS 312, Math 450. II (3 credits)

An introduction to quantum mechanics with applications to nuclear science and nuclear engineering. Topics covered include the Schroedinger equation and neutron-wave equations, neutron absorption, neutron scattering, details of neutron-nuclear reactions, cross sections, the Breit-Wigner formula, neutron diffraction, nuclear fission, transuranic elements, the deuteron problem, masers, and lasers.

NERS 512. Interaction of Radiation and Matter

Prerequisite: NERS 511. II (3 credits)

Classical and quantum-mechanical analysis of the processes by which radiation interacts with matter. Review of nuclear structure and properties. Nuclear models. Nuclei as sources of radiation. Interaction of electromagnetic radiation with matter. Interaction of charged particles with matter. Radiative collisions and theory of Bremsstrahlung. Interaction of neutrons with matter. Interaction mechanisms and cross sections are developed.

NERS 515. Nuclear Measurements Laboratory

Prerequisite: permission of instructor. I (4 credits)

Principles of nuclear radiation detectors and their use in radiation instrumentation systems. Characteristics of important devices with applications in nuclear science. Gamma ray spectroscopy, fast and thermal neutron detection, charged particle measurements, pulse analysis, nuclear event timing, and recent development in nuclear instrumentation.

NERS 518. Advanced Radiation Measurements and Imaging

Prerequisite: NERS 315 or NERS 515. I alternate years (2 credits)

Detection and imaging of ionizing radiation that builds on a basic course in radiation measurements. Topics include statistical limits on energy and spatial resolution, analog and digital pulse processing, pulse shape analysis and discrimination, position sensing techniques, application of Ramo theorem for calculating induced charge, and the use of statistical methods in data analysis. Specific devices used as examples of evolving technology include newly-developed scintillators and wave-shifters, optical sensors, gas-filled imaging and spectroscopic detectors, semiconductor spectrometers from wide bandgap materials, gamma ray/neutron imaging systems, and cryogenic spectrometers.

NERS 521. Radiation Effects in Nuclear Materials

Prerequisite: permission of instructor. I (3 credits)

Radiation effects in crystalline solids; defect production, spike phenomena, displacement cascades, interatomic potentials, channeling, focusing, slowing down. Radiation effects on mechanical behavior of reactor components; creep, hardening, fracture, fatigue. Applications to pressure vessel steels, in-core components, and fusion reactor wall materials.

NERS 522. Nuclear Fuels

Prerequisite: permission of instructor. II alternate years (3 credits)

Nuclear reactor fuels and the fuel cycle; mining, processing, isotope separation and fabrication. Fuel/clad behavior; radiation damage, thermal response, densification, swelling, fission gas release, burnup, clad corrosion, design and modeling. Spent fuel; characterization, performance, reprocessing, disposal.

NERS 531 (ENSCEN 531). Nuclear Waste Management

Prerequisite: Senior Standing. II (3 credits)

Based on the nuclear fuel cycle, this course will review the origin, composition, form and volumes of waste generated by commercial reactors and defense programs. The scientific and engineering basis for near-field and far-field containment in a geologic repository will be reviewed in the context of performance assessment methodologies.

NERS 543. Nuclear Reactor Theory II

Prerequisite: NERS 441 or equivalent. I (3 credits)

A continuation of NERS 441 including neutron resonance absorption and thermalization, perturbation and variational methods, flux synthesis. Analytic and numerical solutions of the neutron transport equation including the S_n and B methods, collision probabilities and Monte Carlo methods.

NERS 551. Nuclear Reactor Kinetics

Prerequisite: preceded or accompanied by NERS 441. II (3 credits)

Derivation and solution of point reactor kinetic equations. Concept of reactivity, inhour equations and reactor transfer function. Linear stability analysis of reactors. Reactivity feedback and nonlinear kinetics. Space-dependent reactor kinetics and xenon oscillations. Introduction to reactor noise analysis.

NERS 554. Radiation Shielding
Prerequisite: NERS 441 or NERS 484. II (4 credits)
The design of radiation shields, including neutrons, photons and charged particles. Dosimetric quantities, detector response functions, materials selection, and energy deposition in shields. Techniques for dose estimation including buildup factors, neutron removal cross-sections and Monte Carlo.
NERS 561. Nuclear Core Design and Analysis I
Prerequisite: NERS 441. II (3 credits)
Analytical investigation of areas of special importance to the design of nuclear reactors. Includes development, evaluation, and application of models for the neutronic, thermal-hydraulic, and economic behavior of both thermal and fast reactors. Typical problems arising in both design and operation of nuclear reactors are considered. This course includes extensive use of digital computers.
NERS 562. Nuclear Core Design and Analysis II
Prerequisite: NERS 561. IIIa (3 credits)
Continuation of subject matter covered under NERS 561 with emphasis on applications of analytical models to the solution of current problems in reactor technology.
NERS 571. Intermediate Plasma Physics I
Prerequisite: NERS 471 or Physics 405. I (3 credits)
Single particle motion, collision, and transport; plasma stability from orbital considerations; Vlasov and Liouville equations; Landau damping; kinetic modes and their reconstruction from fluid description; electrostatic and electromagnetic waves, cutoff and resonance.
NERS 572. (Appl Phys 672) Intermediate Plasma Physics II
Prerequisite: NERS 571. II (3 credits)
Waves in non-uniform plasmas, magnetic shear; absorption, reflection, and tunneling gradient-driven micro-instabilities; BGK mode and nonlinear Landau damping; macroscopic instabilities and their stabilization; non-ideal MHD effects.
NERS 575 (EECS 519). Plasma Generation and Diagnostics Laboratory
Prerequisite: preceded or accompanied by a course covering electromagnetism. II (4 credits)
Laboratory techniques for plasma ionization and diagnosis relevant to plasma processing, propulsion, vacuum electronics, and fusion. Plasma generation techniques includes: high voltage-DC, radio frequency, and e-beam discharges. Diagnostics include: Langmuir probes, microwave cavity perturbation, microwave interferometry, laser schlieren, and optical emission spectroscopy. Plasma parameters measured are: electron/ion density and electron temperature.
NERS 576. Charged Particle Accelerators and Beams
Prerequisite: Physics 240 or EECS 331. I alternate years. (3 credits)
Principles and technology of electrostatic and electrodynamic accelerators, magnetic and electrostatic focusing, transient analysis of pulsed accelerators. Generation of intense electron and ion beams. Dynamics, stability, and beam transport in vacuum, neutral and ionized gases. Intense beams as drivers for inertial confinement and for high power coherent radiation.
NERS 577. Plasma Spectroscopy
Prerequisite: introductory courses in plasma and quantum mechanics. I alternate years (3 credits)
Basic theory of atomic and molecular spectroscopy and its application to plasma diagnostics. Atomic structure and resulting spectra, electronic (including vibrational and rotational) structure of molecules and the resulting spectra, the absorption and emission of radiation and the shape and width of spectral lines. Use of atomic and molecular spectra as a means of diagnosing temperatures, densities and the chemistry of plasmas.
NERS 578 (EECS 517). Physical Processes in Plasmas
Prerequisites: EECS 330. II even years (3 credits)
Plasma physics applied to electrical gas discharges used for material processing. Gas kinetics; atomic collisions; transport coefficients; drift and diffusion; sheaths; Boltzmann distribution function calculation; plasma simulation; plasma diagnostics by particle probes, spectroscopy, and electromagnetic waves; analysis of commonly used plasma tools for materials processing.
NERS 579 (EHS 692). Physics of Diagnostic Radiology
Prerequisite: NERS 484 or Graduate Status. II, IIIa (3 credits)
Physics, equipment and techniques basics to producing medical diagnostic images by x-rays, fluoroscopy, computerized tomography of x-ray images, mammography, ultrasound, and magnetic resonance imaging systems. Lectures and demonstrations.
NERS 580 (BiomedE 580). Computation Projects in Radiation Imaging
Prerequisite: preceded or accompanied by NERS 481 II (1 credit)
Computational projects illustrate principles of radiation imaging from NERS 481 (BiomedE 481). Students will model the performance of radiation systems as a function of design variables. Results will be in the form of computer displayed images. Students will evaluate results using observer experiments. Series of weekly projects are integrated to describe the performance of imaging systems.
NERS 582 (BiomedE 582). Medical Radiological Health Engineering
Prerequisite: NERS 484 (BiomedE 484) or Graduate Status. II (3 credits)
This course covers the fundamental approaches to radiation protection in radiology, nuclear medicine, radiotherapy, and research environments at medical facilities. Topics presented include health effects, radiation dosimetry and dose estimation, quality control of imaging equipment, regulations, licensing, and health physics program design.
NERS 583. Applied Radiation Dose Assessment
Prerequisite: NERS 484 or Graduate Status. II (4 credit)
Principles and methods of protection against radiation hazards. Occupation, environmental, and medical aspects included. Internal and external dose assessment, dosimetry, health effects, and personnel and patient protection. Special health and medical physics computational techniques and problems .

NERS 585 Transportation of Radioactive Materials
Prerequisite: Junior status in engineering. Senior or graduate status in any field
Analysis of risks and consequences of routine transportation of radioactive materials and of transportation accidents involving these materials; history and review of regulations governing radioactive materials, overview of packaging design and vulnerabilities, and current issues and concerns involving radioactive materials transportations. Essays and quantitative analysis both included.
NERS 586 Applied Radiological Measurements
Prerequisite: NERS 484, NERS 515 or equivalent
Instrumentation and applied measurements of interest for radiation safety, environmental sciences, and medical physics. Dosimeters, radon gas, *in situ* gamma ray spectroscopy, skin dose, bioassay, internal dose evaluation, alpha detection, applied instrumentation, and other selected medical physics and health measurements. Includes analytical modeling and computer simulation for comparison with several physical experiments. Lectures and laboratory.
NERS 587. Internal Radiation Dose Assessment
Prerequisite: NERS 484 or Graduate Status. II (3 credits)
Determination of radiation doses due to internal deposition of radioactive materials in the human body. Intake and deposition models of radioactive materials via inhalation or oral ingestion with particular emphasis on internationally accepted models for lungs, GI tract, and bone. Concepts of Annual Limit of Intake to meet risk based standards. Derive Air Concentrations, submersion exposure, retention models, and bioassay principles for determining intake and retention of radionuclides. Lectures and problem sessions.
NERS 588. Radiation Safety and Medical Physics Practicum
Prerequisite: permission of instructor; mandatory satisfactory/ unsatisfactory. I, II, III, IIIa, IIIb (1-12 credits)
Individuals intern at a medical or industrial facility. Students concentrate on a specific radiological health engineering problem and participate in broader facility activities. Assignments are arranged by agreement among the student, faculty member, and facility personnel. This course may be repeated for up to 12 credit hours.
NERS 590. Special Topics in Nuclear Engineering and Radiological Sciences II
Prerequisite: permission of instructor. (to be arranged)
Selected advanced topics such as neutron and reactor physics, reactor core design, and reactor engineering. The subject matter will change from term to term.
NERS 599. Master's Project
Prerequisite: permission of instructor I, II, III, and IIIa or IIIb (1-3 credits)
Individual or group investigations in a particular field or on a problem of special interest to the student. The course content will be arranged at the beginning of each term by mutual agreement between the student and a staff member. This course may be repeated for up to 6 credit hours.
NERS 621 (MSE 621). Nuclear Waste Forms
Prerequisites: NERS 531 (recommended). I even years (3 credits)
This interdisciplinary course will review the materials science of radioactive waste remediation and disposal strategies. The main focus will be on corrosion mechanisms, radiation effects, and the long-term durability of glasses and crystalline ceramics proposed for the immobilization and disposal of nuclear waste.
NERS 622 (Mfg 622) (MSE 622). Ion Beam Modification and Analysis of Materials
Prerequisite: NERS 421, NERS 521 or MSE 351 or permission of instructor. II alternate years (3 credits)
Ion-solid interactions, ion beam mixing, compositional changes, phase changes, micro-structural changes; alteration of physical and mechanical properties such as corrosion, wear, fatigue, hardness; ion beam analysis techniques such as RBS, NRA, PIXE, ion channeling, ion microprobe; accelerator system design and operation as it relates to implantation and analysis.
NERS 644. Transport Theory
Prerequisite: Math 555. I (3 credits)
Mathematical study of linear transport equations with particular application to neutron transport, plasma physics, photon transport, electron conduction in solids, and rarefied gas dynamics; one-speed transport theory; Wiener-Hopf and singular eigen function methods; time-dependent transport processes; numerical methods including spherical harmonics, discrete ordinates, and Monte Carlo techniques; non-linear transport phenomena.
NERS 671. Theory of Plasma Confinement in Fusion Systems I
Prerequisite: NERS 572. I alternate years (3 credits)
Study of the equilibrium, stability, and transport of plasma in controlled fusion devices. Topics include MHD equilibrium for circular and non-circular cross section plasmas; magneto-hydrodynamic and micro-instabilities; classical and anomalous diffusion of particles and energy, and scaling laws.
NERS 672. Theory of Plasma Confinement in Fusion Systems II
Prerequisite: NERS 671. II alternate years (3 credits)
Study of the equilibrium, stability, and transport of plasma in controlled fusion devices. Topics include MHD equilibrium for circular and non-circular cross section plasmas; magneto-hydrodynamic and micro-instabilities; classical and anomalous diffusion of particles and energy, and scaling laws.
NERS 673. Electrons and Coherent Radiation
Prerequisite: NERS 471 or Physics 405. II (3 credits)
Collective interactions between electrons and surrounding structure studied. Emphasis given to generation of high power coherent microwave and millimeter waves. Devices include: cyclotron resonance maser, free electron laser, peniotron, orbitron, relativistic klystron, and crossed-field geometry. Interactions between electron beam and wakefields analyzed.

NERS 674 (Appl Phys 674). High Intensity Laser-Plasma Interactions
Prerequisite: NERS 471, NERS 571 or permission of instructor. I (3 credits)
Coupling of intense electromagnetic radiation to electrons and collective modes in time-dependent and equilibrium plasmas, ranging from underdense to solid-density. Theory, numerical models and experiments in laser fusion, x-ray lasers, novel electron accelerators and nonlinear optics.

NERS 799. Special Projects
(1-6 credits)
Individual or group investigations in a particular field or on a problem of special interest to the student. The project will be arranged at the beginning of the term by mutual agreement between the student and a staff member.

NERS 990. Dissertation/Pre-Candidate
Prerequisite: I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

NERS 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate I, II, III (8 credits); IIIa, IIIb (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Nuclear Engineering and Radiological Sciences Faculty

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Professors
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James J. Duderstadt, Ph.D.; *also University Professor of Science and Engineering; also U-M President Emeritus*
Rodney C. Ewing, Ph.D.; *also Geology and Materials Science and Engineering*
Ronald F. Fleming, Ph.D.
Ronald M. Gilgenbach, Ph.D.; *also Applied Physics*
James P. Holloway, Ph.D
Kimberlee J. Kearfott, Sc.D.; *also Biomedical Engineering*
Edward W. Larsen, Ph.D.
Y. Y. Lau, Ph.D. ; *also Applied Physics*
John C. Lee, Ph.D.
Lumin Wang, Ph.D.; *also Materials Science and Engineering*
Gary S. Was, Sc.D.; *also Materials Science and Engineering*
Professors Emeritus
A. Ziya Akcasu, Ph.D.; *also Macromolecular Science and Engineering*
Terry Kammash, Ph.D.
William Kerr, Ph.D.
John S. King, Ph.D.
Glenn F. Knoll, Ph.D.
Dietrich H. Vincent, Dr. Rer. Nat.
Associate Professors
Michael Atzmon, Ph.D.; *also Materials Science and Engineering*
John E. Foster, Ph.D.
Zhong He, Ph.D.
James P. Holloway, Ph.D.
David K. Wehe, Ph.D.
Adjunct Professors
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Mitchell M. Goodsitt, Ph.D.
Randall K. TenHaken, Ph.D.
Ruth F. Weiner, Ph.D.
Adjunct Associate Professor
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Adjunct Assistant Professor
Jeremy T. Busby, Ph.D.
Assistant Research Scientist
Mark Hammig, Ph.D.
Ling Jian Meng, Ph.D.
Research Investigator
Sebastian Teysseyre, Ph.D.

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Engineering Division Courses

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ENG 100. Introduction to Engineering
I, II (4 credits)
Focused team projects dealing with technical, economic, safety, environmental, and social aspects of a real-world engineering problem. Written, oral, and visual communication required within the engineering profession; reporting on the team engineering projects. The role of the engineer in society; engineering ethics. Organization and skills for effective teams.

ENG 101. Introduction to Computers and Programming
Prerequisite: prior or concurrent enrollment in Math 115 or equivalent. I, II (4 credits)
Algorithms and programming in C++ and MATLAB, computing as a tool in engineering, introduction to the organization of digital computers.

ENG 110. The Engineering Profession
I, II (2 credits)
This course provides exposure to each engineering discipline and helps undecided students select a major. Fundamentals from each engineering discipline are provided through formulating and solving engineering problems. Through this approach, it is expected that first year students will make better, more informed and more stable choices of a major.

ENG 195. Selected Topics in Engineering
(to be arranged)

ENG 280. Undergraduate Research
Prerequisite: permission of instructor. I, II, IIIa, IIIb (1-4 credits)
This course offers research experience to first- and second-year Engineering students in an area of mutual interest to the student and to a faculty member within the College of Engineering. For each hour of credit, it is expected that the student will work three hours per week. The grade for the course will be based on a final project/report evaluated by the faculty sponsor and participation in other required UROP activities, including bimonthly research group meetings and submission of a journal chronicling the research experience.

ENG 301. Engineering Undergraduate Study Abroad
Prerequisite: Student must have 4-5 semesters of foreign language for immersion programs and meet any other prerequisites designated by host university. I, II, III, IIIa, IIIb (1-16 credits)
Students planning to study abroad for fall, winter, spring, summer or spring/summer on College of Engineering approved Study Abroad programs should register under Engineering Division (258). Separate course sections will be listed for each different study abroad destination.

ENG 303 (CEE 303). Computational Methods for Engineers and Scientists
Prerequisite: Eng 101, Math 216. (Required for some programs; see your advisor) I, II (4 credits)
Applications of numerical methods to infrastructure and environmental problems. Development of mathematical models and computer programs using a compiled language (FORTRAN). Formulation and solution of initial and boundary-value problems with emphasis on structural analysis, fluid flow, and transport of contaminants. Lecture, recitation and computation.

ENG 371 (Math 371). Numerical Methods for Engineers and Scientists
Prerequisite: Eng 101 and Math 216, 256, 286 or 316. I, II (3 credits)
This is a survey course of the basic numerical methods which are used to solve scientific problems. In addition, concepts such as accuracy, stability and efficiency are discussed. The course provides an introduction to MATLAB, an interactive program for numerical linear algebra as well as practice in computer programming.

ENG 390. Special Topics in Engineering
Prerequisite: permission of instructor. (to be arranged)
Individual or group study of 300-level, undergraduate topics of current interest.

ENG 391. Directed Overseas Study
Prerequisites: Foreign language skills as necessary; sophomore standing. I, II, III, IIIa, IIIb (1-3 credits)
Directed overseas study in an industrial placement that is overseen by a faculty member at host institution in conjunction with academic courses taken as part of a study abroad program.

ENG 400. Engineering Cooperative Education
Prerequisite: permission of program director. I, II, III (no credit)
Off-campus work under the auspice of the cooperative education program. Engineering work experience in government or industry.

ENG 403. Scientific Visualization
Prerequisite: upper division or Graduate Standing. I (3 credits)
Introduces engineering and science students to scientific visualization principles of data display. Use of color to encode quantitative information. Display of 2- and 3-D scalar and vector data. Interactive computer techniques emphasized. Extensive hands-on practice. Project or research paper required.

ENG 450. Multidisciplinary Design
Prerequisite: Must meet individual engineering departmental requirements for Senior Design. II (4 credits)
A senior capstone interdisciplinary engineering design experience. The student is exposed to the design process from concept through analysis to system integration, prototyping, testing and report. Interdisciplinary projects are proposed from the different areas within engineering. Two hours of lecture and two laboratories.

ENG 477 (NA 477). Principles of Virtual Reality
Prerequisite: Senior Standing or permission of instructor. I (4 credits)
Enabling technologies (display systems, motion trackers, interactive devices, others), applications, human factors and perception, computer graphics and geometric modeling principles, creation of virtual environments, existing tools, special topics. Interdisciplinary group projects will develop VR applications using the facilities in the Duderstadt Center.
ENG 490 (Mfg 490). Special Topics in Engineering
Prerequisite: none. (to be arranged)
Individual or group study of topics of current interest selected by the faculty.
ENG 580 (ChE 580). Teaching Engineering
Prerequisite: Graduate Standing. II alternate years (3 credits)
Aimed at doctoral students from all engineering disciplines interested in teaching. Topics include educational philosophies, educational objectives, learning styles, collaborative and active learning, creativity, testing and grading, ABET requirements, gender and racial issues. Participants prepare materials for a course of their choice, including course objectives, syllabus, homework, exams, mini-lecture.
ENG 590. International Experience in Engineering
Prerequisite: Seniors and Grad Students of engineering only. I, II, III, IIIa, IIIb (2-8 credits)
This independent study course covers selected research areas in engineering. The topic and research plan must be approved by the instructor. A student is expected to participate in the planning of the course, visit a foreign research institution, participate in a research project (analytical and/or experimental), and write a report. The course may continue for more than one semester.
ENG 591. Engineering Graduate Study Abroad
Prerequisite: Student must have 4-5 semesters of foreign language for immersion programs and fulfill any other prerequisites designated by host university. I, II, III, IIIa, IIIb (1-16 credits)
Students planning to study abroad for fall, winter, spring, summer or spring/summer on College of Engineering approved Study Abroad programs should register under Engineering Division (258). Separate course sections will be listed for each different study abroad destination.
ENG 600. Engineering Practicum Projects
Prerequisite: Graduate Standing and permission of the department. I, II (8 credits)
This practice-oriented course is intended to provide students with industrial work experience in their academic discipline. Students may participate in individual or team projects in an industrial setting.
ENG 996. Responsible Research Practices
II (1-2 credits)
The Research Responsibility Program introduces concepts and policies relating the responsible practice of research. It does not provide opportunities for students to put what they are learning into practice in a scholarly context. The course is designed to provide the opportunity to apply what students are learning to the scholarly analysis of an issue that raises questions about responsible research practices. Attendance required.

Environmental Sciences and Engineering

Professor Phillip E. Savage
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The viability and ultimate long-term sustainability of the natural resources and ecosystems of planet Earth have become issues of increasing national and international priority. The professional activities of all engineers and scientists impact the availability and quality of these resources and ecosystems, and, in the sense of life-cycle reality, are in turn impacted by the availability, the quality, and the state of well-being of these resources and ecosystems. The College of Engineering offers several environmentally focused degree programs and endeavors in all of its undergraduate and graduate degree programs to weave a strong thread of environmental awareness, responsibility, and functional knowledge.

The Environmental Sciences and Engineering (ENSCEN) Division serves all environmentally related programs in the College of Engineering. At the graduate level it is associated most closely with the ConsEnSus Program, which is described (pg 237 of the bulletin), but it also serves as an aggregation and categorization of courses in the College, and in other units of the University that have been approved for incorporation in graduate degree programs in Environmental Engineering, such as that offered by the Department of Civil and Environmental Engineering. At the undergraduate level, ENSCEN serves the same functions with respect to identifying and categorizing courses across the University that can be used to satisfy departmental requirements or electives in areas of environmental sciences, engineering, policy, or law.

The courses listed in the ENSCEN Division are subdivided into three major categories with respect to programmatic content in order to facilitate reader orientation. These categories are: A. Environmental Science and Technology; B. Environmental Assessment Management and Policy; and C. Environmental Law and Regulations. Certain degree or concentration programs in the College, such as the ConsEnSus Program, specify required distributions of credit hours among these three programmatic categories of courses. Courses described elsewhere in this Bulletin are listed only by title, number, credit hours, and terms offered. More complete descriptions of those courses are given in the sections of the Bulletin for cross-listed depart-ments. Full descriptions are provided in the ENSCEN list for courses not described elsewhere in this Bulletin (e.g., courses offered in other schools and colleges).

Facilities

Facilities and Laboratories associated with specific programs in which enrolled and courses elected.

Accreditation

Accrues to relevant Departmental MSE/MS/PhD Program

Environmental Sciences and EngineeringMission

Increase the awareness and competency of undergraduate and graduate engineering students with respect to environmental issues they must address in the pursuit of their careers.

Goals

Facilitate faculty and student awareness of and access to formal courses relevant to environmental sustainability studies and concentrations (eg, *ConsEnSus Program*) at the University of Michigan

Environmental Sciences and Engineering Graduate Education Graduate Degrees

The ENSCEN Division is not a degree granting unit of the College of Engineering. See *ConEnSus Program* for relevant graduate concentration opportunities.

Environmental Sciences and Engineering Division Courses

A. Environmental Science and Technology

ENSCEN 211 (NERS 211). Introduction to Nuclear Engineering and Radiological Sciences
Prerequisite: preceded or accompanied by Math 216. II (4 credits)

ENSCEN 304 (AOSS 304). The Atmospheric and Oceanic Environment
Prerequisite: Physics 140, Math 116, Chem130. I (3 credits)

ENSCEN 305 (AOSS 305). Introduction to Atmospheric and Oceanic Dynamics
Prerequisite: AOSS 304, Math 215. II (3 credits)

ENSCEN 408 (AOSS 408). Environmental Problem Solving with Computers
Prerequisite: Eng 103, Math 216. I (3 credits)

ENSCEN 420 (NA 420) (AOSS 420). Environmental Ocean Dynamics*
Prerequisites: NA 320 or AOSS 305 or CEE 325. I (4 credits)

ENSCEN 430 (AOSS 430). Thermodynamics of the Atmosphere
Prerequisite: preceded or accompanied by Math 216. II (3 credits)

ENSCEN 434 (AOSS 434). Mid-Latitude Cyclones
Prerequisite: AOSS 414 or AOSS 451. II (3 credits)

ENSCEN 451 (AOSS 451). Atmospheric Dynamics I
Prerequisite: AOSS 401. II (3 credits)

ENSCEN 458 (AOSS 458). Principles and Applications of Visible and Infrared Remote Sensing
Prerequisite: Math 216, Physics 140 or equivalent. I (3 credits)

ENSCEN 459 (AOSS 459). Principles and Applications of Radio and Active Remote Sensing
Prerequisite: Math 216, Physics 140. II (3 credits)
**ENSCEN 463 (AOSS 463). Air Pollution Meteorology*
Prerequisite: none. II (3 credits)
ENSCEN 464 (Aero 464) (AOSS 464). The Space Environment
Prerequisite: Senior or Graduate Standing in a physical science or engineering. I (3 credits)
ENSCEN 465 (AOSS 465). Space System Design for Environmental Observations
Prerequisite: Senior Standing. I (3-4 credits)
ENSCEN 467 (AOSS 467) (Chem 467) (Geol Sci 465). Biogeochemical Cycles *
Prerequisite: Math 116, Chem 210, Physics 240. I (3 credits)
ENSCEN 475 (AOSS 475). Earth-Ocean-Atmosphere Interactions*
Prerequisite: Senior Standing. II (3 credits)
ENSCEN 479 (AOSS 479). Atmospheric Chemistry*
Prerequisite: Chem 130, Math 216. I (3 credits)
ENSCEN 484 (NERS 484). (BiomedE 484) Radiological Health Engineering Fundamentals*
Prerequisite: NERS 312 or equivalent or permission of instructor. I (4 credits)
ENSCEN 495 (AOSS 495). Thermosphere and Ionosphere
Prerequisite: AOSS 464. II alternate years (3 credits)
ENSCEN 500 (CEE 500) (ChemE 500). Environmental Systems and Processes I
Prerequisite: CEE 460 or equivalent. I (3 credits)
ENSCEN 528 (CEE 528). Flow and Transport in Porous Media*
Prerequisite: CEE 428 or equivalent. II (3 credits)
ENSCEN 533 (Aero 533). Combustion Processes
Prerequisite: Aero 320. (3 credits)
ENSCEN 563 (AOSS 563). Air Pollution Dispersion Modeling
Prerequisite: AOSS 463. II (3 credits)
ENSCEN 564 (AOSS 564). The Stratosphere and Mesosphere
Prerequisite: AOSS 464. II odd years (3 credits)
ENSCEN 575 (AOSS 575). Air Pollution Monitoring*
Prerequisite: AOSS 463, AOSS 578, NRE 538 (previously or concurrently). II (3 credits)
ENSCEN 576 (AOSS 576). Air Quality Field Project
Prerequisite: AOSS 578, NRE 538, AOSS 575, or AOSS 563. IIIa (4 credits)
ENSCEN 686 (CEE 686) (ChemE 686). Case Studies in Environmental Sustainability
Prerequisite: Senior or graduate standing. II (2-3 credits)
B. Environmental Assessment, Management, and Policy
ENSCEN 100 (NERS 100). Radiation and the Environment
Prerequisite: none. I, II (2 credits)
ENSCEN 105 (AOSS 105) (Chem 105). Our Changing Atmosphere
Prerequisite: none. I, II (3 credits)
ENSCEN 123 (AOSS 123) (Geol Sci 123) (SNRE 123). Life and the Global Environment
Prerequisite: none. II (2 credits)
ENSCEN 171 (AOSS 171) (Biol 110) (Univ Course 110) (SNRE 110) (Geol Sci 171). Introduction to Global Change-Part I
Prerequisite: none. I (4 credits)
ENSCEN 202 (AOSS 202). The Atmosphere
Prerequisite: none. I, II (3 credits)
ENSCEN 203 (AOSS 203). The Oceans
Prerequisite: none. I, II (3 credits)
ENSCEN 531 (NERS 531). Nuclear Waste Management*
Prerequisite: Senior Standing. II (3 credits)
ENSCEN 534 (CSIB 564) Strategy for Environmental Management
Prerequisite: CSIB 502. (1.5 credits)
This course builds environmental awareness and literacy for strategic corporate managers. It focuses on how environmental problems and pressures currently impact competitive strategy, technology choices and production and marketing decisions. Environmental challenges, regulations, and values are explored in terms of business risk and opportunity. Companies at the leading edge of environmental management are pro?led via cases and visiting speakers.
ENSCEN 535 (CSIB 565). Strategy for Sustainable Development
Prerequisite: CSIB 564. (1.5 credits)
This course examines the long-term strategic implication of the growing call for sustainable development, i.e., satisfying lives for all within the means of nature. It focuses on the natural and social state of the planet, the ethics and meanings of sustainability, and the business logics bearing upon the transition to sustainable enterprise. Emphasis is placed on transformational leadership in the face of the radical technological, social, economic and institutional changes.
ENSCEN 585 (CEE 585). Solid Waste Management
I (3 credits)
ENSCEN 587 (Nat Res 558). Water Resource Policy *
Prerequisite: Senior or Graduate Standing. I (3 credits)

ENSCEN 588 (EHS 672). Radiological Assessment and Risk Evaluation
Prerequisite: Graduate Status, EHS 583 and EHS 670 or permission of instructor. I (3 credits)
ENSCEN 589 (Nat Res 595). Risk and Benefit Analysis in Environmental Engineering*
Prerequisite: Senior or Graduate Standing. II (3 credits)
C. Environmental Laws and Regulations
ENSCEN 699 (EHS 699). Hazardous Wastes: Law Regulation, Remediation, and Worker Protection*
Prerequisite: Graduate Standing and EHS 503 or EHS 508 or EHS 541 or EHS 650 or EHS 667 or permission of instructor. (3 credits)

***** Denotes courses approved for the ConsEnSus Program***

Study Abroad

Study Abroad
245 Chrysler Center
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College of Engineering Study Abroad Programs

The International Programs in Engineering (IPE) office sponsors full-year, one-semester and summer study abroad programs. English language programs are available in Asia, Australia, Europe, Latin America and the Middle East. Foreign language immersion programs are available for students with the requisite skills.

IPE staff members advise students about program options and provide assistance with applications and credit evaluation. Both graduate and undergraduate students with a good academic record are eligible to participate in College of Engineering study abroad programs.

The IPE office also provides resources for locating funding and maintains a searchable scholarship database. Most forms of student financial aid can be applied to College of Engineering study abroad programs .

Non-College of Engineering Study Abroad Programs

The LS&A Office of International Programs (OIP) offers study abroad programs that are open to College of Engineering students. Students considering an OIP study abroad program must consult the International Programs in Engineering office to determine applicability of credit to engineering degree requirements. For CoE students, grades from OIP programs will not be calculated into the cumulative GPA.

If students decide to pursue a study abroad program that is not sponsored by a UM office, transfer credit will only be awarded if the program sponsor is a fully accredited institution of higher learning and an official transcript is furnished by that institution. Those who contemplate non-UM study abroad should consult the International Programs in Engineering Office prior to enrollment if transfer credit is desired.

Course Listings

ENGR 301. Engineering Undergraduate Study Abroad

Prerequisite: Student must have 4-5 semesters of foreign language for immersion programs and meet any other prerequisites designated by host university. I, II, III, IIIa, IIIb (1-16 credits)

Undergraduate students planning to study abroad for fall, winter, spring, summer or spring/summer on College of Engineering approved Study Abroad programs should register under Engineering Division (258), course #301. Separate course sections will be listed for each different study abroad destination.

ENGR 391. Directed Overseas Study

Prerequisite: Foreign language skills as necessary; sophomore standing. I, II, III, IIIa, IIIb (1-3 credits)

Directed overseas study in an industrial placement that is overseen by a faculty member at host institution in conjunction with academic courses taken as part of a study abroad program.

ENGR 591. Engineering Graduate Study Abroad

Prerequisite: Student must have 4-5 semesters of foreign language for immersion programs and meet any other prerequisites designated by host university. I, II, III, IIIa, IIIb (1-16 credits)

Graduate students planning to study abroad for fall, winter, spring, summer or spring/summer on College of Engineering approved Study Abroad programs should register under Engineering Division (258), course #591. Separate course sections will be listed for each different study abroad destination.

Technical Communication

Technical Communication
301 EPB
Phone: (734) 764-1427

The courses listed provide senior-year and graduate students with intensive training in communication.

Technical Communication Courses

TechComm 215. Technical Communication for Electrical and Computer Engineering

Prerequisite: Engineering 100, Corequisite: EECS 215. I, II (1 credit)

Professional communication to the general public, managers, and other professionals about electrical and computer engineering ideas. Functional, physical and visual/diagrammatic description. Report writing about circuits, signals, and systems, including description and analysis. Job letters and resumes.

TechComm 281. Technical Communication for Computer Science and Engineering

Prerequisite: Engineering 100, Corequisite: EECS 281. I, II (1 credit)

Introduction to professional communication for computer scientists and engineers. Communication to managers and programmers about data structures, algorithms, and programs. Coding conventions and documentation. Functional and visual/diagrammatic descriptions. Letters of transmittal and reports on software systems. Job letters and resumes.

TechComm 300. Technical Communication for Electrical and Computer Science

Prerequisite: Engineering 100, I,II (1 credit)

Professional communication to the general public, managers, and other professionals about electrical and computer engineering ideas as presented in written reports and oral presentations. Functional, physical and visual/diagrammatic description; job letters and resumes.

TechComm 380. Technical Communication in IOE

Prerequisite: preceded or accompanied by IOE 366 and 373. I, II (2 credits)

Successful professional and technical communication commands a wide range of skills, including critical inquiry, analysis and collaboration. Through regular practice, feedback, reflection and revision, this course examines technical communication principles and how to apply them in IOE environments. Specifically, the course emphasizes strategies for effective argumentation and persuasion as well as effective language use and style in written reports and oral presentations intended for IOE audiences.

TechComm 450. Web Page and Site Design

Prerequisite: junior or senior standing. I, II (4 credits)

Practical skills and theoretical principles necessary to design effective WWW pages and sites, including HTML, tools for creating Web pages, graphics, scripting, animation, multimedia (practical skills) and information design, visual design, and theoretical principles (theory). Design and analysis of Web sites.

TechComm 496. Advanced Technical Communication for Electrical Engineering and Computer Engineering

Requisites: TC 300 Co-Requisites: Senior Design Course. I, II (2 credits)

Development of advanced communication skills required of electrical and computer engineers and managers in industry, government, and business. Design and writing of reports, proposals, and memoranda on complex technical material for diverse organizational audiences. Preparation and delivery of organizational oral presentations and briefings.

TechComm 497. Advanced Technical Communication for Computer Science

Prerequisite: TechComm 300 Co-Requisites: Major Design Experience Course in Computer Science. I, II (2 credits)

Advanced technical communication for computer science. Design and writing of user and task analysis, requirements documents, specifications, proposals, reports and documentation, all aimed at diverse organizational audiences. Preparation and delivery of final oral presentations and written project reports.

TechComm 498. Technical and Professional Writing for Industry, Government, and Business

Prerequisite: senior or graduate standing. I, II, IIIa, IIIb (3 credits)

Development of the communication skills required of engineers and managers in industry, government, and business. Focus on (1) the design and writing of reports and memoranda that address the needs of diverse organizational audiences and (2) the preparation and delivery of organizational oral presentations and briefings. Writing and speaking about design and research problems in terms that will satisfy both specialists and non-specialists. A series of short explanatory papers and speeches leading up to a final formal report and public lecture.

TechComm 499. Scientific and Technical Communication

Prerequisite: permission of Technical Communication faculty. (elective credit only)

Conferences and tutorial sessions that provide opportunities for students with special interests to work on a tutorial basis with a member of the Technical Communication faculty. Not intended as substitutes for regularly scheduled courses. Conference and signed contract required with an instructor about the proposed study before enrollment possible. (Directed Study contract forms and additional information are available from the Technical Communication office.)

TechComm 575. Directed Study

Prerequisite: permission of instructor. I, II, IIIa, IIIb (to be arranged)

Conferences and tutorial sessions for students with special interests. May be taken for 1-4 credit hours as arranged by the instructor.

TechComm 610. Dissertation, Dissertation Proposal, and Thesis Writing

Prerequisite: graduate standing. I, II (3 credits)

Intended for American and foreign students writing their dissertations, dissertation proposals, or theses. Writing guidelines and their scientific base for problem definition and literature review; argument structures for the discussion of problems criteria, methodology, results, and conclusions; selection and ordering of information; editing visual aids; and special grammatical problems.

TechComm 675. Directed Study

Prerequisite: graduate standing, permission of instructor. I, II, IIIa, IIIb (to be arranged)

Conferences and tutorial sessions for students with special interests. May be taken for 1-4 credit hours as arranged by the instructor.

Technical Communication Faculty

Technical Communication
301 Engineering Programs Building
Phone: (734) 764-1427
Leslie A. Olsen, Ph.D., *Professor*
Professors Emeritus
J.C. Mathes, Ph.D.
Dwight W. Stevenson, Ph.D.
Associate Professors Emeritus
Rudolf B. Schmerl, Ph.D.
Peter R. Klaver, Ph.D.
Lecturers
Mimi Adam, M.A.
Jack Fishstrom, M.A.
Elizabeth Girsch, M.A., Ph.D.
Erik Hildinger, J.D.
Rod Johnson, Ph.D.
Pauline Khan, M.S.
Mary Lind, M.A.
Peter Nagourney Ph.D.
Robert Sulewski, Ph.D.
Michael Tolinski, M.A.
Deborah Van Hoewyk, M.A.
Richard Wallace, M.S.
Fred C. Ward, M.S.

Applied Physics

Division Office
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Ann Arbor, MI 48109
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The quickening pace of development at the frontier between physics and engineering creates a need for interdisciplinary training and research which is not readily accommodated by traditional single-focus graduate programs. The University of Michigan Applied Physics Program is designed to fill this gap, providing students with the opportunity to gain a solid base in the fundamentals of modern physics while exploring applications in the context of various branches of engineering.

The program, which spans the Physical Science Division of the College of Literature Science and the Arts and the College of Engineering, offers graduate studies leading to the Doctor of Philosophy (Ph.D.) degree in Applied Physics. Coursework and research are structured to meet individual goals so that the program is appropriate for students intending to pursue careers in industry, academia, or government service.

From nonlinear optics to the latest developments in ultramicroscopy, Michigan has a distinguished record of innovation in applied physics. With a broad range of multidisciplinary research, and access to the most advanced facilities, the program offers a dynamic environment for graduate training. The opportunities and challenges for bridging science and technology have never been more exciting, nor the potential impact on our society's needs greater. The University of Michigan Applied Physics Program is committed to a leading role in this endeavor. .

Applied Physics Graduate Education

Admission Criteria for the Ph.D. Degree

The Applied Physics Program is designed for students intending to pursue coursework and research leading to the Ph.D. degree. Accordingly, students are not admitted as candidates for the Master of Science degree. However, our students are usually eligible to receive a Masters degree in Applied Physics or Electrical Engineering at the time they become candidates for the Ph.D. degree.

A completed application and transcripts of all previous academic records must be on file.

The admission committee will take into account the applicant's background in the physical sciences, engineering physics and related disciplines. A good grounding in basic physics is expected with at least 15 hours of introductory and intermediate coursework in classical mechanics, statistical physics, electricity and magnetism, and quantum physics. Graduate Record Examination general scores are required and the GRE Subject Test in Physics is recommended. Three letters of recommendation must be submitted. At least two of the letters must be from an academic institution. Students from non-English-speaking countries are required to demonstrate proficiency in English via the TOEFL examination. The minimum score for admission is 560.

Applications will be processed for Fall term admission. The deadline for applications for financial aid consideration is February 1.

Requirements for the Ph.D. Degree

The curriculum leading to the Ph.D. degree in Applied Physics combines coursework in the fundamentals of physical theory, its applications to modern technology, and practical "hands-on" training in the research laboratories.

Applied Physics is administered as an intercollegiate degree program with participating faculty in the College of Literature Science and the Arts, and the College of Engineering. General admission and degree requirements are administered by the Horace Rackham Graduate School. The program is normally four to five years with an emphasis on coursework during the first two years. Students are encouraged to become involved in research at the earliest opportunity and are required to complete a supervised research project in their first year. When students complete the basic academic core, have satisfied the qualification procedure (see below), have formed a Dissertation Committee, and have obtained approval for their Dissertation Prospectus, they are eligible for admission to Candidacy for the Ph.D. Candidacy is normally achieved after four or five semesters of graduate work.

Candidacy

In order to achieve candidacy and form a dissertation committee, seven prescribed 500 level courses must be passed with a grade B or better. In addition, four elective courses (chosen in consultation with the program advisor according to the student's research needs) must be completed satisfactorily. Satisfactory completion of one four-credit hour course on non-thesis research is also required, under the supervision of a faculty member. Prior approval by the program committee must be obtained before beginning this supervised research course. All first, second, and third year students are required to enroll in the weekly seminar course (AP 514).

Qualifying Procedure

The decision to qualify a student for Ph.D. study is based on the student's academic record, performance in a four-credit hour supervised research project, and the results of a two-part qualifying examination. The first part of the qualifying examination consists of a written examination on basic undergraduate-level physics. The second part of the qualifying examination is an oral examination, beginning with a brief presentation of the student's supervised research followed by questions on standard undergraduate-level physics. The student is expected to qualify within two years of entering the graduate program.

Preliminary Examination

A preliminary examination of the plans for dissertation research will be made by the student's Dissertation Committee. The preliminary examination will take the form of a presentation to the committee of a Dissertation Prospectus stating the objectives and proposed methods of investigation. Over the signatures of the Dissertation Committee, the program committee will authorize the student to proceed with the thesis research.

Students normally will have formed their Dissertation Committee by the end of their fifth term in graduate school. Approval of the Dissertation Prospectus is a program requirement prior to Candidacy.

Applied Physics Courses

AP 514. Applied Physics Seminar

Prerequisite: graduate studies. I, II (1 or 2 credits)

Graduate seminars are required each term to familiarize students with current research and problems. Given by a mix of faculty, external lecturers, and the students themselves to acquaint students with the scope of research activity and opportunities, the goal of the seminar structure is to promote a strong interaction among the interdisciplinary work being done in applied physics.

AP 518. (Elective) Microcomputers in Experimental Research

I (3 credits)

A graduate-level laboratory course in the application of computers to experimental research, this course is designed to give students hands-on experience of modern techniques of data acquisition, data handling and analysis, and graphical presentation of results, using microcomputers. A number of experiments will be carried out which illustrate how to interface modern research instrumentation in a variety of commonly encountered experimental situations.

AP 530 (EECS 530). Electromagnetic Theory I

Prerequisite: EECS 330 or Physics 438. I (3 credits)

Maxwell's equations, constitutive relations and boundary conditions. Potentials and the representation of electromagnetic fields. Uniqueness, duality, equivalence, reciprocity and Babinet's theorems. Plane, cylindrical, and spherical waves. Waveguides and elementary antennas. The limiting case of electro- and magneto-statics.

AP 537 (EECS 537). Classical Optics

Prerequisite: EECS 330 and EECS 334. I (3 credits)

Theory of electromagnetic, physical, and geometrical optics. Classical theory of dispersion. Linear response, Kramers-Kronig relations, and pulse propagation. Light scattering. Geometrical optics and propagation in inhomogeneous media. Dielectric waveguides. Interferometry and theory of coherence. Diffraction, Fresnel and Fraunhofer. Gaussian beams and ABCD law.

AP 540 (EECS 540). Applied Quantum Mechanics I

Prerequisite: permission of instructor. I (3 credits)

Introduction to nonrelativistic quantum mechanics. Summary of classical mechanics, postulates of quantum mechanics and operator formalism, stationary state problems (including quantum wells, harmonic oscillator, angular momentum theory and spin, atoms and molecules, band theory in solids), time evolution, approximation methods for time independent and time dependent interactions including electromagnetic interactions, scattering.

AP 541 (EECS 541). Applied Quantum Mechanics II

Prerequisite: AP 540 or EECS 540. I (3 credits)

Continuation of nonrelativistic quantum mechanics. Advanced angular momentum theory, second quantization, non-relativistic quantum electrodynamics, advanced scattering theory, density matrix formalism, reservoir theory.

AP 546 (EECS 546). Ultrafast Optics

Prerequisite: EECS 537. II (3 credits)

Propagation of ultrashort optical pulses in linear and nonlinear media, and through dispersive optical elements. Laser mode-locking and ultrashort pulse generation. Chirped-pulse amplification. Experimental techniques for high time resolution. Ultrafast Optoelectronics. Survey of ultrafast high field interactions.

AP 550 (EECS 538) (Physics 650). Optical Waves in Crystals

Prerequisite: EECS 434. I (3 credits)

Propagation of laser beam: Gaussian wave optics and the ABCD law. Crystal properties and the dielectric tensor; electro-optic effects and devices; acousto-optic diffraction and devices. Introduction to nonlinear optics: coupled mode theory and second harmonic generation; phase matching.

AP 551 (EECS 539) (Physics 651). Lasers

Prerequisite: EECS 537 and EECS 538. II (3 credits)

Complete study of laser operation: the atom-field interaction; homogeneous and inhomogeneous broadening mechanisms; atomic rate equations; gain, amplification and saturation; laser oscillation; laser resonators, modes, and cavity equations; cavity modes; laser dynamics, Q-switching and modelocking. Special topics such as femto-second lasers and ultrahigh power lasers.

AP 552 (EECS 552). Fiber Optical Communications

Prerequisite: EECS 434 or EECS 538 or permission of instructor. II odd years (3 credits)

Principles of fiber optical communications and networks. Point-to-point systems and shared medium networks. Fiber propagation including attenuation, dispersion and nonlinearities. Topics covered include erbium-doped amplifiers, Bragg and long period gratings, fiber transmission based on solitons and non-return-to-zero, and time- and wavelength-division-multiplexed networks.

AP 601 (Physics 540). Advanced Condensed Matter

(3 credits)

A unified description of equilibrium condensed matter theory (using Green's functions); critical phenomena, Anderson localization and correlated electron theory.

AP 609 (EECS 638) (Physics 542). Quantum Theory of Light

Prerequisite: quantum mechanics electrodynamics and atom physics. I even years. (3 credits)

The atom-field interaction; density matrix; quantum theory of radiation including spontaneous emission; optical Bloch equations and theory of resonance fluorescence; coherent pulse propagation; dressed atoms and squeezed states; special topics in nonlinear optics.

AP 611 (EECS 634) (Physics 611). Nonlinear Optics

Prerequisite: EECS 537 or EECS 538 or EECS 530. I (3 credits)

Formalism of wave propagation in nonlinear media; susceptibility tensor; second harmonic generation and three-wave mixing; phase matching; third order nonlinearities and four-wave mixing processes; stimulated Raman and Brillouin scattering. Special topics: nonlinear optics in fibers, including solitons and self-phase modulation.

AP 619 (Physics 619). Advanced Solid State Physics

Prerequisite: 520 (or 463), Physics 511, Physics 510 or permission of instructor. (3 credits)

Photon, neutron, and electron scattering in condensed matter: elastic and inelastic scattering in condensed matter. The theory of neutron, electron, and photon (Rayleigh, Brillouin, Raman, and x-ray) scattering will be presented with an overview of the corresponding experimental techniques; linear response theory, fluctuation-dissipation theorem, elementary excitations in condensed matter, hydrodynamics and symmetry analysis using group theory. AP 633 (Physics 633). Fluid Dynamics

AP 633 (Physics 633). Fluid Dynamics

(3 credits)

The course begins with a derivation of the hydrodynamical equations as prototypical phenomenological equations, based on general conservation laws and the second law of thermodynamics; two dimensional ideal fluid flow, the Joukowsky theory of the airfoil, gravity waves and the theory of tides, solitary waves, incompressible viscous flow and the Stokes formula, Sommerfeld's theory of lubrication, the turbulent wake, Prandtl's theory of the boundary layer, shock waves, relativistic hydrodynamics, fluctuations in hydrodynamics, etc.

AP 644 (Physics 644). Advanced Atomic Physics

(3 credits)

Laser atom interactions: Absorption, emission, and saturation, theory of line width, multiphoton absorption, stimulated and spontaneous Raman scattering; single photon, multiphoton and above-threshold ionization; Rydberg physics; AC stark shifts and ponderomotive effects; multichannel quantum defect theory; Floquet theory; Mechanical effects of light on atoms (atom traps, molasses), atom interferometry.

AP 669 (Chem 669). Physics of Extended Surfaces

Prerequisite: quantum mechanics or solid state physics, or permission of instructor. (3 credits)

Chemical physics of extended surfaces: basic surface phenomena which control the physical and chemical properties of extended surfaces. A wide range of surface methods and issues regarding metal, semiconductor and insulator surfaces will be discussed. Fundamental principles regarding the geometric and electronic structure of surfaces, adsorption-desorption processes, surface reactions, and ion-surface interactions will be discussed.

AP 672 (NERS 572). Intermediate Plasma Physics II

Prerequisite: NERS 571. II (3 credits)

Waves in non-uniform plasmas, magnetic shear; absorption, reflection, and tunneling gradient-driven microinstabilities; BGK mode and nonlinear Landau damping; macroscopic instabilities and their stabilization; non-ideal MHD effects.

AP 674 (NERS 674). High-Intensity Laser Plasma Interactions

Prerequisite: NERS 471, NERS 571 or permission of instructor. (3 credits)

Coupling of intense electromagnetic radiation to electrons and collective modes in time-dependent and equilibrium plasmas, ranging from underdense to solid-density. Theory, numerical modes and experiments in laser fusion, x-ray lasers, novel electron accelerators and nonlinear optics.

Applied Physics Faculty

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Please visit our faculty site for a list of current faculty, including contact information.

Concentrations in Environmental Sustainability (ConsEnSus)

Implementation of sustainable engineering practices in industry has created a demand for engineers skilled in both rigorous disciplinary background (i.e. Civil, Chemical, Electrical, Mechanical, etc. engineering) and working knowledge of environmental regulations, policies, and practices. The Concentrations in Environmental Sustainability (ConsEnSus) Program is designed to prepare students to meet this demand by providing the opportunity to pursue an MSE degree in a traditional engineering discipline coupled with advanced study in issues relating to engineering practices that will ensure environmental sustainability. The concentration comprises a coherent sequence of courses designed to enhance general environmental literacy and prepare students to integrate environmental principles into professional practice.

Successful completion of the ConsEnSus Program requires a completion of twelve credits of coursework in environmental sustainability. Two specific courses comprising six credit hours of instruction are required of all ConsEnSus participants. These include a choice between ME 599 Scientific Foundations for Environmental Improvement in Manufacturing or CEE 586/NRE 557 Industrial Ecology, and the course ChE/CEE 686, Case Studies in Environmental Sustainability elected for three credits. The remaining six credit hours for the concentration designation coupled with a specific disciplinary degree may be selected from a list of courses approved by the Director and the Program Advisor in a participating department. Courses are divided into three categories: Environmental Law and Regulations; Environmental Assessment and Policy; and Environmental Science and Technology. The six elective credit hours required for completion of the ConsEnSus concentration must be selected such that the student completes courses from at least two of three course categories, with a maximum of three credits from Environmental Law and Regulations and up to six from Environmental Assessment and Policy. A complete course list can be viewed at http://www.engin.umich.edu/prog/consensus/.

Participating College of Engineering departments at the time of this publication include:

- Atmospheric, Oceanic and Space Sciences
  Lead Advisor: Professor Perry Samson, samson@umich.edu, (734)763-6213
- Civil and Environmental Engineering
  Lead Advisor: Professor Terese Olson, tmolson@umich.edu, (734)647-1747
- Chemical Engineering
  Lead Advisor: Professor Bob Ziff, rziff@umich.edu, (734)763-0459
- Mechanical Engineering
  Lead Advisor: Professor Steve Skerlos, skerlos@umich.edu , (734)615-5253
- Naval Architecture and Marine Engineering
  Lead Advisor: Professor Guy Meadows, gmeadows@umich.edu, (734)764-5235

Please contact the home department Lead Advisor or visit http://www.engin.umich.edu/prog/consensus/.

Interdisciplinary Professional Programs (InterPro)

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The University of Michigan College of Engineering established InterPro-the Office of Interdisciplinary Professional Programs-to foster cooperation among disciplines within the College of Engineering and throughout the University of Michigan. InterPro serves as the conduit for incorporating the best practices of existing interdisciplinary programs into new ones and develops programs that are responsive to the needs of industry and professional engineers. Graduate programs currently offered through InterPro include:

- Automotive Engineering
- Financial Engineering
- Global Automotive and Manufacturing Engineering
- Integrated MicroSystems
- Manufacturing Engineering
- Pharmaceutical Engineering

Automotive Engineering
Degree Programs
M.Eng. in Automotive Engineering
Sequential Graduate/Undergraduate Degree

The Master of Engineering in Automotive Engineering is an advanced professional degree program designed specifically for today's modern engineering world. It is intended for engineers who desire to pursue and enhance careers in the automotive industry or in government laboratories with automotive research, development, or regulatory programs. The M.Eng. degree program emphasizes engineering practice and is ideally suited to working engineers who desire broader graduate experience but may not be able to take full time leave from work.

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The M.Eng. degree in Automotive Engineering requires a total of 30 credit hours of course work, of which at least 27 credit hours must be graded, and at least 21 credit hours must be in courses at the 500-level and above. A minimum grade point average of 5.0/9.0 ("B" average) is also required. The credits will be distributed in categories arranged to meet the degree's objectives:

1. *Systems Engineering Core (9 credits, graded)*
   One course should be selected per area from three core areas: Engineering Systems, Powertrain, Vehicle.
2. *Engineering Electives (9 credits; graded)*
   The student must take at least three courses in the following engineering disciplines: Design and Manufacturing, Electronics, Energy, Materials, Noise, Vibration and Harshness, Ride and Handling.
3. *Management and Human Factors (6 credits; graded)*
   Two courses must be taken in the Management and Human Factors core on business and management, ergonomics and human factors, law and professional ethics, operations research, etc.
4. *Automotive Engineering Seminar and Project (6 credits, AUTO 501, (graded); AUTO 503)*
   To provide a significant and industrially relevant team-project experience, a series of seminars will expose students to the wide spectrum of automotive engineering. A capstone project will synthesize the student's knowledge and apply it to an industrially relevant problem.
5.

Applicants are expected to have a bachelor's degree in engineering or a related science. The prerequisites for admission include at least two years of college engineering mathematics; undergraduate course work in at least three of the engineering core areas of Automotive Engineering; and the equivalent of two years of full-time industrial experience in Automotive Engineering. The Graduate Record Examination (General Test) is recommended but not required.
A full-time student can complete the degree program in one calendar year.

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Financial Engineering
M. S. in Financial Engineering

The Financial Engineering Program consists of 36 credit hours leading to the Master of Science in Financial Engineering degree. Graduates are uniquely qualified for a wide range of career opportunities in financial services, banking, insurance, government agencies, energy companies in areas such as financial modeling, derivatives analytics, hedging, risk management and information technology.

Prerequisites:

Entering students should have a strong mathematical background similar to that of University of Michigan undergraduates majoring in IOE, Mathematics and Statistics (with applied concentrations), EECS (with economic interests), Economics or Business (with technical interests). In particular, students should have previously completed:

- Two years of college mathematics including multivariable calculus, differential equations and linear algebra (Math 115, 116, 215, {216 or 316}, {214 or 217 or 417 and 419})
- Two terms of calculus-based probability and statistics (Math/Stat 425 and Stat 426 or IOE 265 and 316/366 or EECS 401 and Stat 426)
- Basic microeconomic theory/time value of money/interest: (Econ 401 or Math 424)
- An introductory finance course (FIN 503)
- Accounting principles (ACC 471 or ACC 501)
- Computer programming experience (EECS 183, C or C++ and spreadsheets)

Courses shown in parentheses indicate University of Michigan courses that typically cover the prerequisite material.

Required core:

All students must complete a required core of courses covering financial concepts in capital budgeting, financial markets, and derivative instruments and securities, analytical tools in optimization, stochastic -processes- and statistics

Electives/Concentration Areas:

In addition to the core courses students must take 3 elective courses chosen in consultation with an advisor to form a concentration area. Examples of concentrations areas are:

- Capital Markets
- Insurance/risk management systems, forecasting
- Operations and information systems

Program Length:

Students with sufficient background and experience (for example, those who are already studying towards a graduate technical degree at U-M) could complete the program in three terms. Students with limited experience and less developed backgrounds would benefit from an internship and a three to four term experience.

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Professor S. Jack Hu Program in Manufacturing

Global Automotive and Manufacturing Engineering
M.Eng. in Global Automotive and Manufacturing Engineering

The Masters of Engineering in Global Automotive and Manufacturing Engineering is a graduate professional degree in engineering for students who have already earned a B.S.E. degree in any field of engineering (e.g., aerospace, mechanical, electrical, civil, industrial, naval, chemical, material science) and who already have industrial work experience. The degree offers global contents, integrates automotive design and manufacturing, provides students with depth in engineering specialty as well as breadth in engineering and business integration.

A total of 30 credit hours, including 3 credits that satisfy the "global experience" is required for graduation, and at least 24 credit hours must be in courses at the 500-level or above. Admission requirements are similar to other master's degree programs in the College of Engineering, except the additional requirement in industrial working experience.

Admitted students in M. Eng. In Automotive and Manufacturing Engineering program must take a global component as part of the curriculum.

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The Master of Engineering (M.Eng.) in Manufacturing is a graduate professional degree in engineering for students who have already earned a B.S.E. degree in any field of engineering (e.g., aerospace, mechanical, electrical, civil, industrial, naval, chemical, materials science), and who have relevant industrial experience.

A total of 30 credit hours is required and at least 24 credit hours must be in courses at the 500-level and above. Entrance requirements are similar to other master's degree programs in the College of Engineering, except that entering students are expected to have the equivalent of two years of full-time relevant industrial experience. Students with outstanding qualifications who do not have two years of industrial experience may be considered for admission if they have relevant summer internship or co-op experience.

Prerequisites for admission include:

1. at least two years of college engineering mathematics (including probability and statistics)
2. a course in manufacturing processes.

Admitted students in the M.Eng. in Manufacturing program must take the course sequence Topics in Manufacturing (Mfg 501); and Manufacturing Project (Mfg 503). Lists of acceptable courses in each distribution area are available; substitutions require the approval of the program advisor.

Joint M.Eng./M.B.A. in Manufacturing

The School of Business Administration and the Program in Manufacturing within the College of Engineering Graduate Studies offer a joint degree program that enables qualified people to pursue concurrent work in business administration and manufacturing studies leading to the M.B.A. and M.Eng. in Manufacturing degrees. The program is arranged so that all requirements are satisfied simultaneously.

This joint degree program is not open to students who have earned either the M.B.A. or M.Eng. in Manufacturing degrees. Students registered in the first year of either program may apply.

Doctor of Engineering (D.Eng.) in Manufacturing

The Doctor of Engineering in Manufacturing (D. Eng. in Mfg.) is a graduate professional degree in engineering for students who have already earned a B.S.E. degree and an M.S.E. degree in any field of engineering (e.g., aerospace, chemical, civil and environmental, electrical engineering and computer science, industrial and operations, materials science, mechanical, naval architecture and marine) or a Master of Business Administration.

The degree can also be pursued in part at the University of Michigan Dearborn Campus. A total of 50 credit hours is required, of which 24 letter-graded credit hours (i.e., not pass/fail) and at least 18 credit hours must be taken at the Ann Arbor Campus. Students must maintain a cumulative GPA of 6.0/9.0 (B+). The entrance requirements are a B.S.E. and M.S.E. or M.B.A., and at least two years of full-time relevant industrial experience. The general portion of the Graduate Record Examination (GRE) is required. Applications are accepted for both fall and winter terms.

Qualifying examinations must be taken in four areas of manufacturing from a variety of examination areas offered by various departments. Following the completion of required course work and qualifying examinations, a student is required to take a preliminary examination to test his/her knowledge of the primary and supporting field. Each student must complete an industrially relevant, engineering-practice-oriented dissertation, supervised by a dissertation committee, as a requirement of the degree.

Interdisciplinary Professional Programs Courses

Automotive Courses

AUTO 499. Special Topics in Automotive Engineering

Prerequisite: permission of instructor. I, II, IIIa, III (3 credits)

Selected topics pertinent to Automotive Engineering.

AUTO 501. Integrated Vehicle Systems Design

Prerequisite: Graduate Student or permission of instructor. I (3 credits)

This course is intended to examine the process by which a first layout is developed for a new vehicle platform. The course will focus on the layout of the major space-defining vehicle subsystems required to arrive at a preliminary vehicle package drawing. The process followed will be based on systems engineering: requirements-to-design concepts -to- performance prediction -to- comparison to requirements -to- iteration.

AUTO 503. Automotive Engineering Project

Prerequisite: permission of the department. I, II, III (3 credits)

This capstone project course is intended to provide students with an industrially-relevant team project work experience in automotive engineering.

AUTO 563. Dynamics and Controls of Automatic Transmissions

Prerequisite: Graduate Standing or permission of instructor. IIIa, III (3 credits)

Automatic transmission is a key element of automotive vehicles for improved driving comfort. This course will introduce the mechanisms, design and control of modern transmission systems. The emphasis will be on the dynamic analysis, and the application of modern control theories for the overall control design, analysis and synthesis problems.

AUTO 599. Special Topics in Automotive Engineering

Prerequisite: Graduate Standing or permission of instructor. I, II, IIIa, III (3 credits)

Selected topics pertinent to Automotive Engineering.

Manufacturing Courses

MFG 402 (ME 401). Engineering Statistics for Manufacturing Systems

Prerequisite: Senior or Graduate Standing. I (3 credits)

Fundamentals of statistics. Independent t-test and paired t-test. Two-level factorial design. Fractional factorial designs. Matrix algebra and canonical analysis. Regression analysis (Least Squares Method). Response surface methodology. Probability. Binomial and Poisson distributions. Single sampling plan. Statistical process control (SPC). Taguchi methods. Introductory time series analysis and Defect Preventive Quality Control.

MFG 410 (NA410). Marine Structures II

Prerequisite: NA 310. I (4 credits)

Structural modeling and analysis techniques applied to ship and marine structure components. Equilibrium and energy methods applied to elastic beam theory; static bending, torsion and buckling. Shear flow and warping of multi-cell cross sections. Stiffened and composite plates. Plastic analysis of beams. Thick walled pressure vessels. Course project using finite element analysis.

MFG 414 (ChemE 414) (MacroSE 414) (MSE 414).

Prerequisite: MSE 412 or equivalent. II (3 credits)

Theory and practice of polymer processing. Non-Newtonian flow, extrusion, injection molding, fiber, film and rubber processing. Kinetics of and structural development during solidification. Physical characterization of microstructure and macroscopic properties. Component manufacturing and recycling issues, compounding and blending.

MFG 426 (IOE 425). Manufacturing Strategies

Prerequisite: Senior Standing. I, II (2 credits)

Review of philosophies, systems, and practices utilized by world-class manufacturers to meet current manufacturing challenges, focusing on "lean production" in the automotive industry, including material flow, plant-floor quality assurance, job design, work and management practices. Students tour plants to analyze the extent and potential of the philosophies.

MFG 433 (EIH 556) (IOE 433). Occupational Ergonomics

Prerequisite: Not open to students who have credits for IOE 333.(3 credits)

Principles, concepts and procedures concerned with worker performance, health and safety. Topics include biomechanics, work physiology, psycho-physics, work stations, tools, work procedures, word standards, musculo-skeletal disorders, noise, vibration, heat stress, and the analysis and design of work.

MFG 441 (IOE 441). Production and Inventory Control

Prerequisite: IOE 310, IOE 316. I, II (3 credits)

Basic models and techniques for managing inventory systems and for planning production. Topics include deterministic and probabilistic inventory models; production planning and scheduling; and introduction to factory physics.

MFG 447 (IOE 447). Facility Planning

Prerequisite: IOE 310, IOE 316. I (3 credits)

Fundamentals in developing efficient layouts for single-story and multi-story production and service facilities. Manual procedures and microcomputer-based layout algorithms. Algorithms to determine the optimum location of facilities. Special considerations for multi-period, dynamic layout problems.

MFG 448 (ChemE 447). Waste Management in Chemical Engineering

Prerequisite: ChemE 342, ChemE 343. I (3 credits)

Control of gaseous, liquid and solid wastes. Regulations and management procedures. Waste minimization and resource recovery. Separations and reaction engineering approaches.

MFG 449 (IOE 449). Material Handling Systems

Prerequisite: IOE 310, IOE 316. II alternate years (2 credits)

Review of material handling equipment used in warehousing and manufacturing. Algorithms to design and analyze discrete parts material storage and flow systems such as Automated Storage/Retrieval Systems, order picking, conveyors, automated guided vehicle systems and carousels.

MFG 452 (ME 452). Design for Manufacturability

Prerequisite: ME 350. II (3 credits)

Conceptual design. Design for economical production, Taguchi methods, design for assembly; case studies. Product design using advanced polymeric materials and composites; part consolidation, snap-fit assemblies; novel applications. Design projects.

MFG 453 (ME 451). Properties of Advanced Materials for Design Engineers

Prerequisite: ME 382. II (3 credits)

Mechanical behavior and environmental degradation of polymeric-, metal-, and ceramic-matrix composites; manufacturability of advanced engineering materials; use of composite materials in novel engineering designs.

MFG 454 (ME 454). Computer Aided Mechanical Design

Prerequisite: Eng 101, ME 360. II (3 credits)

Introduction to the use of the digital computer as a tool in engineering design and analysis of mechanical components and systems. Simulation of static, kinematic and dynamic behavior. Optimal synthesis and selection of elements. Discussion and use of associated numerical methods and application software. Individual projects.

MFG 455 (IOE 452). Capital Budgeting

Prerequisite: IOE 201, IOE 310, IOE 366. I (3 credits)

The financial background for capital budgeting decisions is developed. Decisions with capital rationing, portfolio optimization, and rate selection are considered. Examples and cases are used to illustrate the capital asset pricing model and efficient market theory.

MFG 456 (IOE 453). Derivative Instruments

Prerequisite: IOE 201, IOE 310, IOE 366. II (3 credits)

The tools, methodology, and basic theory of financial engineering is developed. Decisions involving option pricing, hedging with futures, asset-liability, matching, and structuring synthetic securities are considered and illustrated with examples and cases.

MFG 458 (MSE 485). Design Problems in Materials Science and Engineering

Prerequisite: MSE 480. I, II (1-4 credits) (to be arranged)

Design problem supervised by a faculty member. Individual or group work in particular field of materials of particular interest to the student.

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Advisor: Professor Yogesh B Gianchandani

Integrated MicroSystems

M.Eng. in Integrated MicroSystems

The Master of Engineering in Integrated MicroSystems is a 30 credit hour interdisciplinary program. The credit hours are distributed among the following areas: MicroElectroMechanical Systems (MEMS), MEMS Technology and Materials, Wireless Communications, Business and Management, and Interdisciplinary Teamwork. This program is designed to strengthen students' core engineering skills in a given discipline while being flexible enough to provide the opportunity to explore complementary areas. Moreover, our students will gain valuable business skills for product and process development. The interdisciplinary design team project focuses on current problems in MEMS industry.
The program also incorporates courses in business and management and provides students with the opportunity to work on a team project creating an interdisciplinary microsystem with potential commercialization.
The credit hours are distributed among the following areas:

WIMS/MEMS, including design and analysis, microfabrication technology

- Product Development and Manufacturing
- Business and Management
- Design Team Project

This program is designed to strengthen a student's core engineering skills in a given discipline while being flexible enough to provide the opportunity to explore complementary areas. Moreover, our students will gain valuable business skills for product and process development. The interdisciplinary design team project focuses on current problem in MEMS/WIMS industry.
Professionals with a BS in engineering, chemistry, physics, biology or mathematics, who are employed in WIMS and related activities in the microelectronics industry, or recent graduates, may be admitted into the program, if they meet the prerequisites.

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Advisor: Professor Henry Y. Wang

Pharmaceutical Engineering

Degree Programs

M.Eng. in Pharmaceutical Engineering

Sequential Graduate/Undergraduate Degree

The Master of Engineering in Pharmaceutical Engineering is an interdisciplinary program of the College of Engineering and the College of Pharmacy at the University of Michigan. This new program is in response to changes in the laboratory and marketplace and reflects the most up-to-date advances in the pharmaceutical industry. Selected topics include process engineering in drug discovery; computational biology, chemistry, and engineering; receptor biology and chemical signaling; automated, high-throughput characterization and analyses; solid-state science and engineering; scale translation in pharmaceutical development; biomanufacturing and cGMP issues; and novel gene and drug delivery systems.
Practical training is a key component of the enrolled students' experience. Summer internships at various pharmaceutical and life science-related companies are available for qualified students.
Professionals with a BS in chemical engineering or a related field who are employed in a pharmaceutical or life science-related company may be admitted into the program, if they meet all the prerequisites. U-M Chemical Engineering undergraduates and Pharmacy undergraduates with a GPA of 3.5 and above are also encouraged to apply. Chemical Engineering students should apply beginning the second semester of their junior year and Pharmacy students during the first semester of their first year at the College of Pharmacy.

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Advisor: Professor Jianjun Shi - PIM
Advisor: Professor Yavuz A. Bozer - MEM - TMI

Manufacturing

Degree Programs

- M.Eng. in Manufacturing (PIM)
- M.Eng. in Manufacturing (TMI)
- Joint M.Eng. in Manufacturing/MBA Degree
- D.Eng. in Manufacturing
- Sequential Graduate/Undergraduate Degree

M.Eng. in Manufacturing

The design problem is arranged at the beginning of each term by mutual agreement between the student and a faculty member. Written and oral reports are required.

MFG 460 (NA 460). Ship Production Engineering, Planning and Control

Prerequisite: NA 270, NA 276, NA 277. I (4 credits)

Application of production engineering and operations management to the production of complex marine systems, such as ships, offshore structures, and yachts. Applicability of various manufacturing and operations management philosophies, production engineering, planning and scheduling, performance measurement, and control to the operation of ship and boat yards.

MFG 461 (IOE 461). Quality Engineering Principles and Analysis

Prerequisite: IOE 366. I (3 credits)

This course provides students with the analytical and management tools necessary to solve manufacturing quality problems and implement effective quality systems. Topics include voice of the customer analysis, the Six Sigma problem solving methodology, process capability analysis, measurement system analysis, design of experiments, statistical process control, failure mode and effects analysis, quality function deployment, and reliability analysis.

MFG 463 (IOE 463). Measurement and Deisgn of Work

Prerequisite: IOE 333 or IOE 395 or BME 231 and IOE 265 and STATS 412. I (2 credits)

Contemporary work measurement techniques are used to evaluate, predict, and enhance human performance through improved design of manufacturing and service work environments. Lectures and laboratory exercises cover the following topics: human variability in work performance, time study, learning curves, performance rating, allowances, work sampling, and pre-determined time systems.

MFG 466 (IOE 466) (Stat 466). Statistical Quality Control

Prerequisite: IOE 265 (Stat 265 and IOE 366 or Stat 403). I, II (3 credits)

Quality Improvement Philosophies; Modeling Process Quality, Statistical Process Control, Control Charts for Variables and Attributes, CUSUM and EWMA, Short Production Runs, Multivariate Quality Control, Auto Correlation, Engineering Process Control, Economic Design of Charts, Fill Control, Precontrol, Adaptive Schemes, Process Capability, Specifications and Tolerances, Gage Capability Studies, Acceptance Sampling by Attributes and Variables, International Quality Standards.

MFG 470 (NA 470). Foundations of Ship Design

Prerequisite: NA 321, NA 332, NA 340, co-requisite: NA 310. I (4 credits)

Organization of ship design. Preliminary design methods for sizing and form; powering, maneuvering, and seakeeping estimation; arranging; propulsion; structural synthesis; and safety and environmental risk of ships. Extensive use of design computer environment. Given owner's requirements, students individually create and report the conceptual/preliminary design for a displacement ship.

MFG 480 (MSE 480). Materials and Engineering Design

Prerequisite: Senior Standing. I (3 credits)

Design concepts. Engineering economics. Problems of scaling. Materials substitution. Competitive processes. Case histories. Professional and ethical considerations. Written and oral presentations of solutions to design problems.

MFG 488 (ME 487). Welding

Prerequisite: ME 382. I (3 credits)

Study of the mechanism of surface bonding, welding metallurgy, effect of rate of heat input on resulting microstructures, residual stresses and distortion, economics and capabilities of the various processes.

MFG 492 (ME 482). Machining Processes

Prerequisite: Senior Standing. II (4 credits)

Mechanics of 2-D and Basic 3-D cutting. Industrially-applicable, mechanistic force models for practical processes including turning, facing, boring, face milling, end milling, and drilling. Surface generation and wear-based economic models. Motivation for and methods of applying developed models in simultaneous engineering. Three hours of lecture and one two-hour laboratory.

MFG 499. Special Topics to be specified by department

(to be arranged)

MFG 501. Topics in Manufacturing

Prerequisite: Graduate Standing in PIM. I, II (3 credits)

This course is intended to provide students with an understanding of the changing role manufacturing plays in developed economies and the major dynamics creating these changes.

MFG 503. Manufacturing Project

Prerequisite: Mfg 501. I, II, III (3 credits)

This project course is intended to provide students with an industrially-relevant team project experience in manufacturing.

MFG 505 Financial Analysis for Modern Manufacturing

Prerequisite: Senior Standing or Graduate Standing. I (3 credits)

This course will discuss and evaluate how accounting systems impact the implementation of modern manufacturing. Traditional accounting practices and systems will be analyzed to show how they can impede a shift from traditional mass production to more efficient lean manufacturing systems. Alternative measurement tools such as metrics for lean manufacturing, theory of constraints, enterprise risk management, will be presented that facilitate the implementation of modern lean manufacturing systems. Case study will be used to illustrate the impact of traditional and newer measurement methods.

MFG 513 (ME 513). Automotive Body Structures

Prerequisite: ME 311. I (3 credits)

Emphasis is on body concept for design using first order modeling of thin walled structural elements. Practical application of solid/structural mechanics is considered to design automotive bodies for global bending, torsion, vibration, crashworthiness, topology, material selection, packaging, and manufacturing constraints.

MFG 514 (MacroSE 514) (MSE 514). Composite Materials

Prerequisite: MSE 350. I alternate years. (3 credits)

Behavior, processing and design of composite materials, especially fiber composites. Emphasis is on the basic chemical and physical processes currently employed and expected to guide the future development of the technology.

MFG 517 (ChemE 517). Biochemical Science and Technology

Prerequisite: ChE 344, Biol 311 or equivalent; permission of instructor. II (3 credits)

Concepts necessary in the adaptation of biological and biochemical principles to industrial processing in biotechnology and pharmaceutical industries. Topics include rational screening, functional genomics, cell cultivation, oxygen transfer, etc. Lectures, problems, and library study will be used.

MFG 518 (ME 518). Composite Materials: Mechanics, Manufacturing, and Design

Prerequisite: Senior or Graduate Standing. I alternate years (3 credits)

Composite materials, including naturally occurring substances such as wood and bone, and engineered materials from concrete to carbon-fiber reinforced epoxies. Development of micromechanical models for a variety of constitutive laws. Link between processing and as-manufactured properties through coupled fluid and structural analyses.

MFG 534 (BiomedE 534) (IOE 534). Occupational Biomechanics

Prerequisite: IOE 333, IOE 334 or IOE 433 (EIH 556). II (3 credits)

Anatomical and physiological concepts are introduced to understand and predict human motor capabilities, with particular emphasis on the evaluation and design of manual activities in various occupations. Quantitative models are developed to explain (1) muscle strength performance, (2) cumulative and acute musculoskeletal injury, (3) physical fatigue, and (4) human motion control.

MFG 535 (IOE 533). Human Motor Behavior and Engineering Systems

Prerequisite: IOE 333 and IOE 366. I (3 credits)

Principles of engineering psychology applied to engineering and industrial production systems visual task measurement and design, psycho-physical measurements, signal detection theory and applications to industrial process control. Human information processing, mental workload evaluation, human memory and motor control processes.

MFG 536 (CEE 536). Critical Path Methods

Prerequisite: Senior or Graduate Standing. I, IIIa (3 credits)

Basic critical path planning and scheduling with arrow and precedence networks; project control; basic overlapping networks; introduction to resource leveling and least cost scheduling; fundamental PERT systems.

MFG 539 (IOE 539). Occupational Safety Engineering

Prerequisite: IOE 265 or Biostat 500. I (3 credits)

Design/modification of machinery/products to eliminate or control hazards arising out of mechanical, electrical, thermal, chemical, and motion energy sources. Application of retrospective and prospective hazard analysis, systems safety, expert systems and accident reconstruction methodologies. Case examples: industrial machinery and trucks, construction and agriculture equipment, automated manufacturing systems/processes.

MFG 541 (IOE 541). Inventory Analysis and Control

Prerequisite: IOE 310, IOE 316. (3 credits)

Models and techniques for managing inventory systems and for planning production. Topics include single item and multi-item inventory models, production planning and control, and performance evaluation of manufacturing systems.

MFG 542 (MSE 542). Reactions in Ceramic Processes

Prerequisite: MSE 440 or Graduate Standing. I, II (3 credits)

Dissociation, sintering, vitrification, devitrification, and thermochemical reactions in ceramic processing.

MFG 543 (IOE 543). Theories of Scheduling

Prerequisite: IOE 316 and IOE 310. II (3 credits)

The problem of scheduling several tasks over time, including the topics of measures of performance, single-machine sequencing, flow shop scheduling, the job shop problem, and priority dispatching. Integer programming, dynamic programming, and heuristic approaches to various problems are presented.

MFG 545 (IOE 545). Queue Networks

Prerequisite: IOE 515 or EECS 501. I (3 credits)

Introduction to queuing networks. Topics include product and non-product form networks, exact results and approximations, queuing networks with blocking, and polling systems. Applications from manufacturing and service industries are given as examples.

MFG 549 (IOE 549). Plant Flow Systems

Prerequisite: IOE 310, IOE 416. II (3 credits)

Analytical models for the design and throughput performance evaluation of material handling systems used in discrete parts flow production facilities. Analysis of design and control issues for manual and automated handling systems including lift trucks, micro-load automatic storage/retrieval systems and automated guided vehicle systems. MFG 551 (CEE 554). Materials in Engineering Design

MFG 551 (CEE 554). Materials in Engineering Design

Prerequisite: CEE 351 or per instructor. II (3 credits)

Integrated study of materials properties, processing, performance, structure, cost, and mechanics, as related to engineering design and materials selection. Topics include design process, materials properties and selection; scaling; materials database, processing and design, and optimization. Examples will be drawn from cement and ceramics, metals, polymers and composites.

MFG 552 (ME 552). Electromechanical System Design

Prerequisite: EECS 210 or equivalent. I (3 credits)

Design of electromechanical systems with emphasis placed on the integration of mechanical and electrical principles. Topics include: electromechanical device design: generators/alternators, electrical motors, measurement/sensing devices; digital control: microprocessors, AD/DA converters, data transmission and acquisition; electromechanical system design: mixed domain modeling, real time control and mechatronic systems.

MFG 553 (ME 553). Microelectromechanical Systems
Prerequisite: Senior or Graduate Standing. II alternate years (3 credits)
Basic integrated circuit (IC) manufacturing processes; electronics devices fundamentals; microelectromechanical systems fabrications including surface micromachining, bulk micromachining, LIGA and others. Introduction to microactuators and microsensors such as micromotors, grippers, accelerometers and pressure sensors. Mechanical and electrical issues in micromachining. IC CAD tools to design microelectromechanical structures using MCNC MUMPs service. Design projects.

MFG 554 (ME 554). Computer Aided Design Methods
Prerequisite: ME 454 or ME 501. I (3 credits)
Generalized mathematical modeling of engineering systems, methods of solution and simulation languages. Analysis methods in design; load, deformation, stress and finite element considerations; nonlinear programming. Computational geometry; definition and generation of curves and surfaces. Computer graphics; transformations; clipping and windowing; graphics systems; data structures; command languages; display processors.

MFG 555 (ME 555). Design Optimization
Prerequisite: Math 451 and Math 217 or equivalent. II (3 credits)
Mathematical modeling of engineering design problems for optimization. Boundedness and monotonicity analysis of models. Differential optimization theory and selected numerical algorithms for continuous nonlinear models. Emphasis on the interaction between proper modeling and computation. Students propose design term projects from various disciplines and apply course methodology to optimize designs.

MFG 556 (ME 576). Fatigue in Mechanical Design
Prerequisite: stress-based finite element course recommended. I, II (3 credits)
A broad treatment of stress, strain, and strength with reference to engineering design and analysis. Major emphasis is placed on the analytical and experimental determination of stresses in relationship to the fatigue strength properties of machine and structural components. Also considered are deflection, post-yield behavior, residual stresses, temperature and corrosion effects.

MFG 557 (ME 577). Materials in Manufacturing and Design
Prerequisite: Senior or Graduate Standing. I, II (3 credits)
Material selection on the basic cost, strength, formability and machinability. Advanced strength analysis of heat treated and cold formed parts including axial, bending, shear and cyclic deformation. Correlations of functional specifications and process capabilities. Problems in redesign for productibility and reliability.

MFG 558 (ME 558). Discrete Design Optimization
Prerequisite: Senior or Graduate Standing. I, alternate years (3 credits)
Fundamentals of discrete optimization for engineering design problems. Mathematical modeling of engineering design problems as discrete optimization problems, integer programming, dynamic programming, graph search algorithms, and introduction to NP completeness. A term project emphasizes applications to realistic engineering design problems.

MFG 559 (ME 559). Smart Materials and Structures
Prerequisite: EECS 210 or equivalent. I alternate years (3 credits)
This course will cover theoretical aspects of smart materials, sensors and actuator technologies. It will also cover design, modeling and manufacturing issues involved in integrating smart materials and components with control capabilities to engineering smart structures.

MFG 560 (ME 551). Mechanisms Design
Prerequisite: ME 350. II (3 credits)
Basic concepts. Type synthesis - creative design of mechanisms; graph theory. Precision-point Burmester theory for dimensional synthesis of linkages. Applications. Cam and follower system synthesis. Joint force analysis and dynamic analysis formulations. Analytical synthesis of programmable and compliant mechanisms. Use of software for synthesis and analysis. Design projects.

MFG 561 (IOE 565) (ME 563). Time Series Modeling, Analysis, Forecasting
Prerequisite: IOE 366 or ME 401. I (3 credits)
Time series modeling, analysis, forecasting, and control, identifying parametric time series, autovariance, spectra, Green's function, trend and seasonality. Examples from manufacturing, quality control, ergonomics, inventory, and management.

MFG 562 (ME 560). Modeling Dynamic Systems
Prerequisite: ME 360. I (3 credits)
A unified approach to the modeling, analysis and simulation of energetic dynamic systems. Emphasis on analytical and graphical descriptions of state-determined systems using Bond Graph language. Analysis using interactive computer simulation programs. Applications to the control and design of dynamic systems such as robots, machine tools and artificial limbs.

MFG 563 (NA 562). Marine Systems Production Business Strategy and Operations Management
Prerequisite: Graduate Standing. I (4 credits)
Combination capstone and management development course to provide students the opportunity to apply basic naval architectural and related engineering knowledge to a real life business situation and to apply newly gained management skills. Management and organization concepts, theories and processes will be presented in the context of the marine industry.

MFG 566 (ChemE 566). Process Control in Chemical Industries
Prerequisite: ChemE 343, ChemE 460. II (3 credits)
Techniques of regulation applied to equipment and processes in the chemical and petro-chemical industries. Linear and nonlinear control theory, largely in the spectral domain. Controller types, transducers, final control elements, interacting systems, and applications.

MFG 567 (EECS 567) (ME 567). Introduction to Robotics: Theory and Practice
Prerequisite: EECS 380. II (3 credits)
Introduction to robots considered as electro-mechanical computational systems performing work on the physical world. Data structures representing kinematics and dynamics of rigid body motions and forces and controllers for achieving them. Emphasis on building and programming real robotic systems and on representing the work they are to perform.

MFG 569 (IOE 566). Advanced Quality Control
Prerequisite: IOE 466. II (3 credits)
An applied course on Quality Control including Statistical Process Control Modifications, Linear, Stepwise and Ridge Regression Applications, Quality Function Deployment, Taguchi Methods, Quality Policy Deployment, Tolerancing Systems, Process Control Methodologies and Measurement Systems and Voice of the Customer Methodologies Time Series, Experimental Design, Total Quality Management and case studies.

MFG 571 (NA 571). Ship Design Project
Prerequisite: prior arrangement with instructor. I, II, IIIa (to be arranged)
Individual (or team) project, experimental work, research or directed study of selected advanced topics in ship design. Primarily for graduate students.

MFG 572 (NA 570). Advanced Marine Design
Prerequisite: Graduate Standing required. II (4 credits)
Organization of marine product development; concurrent marine design. Shipbuilding policy and build strategy development. Group behaviors; leadership and facilitation of design teams. General theories and approaches to design. Conceptual design of ships and offshore projects. Nonlinear programming, multicriteria optimization, and genetic algorithms applied to marine design.

MFG 573 (NA 561). Marine Product Modeling
Prerequisite: NA 570. II (3 credits)
Fundamental aspects of marine product modeling, data exchange, and visualization. Simulation Based Design. Introduction to activity modeling and information modeling. Overview of Object Oriented Programming. Geometric modeling of solids and surfaces. Simulation and visualization. Virtual prototyping.

MFG 575 (NA 575). Computer-Aided Marine Design Project
Prerequisite: none. I, II, IIIa, IIIb, III (2-6 credits), (to be arranged)
Development of computer-aided design tools. Projects consisting of formulation, design, programming, testing, and documentation of programs for marine design and constructional use.

MFG 577 (MSE 577). Failure Analysis of Materials
Prerequisite: MSE 350. II (3 credits)
Analysis of failed structures due to tensile overload, creep, fatigue, stress corrosion, wear and abrasion, with extensive use of scanning electron microscope. Identification and role of processing defects in failure.

MFG 578 (NA 580). Optimization, Market Forecast and Management of Marine Systems
Prerequisite: NA 500. I (4 credits)
Optimization methods (linear, integer, nonlinear, sequential) concepts and applications in the operations of marine systems. Forecasting methods (ARMA, Fuzzy sets, Neural nets) concepts and applications to shipping and shipbuilding decisions. Economics of merchant shipbuilding and ship scrapping. Elements of maritime management: risk and utility theory. Deployment optimization.

MFG 579 (NA 582). Reliability and Safety of Marine Systems
Prerequisite: EECS 401 or Math 425 or Stat 412. II (3 credits)
Brief review of probability, statistics, trade-off analysis, and elements of financial management. Thorough presentation of the methods and techniques of reliability analysis. Marine reliability, availability, maintenance, replacement, and repair decisions. Safety and risk analysis. FMEA, fault-tree and event-tree analysis. Marine applications.

MFG 580 (ME 572). Rheology and Fracture
Prerequisite: ME 382. I (3 credits)
Mechanisms of deformation, cohesion, and fracture of matter. Unified approach to the atomic-scale origins of plastic, viscous, viscoelastic, elastic, and anelastic behavior. The influences of time and temperature on behavior. Stress field of edge and screw dislocations, dislocation interactions, and cross slip.

MFG 581 (ME 573). Friction and Wear
Prerequisite: background in materials and mechanics desirable. II (3 credits)
The nature of solid surfaces, contact between solid surfaces, rolling friction, sliding friction, and surface heating due to sliding; wear and other types of surface attrition are considered with reference to practical combinations of sliding materials, effect of absorbed gases, surface contaminants or other lubricants on friction, adhesion, and wear; tire and brake performance.

MFG 582 (MSE 523) (ME 582). Metal-Forming Plasticity
Prerequisite: ME 211. I alternate years (3 credits)
Elastic and plastic stress-strain relations; yield criteria and flow rules; analyses of various plastic forming operations. Effects of work hardening and friction, temperature, strain rate, and anisotropy.

MFG 583 (IOE 583)(ME 583). Scientific Basis for Reconfigurable Manufacturing
Prerequisite: Graduate Standing or permission of the instructor. II alternate years (3 credits)
Principles of reconfigurable manufacturing systems (RMS). Students will be introduced to fundamental theories applicable to RMS synthesis and analysis. Concepts of customization, integrability, modularity, diagnosability, and convertibility. Reconfiguration design theory, life-cycle economics, open-architecture principles, controller configuration, system reliability, multi-sensor monitoring, and stream of variations. Term projects.

MFG 584 (ME 584). Control of Machining Systems
Prerequisite: ME 461 or equivalent. II (3 credits)
Advanced control and sensing methodologies for machining processes: milling, turning, drilling, grinding and laser cutting. Machine tool structure. CNC programming. Drive components. Trajectory interpolators. Selection of control parameters. Software compensation and adaptive control. The design process of a comprehensive machining system. Two-hour lecture and two-hour lab per week.

MFG 585 (ME 585). Machining Dynamics and Mechanics
Prerequisite: Graduate Standing. I even years (3 credits)

Dynamic cutting process models and process stability issues. Advanced cutting process mechanics and modeling including cutting process damping, thermal energy and cutting temperature, and wear evolution. Single and multi-DOF stability analysis techniques, stability margins and stability charts. Modeling approximations for industrial applications.

MFG 587 (ME 587). Reconfigurable Manufacturing for Market Responsiveness

Prerequisite: one 500-level MFG, DES or BUS class. II (3 credits)

Product-process-business relationships. Manufacturing paradigms and the market. Product design for customization. Paradoxial products. Mass-production model. Mass-customization principles. Reconfigurable manufacturing systems-design and principles. Reconfigurable machine tools. Impact of system configuration on productivity, quality, scalability, and convertibility. IT for market responsiveness. Business models. Reconfigurable enterprises. Introduction for financial planning and business plans.

MFG 588 (ME 588) (IOE 588). Assembly Modeling for Design and Manufacturing

Prerequisite: ME 381 and 401 or equivalent. I alternate years (3 credits)

Assembly as product and process. Assembly representation. Assembly sequence. Datum flow chain. Geometric Dimensioning and Tolerancing. Tolerance analysis. Tolerance synthesis. Robust design. Fixturing. Joint design and joining methods. Stream of variation. Auto body assembly case studies.

MFG 590. Study or Research in Selected Manufacturing Topics

Prerequisite: permission of instructor. I, II, IIIa, IIIb, III (1-3 credits)

Individual study of specialized aspects of Manufacturing engineering.

MFG 591 (ME 586). Laser Material Processing

Prerequisite: senior or graduate standing. I (3 credits)

Application of lasers in materials processing and manufacturing. Laser principles and optics. Fundamental concepts of laser/material interaction. Laser welding, cutting, surface modification, forming, and rapid prototyping. Modeling of processes, microstructure and mechanical properties of processed materials. Transport phenomena. Process monitoring.

MFG 599. Special Topics

Prerequisite: see individual department requirements. I, II, IIIa, IIIb, III (3 credits)

MFG 605 (OMS 605). Manufacturing and Supply Operations

Prerequisite: none. II (3 credits)

This is a course on the basic concepts and techniques of operations and inventory management. The foundation of the course is a system of manufacturing laws collectively known as "Factory Physics". These laws relate to measures of plant performance, such as throughput, cycle time, work-in-process, customer service, variability, and quality, in a consistent manner and provide a framework for evaluating and improving operations. Concepts and methods are examined via exercises and case studies.

MFG 617 (ChemE 617). Advanced Biochemical Technology

Prerequisite: ChemE 517 or permission of instructor. II alternate years (3 credits)

Practical and theoretical aspects of various unit operations required to separate and purify cells, proteins, and other biological compounds. Topics covered include various types of chromatography, liquid/liquid extractions, solid/liquid separations, membrane processing and field enhanced separations. This course will focus on new and non-traditional separation methods.

MFG 622 (MSE 622) (NERS 622). Ion Beam Modification and Analysis of Materials

Prerequisite: NERS 421, NERS 521 or MSE 350 or permission of instructor. II alternate years (3 credits)

Ion-solid interactions, ion beam mixing, compositional changes, phase changes, micro-structural changes; alteration of physical and mechanical properties such as corrosion, wear, fatigue, hardness; ion beam analysis techniques such as RBS, NRA, PIXE, ion channeling, ion micro-probe; accelerator system design and operation as it relates to implantation and analysis.

MFG 645 (IOE 645) (Stat 645). Topics in Reliability and Maintainability

Prerequisite: IOE 515 (Stat 526) and IOE 562 (Stat 535). (3 credits)

Advanced topics in reliability and maintainability. Examples include models for component and system reliability, probabilistic design, physics of failure models, degradation modeling and analysis, models form maintainability and availability, and maintenance and monitoring policies

MFG 990. Dissertation/Pre-Candidate

Prerequisite: permission of thesis committee; mandatory satisfactory/unsatisfactory. I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)

Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

MFG 995. Dissertation/Candidate

Prerequisite: College of Engineering authorization for admission as a doctoral candidate; mandatory satisfactory/unsatisfactory. I, II, III (8 credits); IIIa, IIIb (4 credits)

Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Macromolecular Science and Engineering

Director
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Macromolecular Science and Engineering is an interdisciplinary program that provides the academic and research basis for studies in the science and technology of synthetic and natural macromolecules. Such large molecules exhibit unusual and specific properties as compared to small molecules and a large field has developed in unraveling the scientific foundations of this behavior, both in the synthetic and the biological areas.

The Program at U-M is one of the very few where students can achieve competence in both the traditional discipline of their choice and the interdisciplinary field of Macromolecular Science and Engineering. It is a unique graduate program structure that allows a tailor fitting by the students to their individual interests while permitting the faculty to train the students in the Program to a high level of competence. A Ph.D. is offered in Macromolecular Science and Engineering with concentrations in the areas of Biomaterials Engineering, Biomedical Engineering, Chemistry, Chemical Engineering, Materials Science and Engineering, Organic Electronics, or Physics. Other areas of interest include Electrical Engineering and Computer Science and Mechanical Engineering. The focus is mainly on the Ph.D., but Master's degrees are also granted.

The faculty members are drawn from the Colleges of Engineering, Literature Science and the Arts, the Dental School and the Medical School. The Macro Program is an interdisciplinary endeavor, permitting students to acquire a broad understanding of macromolecular science. The faculty believe the approach taken permits the students to eventually make a more significant contribution to macromolecular science. It also allows the students to develop the self-confidence needed to adapt to the changes inherent in modern research and development. The specific Program requirements include completing most of the course requirements prescribed in each option by the end of the second year, passing a two part comprehensive written examination, selection of a research area and a Research Supervisor and Dissertation Committee. There are also some general Ph.D. Degree requirements set by the Rackham Graduate School.

Counseling on both the general and specific requirements is provided by an advisor representing the Executive Committee of the Macromolecular Science and Engineering Program. The advisor is designated through a selection process during the student's first month.

The student then chooses among several major options: Biomaterials Engineering, Biomedical Engineering, Chemistry (organic or physical), Chemical Engineering, Materials Science and Engineering, Organic Electronics, or Physics. An individualized option is also available.

The progress to a Ph.D. is normally four to five years with coursework being emphasized during the first two years. Students are approved for candidacy after they have completed the basic prescribed courses satisfactorily, passed the comprehensive exam, formed a Dissertation Committee and passed a preliminary oral examination by that Committee. Candidacy is usually achieved within four terms.

Macromolecular Science and Engineering Undergraduate Education

Sequential Graduate/Undergraduate Study (SGUS)

The Macro Program offers SGUS degrees in collaboration with several participating departments (BiomedE, ChemE, Chemistry, MSE, ME and Physics). These degrees make it possible for students to receive both a B.S. and M.S. degree in an accelerated fashion.

Research

An early start in research is encouraged as soon as the students have demonstrated satisfactory progress in courses and have selected a Research Supervisor. The interdisciplinary nature of the Program allows for a wide range of research possibilities.

Representative Ph.D. Course Programs

It is recommended that in all the options an introductory course such as MacroSE 412 be taken as part of these credits by all students who do not have a strong polymer background. The majority of the option courses taken should be 500- level or above. See "Course Descriptions" for individual course information.

Biomaterials Engineering Option

A minimum of 30 hours of course work from Biomaterials Engineering and Macromolecular Science Courses. This must include a minimum of 12 hours from Biomaterials and 12 hours from MacroSE. These courses must include a graduate course in biomaterials, biochemistry and biophysics.

Biomedical Engineering Option

A minimum of 30 hours of course work from Biomedical Engineering and Macromolecular Science Courses. This must include a minimum of 12 hours from Biomedical Engineering and 12 hours from MacroSE. These courses must include a graduate course in biomaterials, biochemistry, and/or biophysics and biomedical engineering.

Chemistry Option (Synthetic or Physical)

A minimum of 30 hours of course work from Chemistry and Macromolecular Science Courses. This must include a minimum of 12 hours from Chemistry and 12 hours from MacroSE.

For a Synthetic option, these courses must include: MacroSE 790, MacroSE 800, MacroSE 536, MacroSE 538, two courses from Chem 507, 540, 541 or 543, and one from Chem 511, 542 or 616.

For a Physical option, these courses must include: MacroSE 790, MacroSE 800, MacroSE 536, Chem 571, Chem 576, Chem 580 and another approved Chemistry course.

Chemical Engineering Option
A minimum of 30 hours of course work from Chemical Engineering and Macromolecular Science courses. This must include a minimum of 12 hours from ChE and 12 hours from Macromolecular Science. These courses must include: MacroSE 790, MacroSE 800, MacroSE 535, MacroSE 536, ChE 528, graduate courses in transport phenomena, numerical methods or mathematical modeling and polymer processing.

Materials Science and Engineering Option
A minimum of 30 hours of course work from Materials Science and Engineering and Macromolecular Science courses. This must include a minimum of 12 hours from MSE and 12 hours from MacroSE.
These courses must include: MacroSE 790, MacroSE 800, MacroSE 535, MacroSE 536, a graduate course in metals and a graduate course in ceramics.

Physics Option
A minimum of 30 hours of course work from Physics and Macromolecular Science courses. This must include a minimum of 12 hours from Physics and 12 hours from MacroSE.
These courses must include: MacroSE 790, MacroSE 800, MacroSE 536, graduate Physics or Applied Physics courses, and an advanced course in physical properties of polymers.

Individualized Options
An individualized option may be proposed by students. Such students must submit a detailed program in writing to the Executive Committee for approval.

MacroSE 412 (ChemE 412) (MSE 412). Polymeric Materials
Prerequisites: MSE 220 or 250. I (3 credits)
The synthesis, characterization, microstructure, rheology, and properties of polymer materials. Polymers in solution and in the liquid, liquid-crystalline, crystalline, and glassy states. Engineering and design properties, including viscoelasticity, yielding, and fracture. Forming and processing methods. Recycling and environmental issues.
MacroSE 414 (ChemE 414) (Mfg 414) (MSE 414). Applied Polymer Processing
Prerequisites: MSE 412 or equivalent. II (3 credits)
Theory and practice of polymer processing. Non-Newtonian flow, extrusion, injection-molding, fiber, film, and rubber processing. Kinetics of and structural development during solidification. Physical characterization of microstructure and macroscopic properties. Component manufacturing and recycling issues, compounding and blending.
MacroSE 511 (ChemE 511) (MSE 511). Rheology of Polymeric Materials
Prerequisite: a course in fluid mechanics or permission from instructor. (3 credits)
An introduction to the relationships between the chemical structure of polymer chains and their rheological behavior. The course will make frequent reference to synthesis, processing, characterization, and use of polymers for high technology applications.
MacroSE 512 (ChemE 512) (MSE 512). Polymer Physics
Prerequisite: Senior or Graduate Standing in engineering or physical science. II (3 credits)
Structure and properties of polymers as related to their composition, annealing and mechanical treatments. Topics include creep, stress relaxation, dynamic mechanical properties, viscoelasticity, transitions, fracture, impact response, dielectric properties, permeation, and morphology.
MacroSE 514 (Mfg 514) (MSE 514). Composite Materials
Prerequisite: MSE 350. I alternate years (3 credits)
Behavior, processing and design of composite materials, especially fiber composites. Emphasis is on the basic chemical and physical processes currently employed and expected to guide the future development of the technology.
MacroSE 515 (MSE 515). Mechanical Behavior of Solid Polymeric Materials
Prerequisite: ME 211, MSE 412. II even years (3 credits)
The mechanical behavior of polymers from linear viscoelastic to yield and fracture are covered. Specific topics include dynamic-mechanical relaxations, creep, yielding, crazing, fatigue, and fracture mechanics. The materials include toughened plastics, polymer alloys and blends, and composite materials. Structured design with plastics is also considered.
MacroSE 517 (ME 517). Mechanics of Polymers I
Prerequisite: ME 511 (AM 511) or permission of instructor. II (3 credits)
Constitutive equation for linear small strain viscoelastic response; constant rate and sinusoidal responses; time and frequency dependent material properties; energy dissipation; structural applications including axial loading, bending, torsion; three dimensional response, thermo-viscoelasticity, correspondence principle, Laplace transform and numerical solution methods.
MacroSE 535 (Chem 535). Physical Chemistry of Macromolecules
Prerequisite: Chem 463 or Chem 468. I (3 credits)
The theory and application of useful methods for studying natural and synthetic polymers will be stressed. The methods discussed include osmotic pressure, sedimentation equilibrium, Brownian motion, diffusion, sedimentation transport, intrinsic viscosity, scattering of light and x-rays, optical and resonance spectra, flow and electric bi-refringence, depolarization of fluorescence, circular dichroism and magneto optical rotatory dispersion, electrophoresis, titration curves, kinetics of polymerization, suitable distribution functions for expressing heterogeneity, rigidity and viscosity of gels.
MacroSE 536 (Chem 536). Laboratory in Macromolecular Chemistry
Prerequisite: Chem 535 or permission of instruction. I alternate years (2 credits)
Experimental methods for the study of macromolecular materials in solution and in bulk state.

MacroSE 538 (Chem 538). Organic Chemistry of Macromolecules
Prerequisite: Chem 215, Chem 216, and Chem 230 or Chem 241/242, 260. I (3 credits)
The preparation, reactions, and properties of high molecular weight polymeric materials of both natural and synthetic origin. Two lectures and reading.
MacroSE 751 (Chem 751) (ChemE 751) (MSE 751) (Physics 751). Special Topics in Macromolecular Science
Prerequisite: permission of instructor. (2 credits)
MacroSE 790. Faculty Activities Research Survey (1 credit)
This course introduces students to the research activities of MacroSE faculty with the intent of helping a student to choose his research advisor in the first term.
MacroSE 800. Macromolecular Seminar I, II
(2 credits)
Student presentation of selected seminar topics in macromolecular science and engineering.
MacroSE 890. Introduction to Research Techniques
Prerequisite: permission of chairman. every term (1-8 credits)
This course is used for research carried out to earn the master's degree.
MacroSE 990. Dissertation Research Precandidacy
Prerequisite: permission. every term (1-8 credits)
This course number is used for doctoral research by students not yet admitted to candidacy. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
MacroSE 995. Dissertation Research/Candidacy
Prerequisite: permission. every term (8 credits); (4 credits) in half-term
This course number is used for doctoral research by students who have been admitted to candidacy. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Macromolecular Science and Engineering Faculty

Richard M. Laine, Director; *also Materials Science and Engineering*
Professors
Ellen M. Arruda; *also Mechanical Engineering*
Arthur J. Ashe III; *also Chemistry*
Mark Banaszak-Holl; *also Chemistry*
Frank E. Filisko; *also Materials Science and Engineering*
Sharon Glotzer; *also Chemical Engineering*
Theodore Goodson III; *also Chemistry*
Peter F. Green; *also Materials Science and Engineering*
Erdogan Gulari; *also Chemical Engineering*
Jerzy Kanicki; *also Electrical Engineering and Computer Science*
Richard M. Laine; *also Materials Science and Engineering; also Chemistry*
Ronald G. Larson; *G.G. Brown Professor of Chemical Engineering and Chair; also Chemical Engineering*
Peter X. Ma; *also Biologic and Materials Science*
Paul G. Rasmussen; *also Chemistry*
Richard E. Robertson; *also Materials Science and Engineering*
Alan S. Wineman; *also Mechanical Engineering*
Robert Zand; *also Biological Chemistry; Research Scientist (Biophysics)*
Professors Emeritus
Ziya Akcasu; *also Nuclear Engineering*
Samuel Krimm; *also Biophysics Research Division; Physics*
M. David Curtis; *also Chemistry*
Associate Professors
Zhan Chen; *also Chemistry*
L. Jay Guo; *also Electrical Engineering and Computer Science*
Max Shtein; *also Materials Science and Engineering*
Michael J. Solomon; *also Chemical Engineering*
Assistant Professors
Jinsang Kim; *also Material Science and Engineering*
Joerg Lahann; *also Chemical Engineering*
Adam Matzger; *also Chemistry*
Shuichi Takayama; *also Biomedical Engineering*

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Military Officer Education Programs

The University of Michigan, in cooperation with the armed services of the United States, provides an opportunity for all eligible male and female students to earn a commission in any of the three services (Army; Navy, including Marine Corps; and Air Force) upon completion of the degree requirement. This opportunity is available through enrollment in the Military Officer Education Program (MOEP), which is known nationally as the Reserve Officers Training Corps (ROTC).
All three officer education programs (Army, Navy, and Air Force) offer four- and two-year program options, financial benefits, and scholarship opportunities. Minor variations, however, do exist among the programs, and students should consult the specific information under the respective program.

Financial Benefits
All students enrolled in advanced (junior and senior year) officer education courses, whether or not on scholarship, receive a monthly stipend for the academic year. A uniform and the necessary books and equipment are furnished to all students. In addition, pay and travel allowances are provided for attendance at summer field training courses.

Scholarships
In addition to the financial benefits provided for all students enrolled in the advanced courses, a limited number of two-, three-, and four-year merit-based scholarships are awarded on a competitive basis by each of the Officer Education Programs. These scholarships provide tuition, laboratory fees, payment for required books, and a monthly stipend.

Course Election by Non-Program Students
Officer education courses are also open to University students not enrolled in the program by permission of the instructor.

Air Force Officer Education Program

Chair: Colonel Douglas J Goebel
Faculty: Captain Christine Szumko, Capt Carolyn Hackworth, Captain Vicki Misek
Program Office
Room 154, North Hall
Phone: (734) 764-2403
Students who enroll as cadets in the Air Force Officer Education Program, which is known nationally as the Air Force Reserve Officers Training Corps (AFROTC), successfully complete the program and receive a University degree are commissioned as Second Lieutenants in the United States Air Force.

Career Opportunities
Men and women can serve in a wide range of technical fields such as meteorology, research and development, communications and electronics, engineering, transportation, logistics, and intelligence as well as in numerous managerial and training fields such as administrative services, accounting and finance, personnel, statistics, manpower management, education and training, investigation, and information services. There are also opportunities in the pilot, navigator, space operations, and missile career fields. Advanced education or technical training for these career areas may be obtained on active duty at Air Force expense.

Four-Year and Two-Year Programs
The four-year program consists of eight terms (16 credit hours) of course work. The first terms (freshman and sophomore years) comprise the General Military Course (GMC). No military obligation is incurred during the freshman year for AFROTC scholarship recipients and none during the freshman or sophomore years for non-scholarship AFROTC students. During the summer following the GMC, students are required to attend a four-week field training session. After completing field training, students enroll in the last four terms (junior and senior years) of AFROTC called the Professional Officer Course (POC). Once students attend the first POC class, they assume a contractual obligation to complete the program, accept a commission, and discharge the military service obligation.
The two-year program is for junior-level college students or graduate students with a two-year degree program who have not participated in the GMC but want to enter the POC. Application for the two-year program should be made by November 1 of the student's sophomore year. Students must attend a six-week field training session prior to entering the POC. Once they attend the first class, these students incur the same obligation as four-year program students.

Financial Benefits and Scholarships
For a detailed description of the available financial benefits and scholarships, consult the appropriate sections in the general introduction to the Military Officer Education Programs.

Course of Study
Students enroll in one course in Aerospace Studies (AS) during each term of participation in the program for a total of 16 credit hours.

- Basic course sequence (first and second year): Aerospace Studies 101, 102, 201, 202 (4 hours).
- Advanced course sequence (third and fourth years): Aerospace Studies 310, 311, 410, 411 (12 hours).

This sequence of courses attempts to develop an understanding of the global mission and organization of the United States Air Force, of the historical development of air power and its support of national objectives, of concepts of leadership, management responsibilities and skills, of national defense policy, and of the role of the military officer in our society.

Flying Activities
Cadets who are chosen for pilot training, based on the physical and mental requirements, will receive up to 50 hours of dual and solo flight instruction under the supervision of an Air Force introductory flight course usually between their junior and senior years.

Military Obligation
After being commissioned, graduates of the program will be called to active duty with the Air Force in a field usually related to their academic degree program. The period of service is four years for non-flying officers, eight years for navigators after completion of navigator training, and ten years for pilots after completion of flight training.

Air Force Officer Education Course Listings
(Subject = AERO)
Course descriptions are found on the College of Engineering web site at http://courses.engin.umich.edu/
101. The Air Force Today
Prerequisite: none. I (1 credit)
102. The Air Force Today
Prerequisite: AS 101. II (1 credit)
201. Evolution of U.S. Air Power
Prerequisite: AS 102. I (1 credit)
202. Evolution of U.S. Air Power
Prerequisite: AS 201. II (1 credit)
310. Air Force Leadership and Management
Prerequisite: AS 202. I (3 credits)
311. Air Force Leadership and Management
Prerequisite: AS 310. II (3 credits)
410. National Security Forces in Contemporary American Society
Prerequisite: AS 311. I (3 credits)
411. National Security Forces in Contemporary American Society
Prerequisite: AS 410. II (3 credits)
Note: *A Leadership Laboratory (0 credit), meeting for one-and-one-half hours each week, accompanies each of the above-listed courses.*

Army Officer Education Program
Chair: Lieutenant Colonel Robert Hilton
Assistant Chair: Captain David Connelly
Program Office
Room 212, North Hall
Phones: (734) 764-2400, (734) 764-2401
Scholarships: (734) 647-3029
Upon graduation and completion of program requirements, students receive a commission as second lieutenant in the United States Army Reserve or in the Active Army.

Career Opportunities
Graduates may request active duty in the Army as commissioned officers, or choose reserve duty service in the Army National Guard or Army Reserve in order to pursue a civilian career or graduate schooling.
Active duty officers are available for worldwide assignment. Service in the Army's 97 career specialties provides an opportunity to gain extensive management experience.

Four-Year, Three-Year, and Two-Year Programs
Students may choose one of three program options as described in the general introduction to the Military Officer Education Programs. All programs include a five-week advanced summer camp at an Army post, which is taken as part of the advanced course sequence normally between the junior and senior years. The first two years of the four-year program can be taken without an obligation to the Army. Students who intend to enroll in the two-year program should contact the chairman by February of their sophomore year to apply for attendance at a five-week summer basic camp before enrollment in the program the following fall term. Two-year candidates must have a total of two years of school remaining at the undergraduate and/or graduate level. Students with prior military service (or prior ROTC training) may enroll in the program with advanced standing.

Financial Benefits and Scholarships
Army ROTC scholarships are merit-based and provide full tuition plus books and fees. All advanced course students receive a monthly stipend to help cover room and board. The stipend is $400/month for third year students and $500/month for fourth year students. Engineering students may request an additional year of scholarship benefits if they are enrolled in a five-year program. Two, three & four year scholarships are available.

Simultaneous Membership Program
Non-scholarship students can choose to join a Reserve or National Guard unit of their choice while enrolled at the University. The student trains as an officer trainee, gaining valuable leadership training as a member of the Reserve Forces and can collect over $1,000 a month.

Branch Assignments
In their last year, cadets are classified for branch assignments to one of the following 16 branches of the Army in accordance with their personal preference, aptitude, academic background, and the needs of the Army: Corps of Engineers, Signal Corps, Aviation, Armor, Field Artillery, Air Defense Artillery, Adjutant General's Corps, Military Intelligence, Finance Corps, Infantry, Medical Service Corps, Military Police Corps, Ordnance Corps, Quartermaster Corps, Transportation Corps, and Chemical Corps.

Course of Study
Students enroll in one course in Military Science (MS) during each term of participation in the program for a total of 12 credit hours distributed as follows:

- Basic Course sequence (first and second years): Military Science 101, 102, 201, 202 (4 hours total).
- Advanced Course sequence (third and fourth years): Military Science 301, 302, 401, 402 (8 hours total).

The complete course of instruction includes professional ethics, professional writing and briefing, principles of military leadership, staff management principles, military justice, and tactics. In addition to the classroom courses, students participate in Leadership Laboratories (one 90 minute period per week). Training includes orienteering, rappelling, marksmanship, land navigation, and physical training. In addition, courses in effective writing and military history are required for completion of the program.

Military Obligation
Students may request active duty or non-active duty assignments in the Army Reserve or National Guard. All Advanced Course students are obligated to four years of service which may be served in an active or reserve status depending on individual preference and Army needs and an additional four years of IRR (on call) status. No obligation is incurred during the freshman and sophomore years, unless the student is on scholarship.
Note: A Leadership Laboratory (0 credit), meeting for one and one-half hour each week, accompanies each of the above listed MS courses.

Army Officer Education Course Listings
(Subject = MILSCI)
Course descriptions are found on the College of Engineering web site at http://courses.engin.umich.edu/
101. Introduction to Officership
Prerequisite: none. (1 credit)
102. Introduction to Leadership
Prerequisite: none. (1 credit)
103. Leadership Laboratory
Prerequisite: none. (1 credit)
201. Innovative Tactical Leadership
Prerequisite: none. (1 credit)
202. Leadership in Changing Environments
Prerequisite: none. (1 credit)
301. Leading Small Organizations I
Prerequisite: permission of Chairman. (2 credits)
302. Leading Small Organizations II
Prerequisite: permission of Chairman. (2 credits)
401. Leadership and Management
Prerequisite: permission of Chairman. (2 credits)
402. Military Professionalism and Professional Ethics
Prerequisite: permission of Chairman. (2 credits)

Navy Officer Education Program
Captain Edward C. Zurey Commander Clark V. Brigger
Capt Timothy R. Zelek
LT Regina A. Koetters
LT Thomas P. Taylor
LT Andrew D. Notbohm
GySgt Troy B. Britton
Program Office
Room 100, North Hall
Phone: (734) 764-1498

Students enrolled as midshipmen in the Navy Officer Education Program who successfully complete the program and receive a university degree are commissioned as officers in the United States Navy or Marine Corps.

Career Opportunities
Graduates of the program have a wide range of job and career opportunities as commissioned officers in the Navy or Marine Corps. Navy officers may choose duty in surface ships, aviation, submarines, or nursing. Marine Corps officers may choose aviation, infantry, armor, or artillery specialties. After graduation, all commissioned officers receive additional training in their chosen field.

Program Length
The program normally includes eight terms of course work. A military obligation is incurred at the beginning of the sophomore year for scholarship students. Non-scholarship students may enroll in the College Program and take normal ROTC courses, but without incurring a military obligation. College Program students are considered for scholarship each year; selections are made based on university academic performance.

Financial Benefits and Scholarships
Scholarships cover tuition, lab fees, books, uniforms, and a monthly stipend, for a length of two to five years of study. For a more detailed description of the available financial benefits and scholarships, consult the following websites: www.umich.edu/~navyrotc and https://www.nrotc.navy.mil/. Additionally, the Navy awards scholarships for study at the University of Michigan to students chosen on the basis of selections made by a national committee. Criteria for eligibility vary among the several programs offered. Details are available from the program chair.

Course of Study
Students enroll in Naval Science (NS) courses during each term of participation in the program. In addition, all students are required to elect college course work in calculus, physics, and other Navy required courses. Students also participate in a four- to six-week summer training exercise during the periods between academic years.

Military Obligation
Depending on the program in which they are enrolled, graduates have a four or five year active duty service obligation. Those who are selected for additional education may incur an additional service obligation upon completion of that training.

Navy Officer Education Course Listings
(Subject = NAVSCI)
Course descriptions are found on the College of Engineering web site at http://courses.engin.umich.edu/
101. Introduction to Naval Science
Prerequisite: none. I (2 credits)
102. Seapower and Maritime Affairs
Prerequisite: none. II (2 credits)
201 (NA 102). Introduction to Ship Systems
Prerequisite: none. I (3 credits)
202 (EECS 250). Electronic Sensing Systems
Prerequisite: Physics 240 or EECS 230. II (3 credits)
301 (Astron 261). Navigation
Prerequisite: none. I (3 credits)
302. Naval Operations
Prerequisite: none. II (3 credits)
310 (UC 310). Evolution of Warfare
Prerequisite: none (3 credits)
401. Leadership and Management
Prerequisite: NavSci 101 & 102 or Permission of Instructor. (3 credits)
402 (UC 402). Leadership and Ethics
Prerequisite: NavSci 101 & 102 or Permission of Instructor II (2 credits)
410 (UC 410). Amphibious Warfare
Prerequisite: none. (3 credits)
Note: *The courses listed herein are offered primarily for the students participating in the program; however, they are open to, and may be taken by, any University enrolled student.*