COLLEGE OF ENGINEERING

CLASS
OF
96

ABOUT THE COVER:
Shégan Jamal Campbell (BSE '96 EE)
walked across the Crisler Arena stage at
College of Engineering Commencement
1996 with his exuberance showing.
Among those in the audience who
responded in-kind were several members
of the large extended Campbell family
including his father, Dr. Milton Bernard
Campbell (DDS '76 Dental Surgery).
After graduation, Shégan traveled from
his home in Detroit, Michigan, to work
as a design engineer at Intel in Chandler,
Arizona, before beginning his master's
degree program in electrical circuits
/analog design at Stanford University
in September 1996.

Cover design: *Marie Howard*
Photo: *Peter Yates*

Summer 1996

Dear Prospective Student,

At the University of Michigan you have the opportunity to learn from, and work with, some of the most accomplished men and women in the country—as classmates and as teachers. Our faculty is the best, and our learning becomes richer and more interesting through their exploration of new knowledge and new technologies. Studying with some of the world's most gifted engineers-in-training makes learning more stimulating. The College of Engineering emphasizes team building, collaboration and cooperation. Your most important challenges at Michigan will be with yourself, to do your absolute best. This environment helps you understand that you can succeed at Michigan and your accomplishments will be your own.

In addition to top faculty and students at the College of Engineering, you will have access to state-of-the-art technology—tools that are just beginning to be introduced in industry. As an undergraduate or graduate student, you will have the unique opportunity to use this technology in class, labs, and on assignments. When you leave Michigan, you will find this experience has put you ahead of most others in the market place.

Keep in mind that the College of Engineering is not all books and classes. After classes are done for the day, some of the best avenues for personal and professional interests are right here at the College. Engineering has nearly 40 student-run professional societies, honor societies, and project teams. These are opportunities to connect with the professional world, explore options and interests, develop your leadership skills, and just have fun. Getting involved helps you form the friendships that make a very large school a supportive community.

Good luck and Go Blue!

Catherine S. Peponis ('96E)
President
University of Michigan Engineering Council (UMEC*)

*UMEC is the College of Engineering student government.

Letter from the President

Ranked among the finest engineering colleges in the world, the College of Engineering and its more than 56,000 alumni are a source of great pride for the University, the state of Michigan, and the nation. Since the U-M awarded its first engineering degrees in 1860, engineering at Michigan has grown to 17 academic programs in 11 departments. Always pushing to expand the frontiers of science and technology, the College is home to two National Science Foundation Research Centers—the Center for Ultrafast Optics Science and the Center for Reconfigurable Machining—and the exciting new Media Union.

Engineering students, like all Michigan students, are encouraged to hone their leadership and team-building skills through involvement in social and pre-professional organizations. Whether it is building a solar car or working with a manufacturing company to design a new product, here or abroad, students gain practical experience while learning the latest in engineering theory. Not surprisingly, Michigan engineering graduates are highly sought by industry, government, and académe and go on to be leaders in their respective fields.
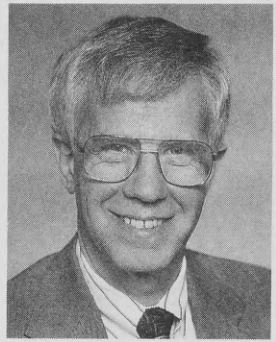
As alumni, they wear with pride the mantle "leaders and best." I would like to invite you to be part of this tradition of excellence—the College of Engineering—where the best promises to keep getting better.

Sincerely,

Homer A. Neal

Homer A. Neal
(M.S. Physics '63; Ph.D. Physics '66)
Interim President
University of Michigan

Letter from the Dean

Whether you are a prospective student or a current student, I welcome your interest in the University of Michigan College of Engineering.

If you are considering Michigan for your undergraduate engineering degree, you may still be wondering just what engineering is all about. This is not surprising since most of you have never been exposed to engineering in high school and many folks in the general public really do not know what engineers do or how valuable they are to society. In my mind, words like creator, innovator, problem solver, builder, fixer, and leader are best used to describe engineers.

As an engineering student, you will learn to think logically, solve problems, be creative and innovative, deal with uncertainty and change, apply technology in a socially and environmentally responsible manner, communicate effectively, and be capable of collaborating with others. At Michigan, you will have the opportunity to develop these skills by using them. Classroom assignments may be complemented by student society projects, such as building a cement canoe that floats or a helicopter powered by human energy.

If you are considering Michigan for your graduate engineering degree, I am sure you are aware that Michigan is a "research university," and that *U.S. News and World Report* ranked our graduate engineering program 5th in the country. Research universities have essentially two missions—to disseminate knowledge and to create new knowledge. This gives our students a unique opportunity to interact with individual faculty who are developing completely new things, not just teaching about things already known.

While some of you graduating with an engineering degree may not ultimately pursue an engineering career, I believe that completion of an engineering program will serve you well. We live in an increasingly complex world, both socially and technically. This means that individuals who are comfortable with technology and know how to use it will be well poised for the future.

You are about to begin an exciting time of discovery, whichever level of study you anticipate at Michigan. This is a multi-dimensional university, not only noted for outstanding technical education, but for exceptional liberal arts and fine arts education as well. I urge you to take advantage of the opportunity you will have to become a well-rounded individual. I'm sure you will have fun doing so.
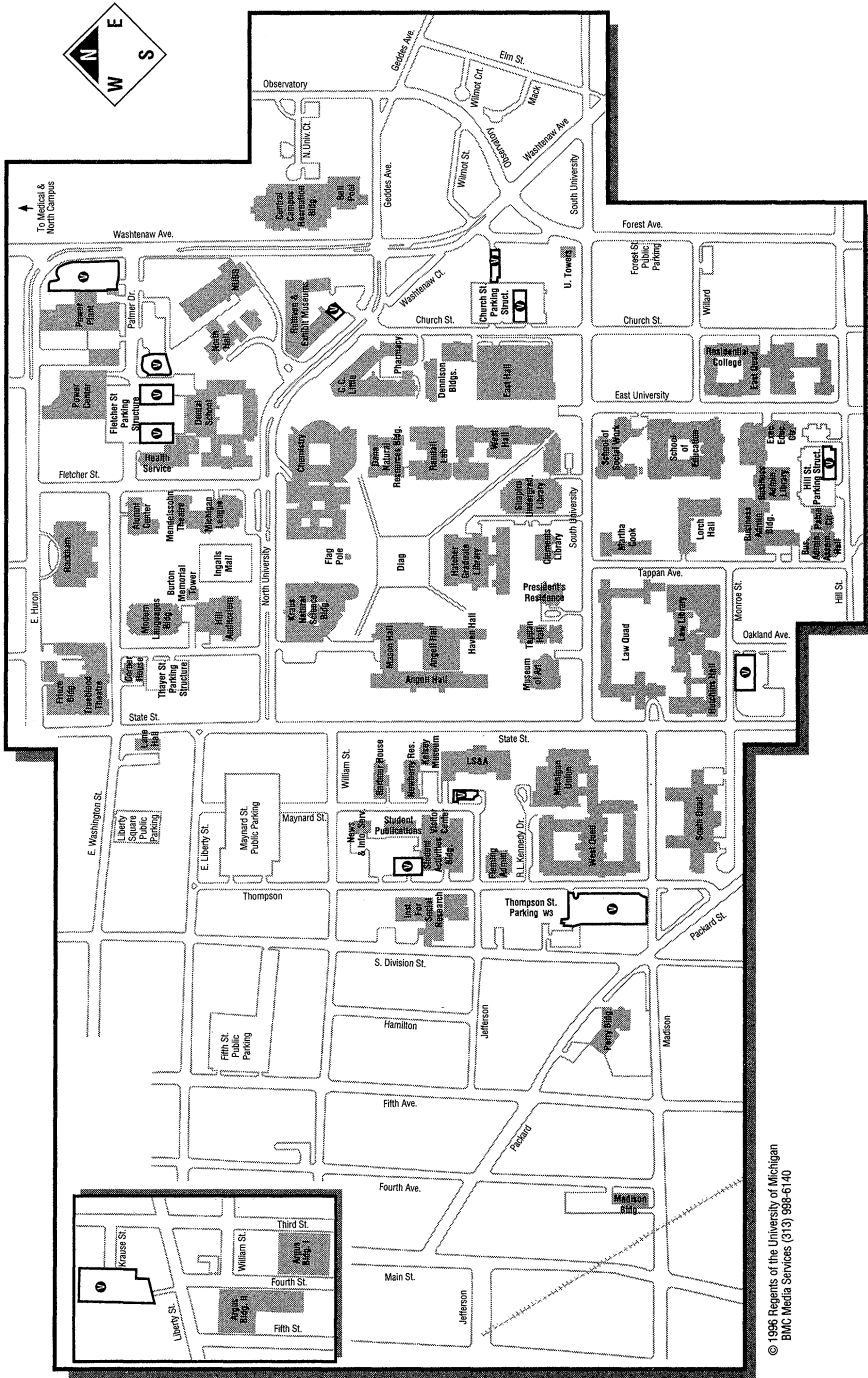
Best regards,

Stephen W. Director
Dean
College of Engineering

University of Michigan Central Campus

Ann Arbor, Michigan

N E W S

Observatory

To Medical & North Campus

Washtenaw Ave.

Geddes Ave.

Elm St.

Wilmot Crt.

Mack

Washtenaw Ave.

South University

Forest Ave.

N. Univ. Ct.

Central Campus Recreation Bldg.

Bell Pool

Forest St. Public Parking

Willard

Perry Pool

Palmer Dr.

WIBS

Rackham & Exhibit Museum

Church St.

Church St. Parking Struct.

U. Towers

Church St.

Church St.

Residential College

East Quad

Keen Hall

Pharmacy

East Hall

Fletcher St. Parking Structure

Power Center

Denture Service

Dana Space

C.C. Little

Dennison Bldgs.

East University

East University

Fletcher St.

Health Service

Chemistry

Dow Natural Resources Bldg.

Randall Lab

West Hall

School of Social Work

School of Education

East Eng. Ctr.

Perry Center

Mendelssohn Theatre

Michigan League

Ingalls Mall

Flag Pole

Diag

Shapiro Undergrad Library

South University

Hatcher Graduate Library

Graduate Library

Marsha Cook

Business Admin. Bldgs.

Bus. Admin. Parking Struct.

E. Huron

Stockwell

Rackham Bldg.

Burton Memorial Tower

Hill Auditorium

Kraus Natural Science Bldg.

North University

Haven Hall

Hatcher Graduate Library

President's Residence

Tappan Ave.

Lorch Hall

Hill St. Parking Struct.

Hill St.

Frieze Bldg.

Trueblood Theatre

Thayer St. Parking Structure

Lane Hall

Mason Hall

Angell Hall

Haven Hall

Museum of Art

Tappan Hall

Law Quad

Law Library

Monroe St.

Oakland Ave.

State St.

State St.

Gregory/Krause

Newberry Res.

Kelsey Museum

L.S.&A.

Michigan Union

E. Washington St.

Liberty Square Public Parking

E. Liberty St.

Maynard St. Public Parking

William St.

Maynard St.

News & Info. Serv.

Student Publications

Student Activities Center

R.L. Kennedy Dr.

Fletcher Admin.

West Quad

South Quad

Benzinger Hall

Thompson

E. Liberty St.

First Baptist Church

Student Research

Thompson St. Parking W3

Packard St.

S. Division St.

Hamilton

Jefferson

Perry Bldg.

Madison

Fifth St. Public Parking

Fifth Ave.

Packard

Fourth Ave.

Madison Bldg.

Third St.

Main St.

William St.

Angel Bldg.

Krause St.

Fourth St.

Liberty St.

Angel Bldg. II

Fifth St.

Jefferson

University of Michigan North Campus

College of Engineering

PLYMOUTH ROAD — From US 23

HURON PARKWAY

Key

| ▨ | Metered parking |

N

Campus Map ■

HUBBARD

HUBBARD

UPLAND

HUBBARD

Space Research Building

HAYWARD

HAYWARD

MUIRFIN

G.G. Brown Laboratories

BEAL AVENUE

DRAPER

Herbert H. Dow Building

Electrical Engineering & Computer Science Building (EECS)

JEWRE Building

François-Xavier Bagnoud Building

Engineering Programs Building

Naval Architecture & Marine Engineering Buildings

Ann and Robert H. Lurie Tower

Walter E. Lay Automotive Laboratory

Chrysler Center

Robert H. Lurie Engineering Center

Industrial and Operations Engineering Building

Phoenix Memorial Lab

Mortimer E. Cooley Building

HURON PARKWAY

School of Music

Bus Stops Bursley-Baits

Pierpont Commons

Media Union

BONISTEEL BOULEVARD

Center for Display Technology & Manufacturing

Institute of Science & Technology Building

Bentley Library

From Fuller Rd. & Central Campus

Art & Architecture Building

Computing Center

Advanced Technology Laboratories Building

Ford Library

To Fuller Rd. and Central Campus

BEAL AVENUE

GLAZIER WAY

FULLER ROAD

To Geddes Road

HURON PARKWAY

NORTH TO FLINT

PLYMOUTH

WEST TO JACKSON 94

ANN ARBOR AREA Ⓗ

MAIN

WASHTENAW

YPSILANTI AREA

US 12

MICHIGAN

EAST TO DETROIT

N

STATE

23

PACKARD

WILLOW RUN AIRPORT

94

SALINE

SOUTH TO TOLEDO

METROPOLITAN AIRPORT

1 MILE

College of Engineering

1996–97

The University of Michigan

Homer A. Neal, *Interim President of the University of Michigan*
James C. Renick, *Chancellor of the University of Michigan-Dearborn*
Charlie Nelms, *Chancellor of the University of Michigan-Flint*
J. Bernard Machen, *Provost and Executive Vice President for Academic Affairs*
Farris W. Womack, *Executive Vice President and Chief Financial Officer*
Roberta R. Palmer, *Secretary of the University*
Thomas C. Kinnear, *Vice President for Development*
Frederick C. Neidhardt, *Interim Vice President for Research*
Maureen Hartford, *Vice President for Student Affairs*
Walter L. Harrison, *Vice President for University Relations*

College of Engineering

Stephen W. Director, *Dean of the College of Engineering*
William R. Martin, *Associate Dean for Academic Affairs*
George R. Carignan, *Associate Dean for Graduate Education and Research*
J. Wayne Jones, *Associate Dean for Undergraduate Education*
Gene E. Smith, *Assistant Dean for Advising and Career Planning*
Anne W. Monterio, *Assistant Dean for Students*

Administrative Directors for Student Services

Gary Boling, *Director of Engineering Placement*
Sharon Burch, *Director of Transfer Admissions and Recruitiment*
Derrick E. Scott, *Director of Minority Engineering Program Office*
Joan Clauss, *Head of Cooperative Education Program*

Contents

General Information

Fall Term, 1996

Ann Arbor Campus *(Contact Registrar's Office at 313-764-6280.)*

* Registration	**Aug. 29-30**	**Thursday-Friday**
Labor Day (Holiday)	September 2	Monday
Classes begin	September 3	Tuesday
Thanksgiving recess 5 p.m.	November 27	Wednesday
Classes resume 8 a.m.	December 2	Monday
Classes end	December 10	Tuesday
Study Days	December 11-12	Wednesday-Thursday
Examinations	**December 13**	**Friday**
	December 16-20	**Monday-Friday**
Commencement	December 15	Sunday

Dearborn Campus *(Contact Registrar's Office at 313-593-5200.)*

* Registration	August 22-23	Thursday-Friday
Classes begin	September 4	Wednesday

Flint Campus *(Contact Registrar's Office at 810-762-3344.)*

* Registration		
Classes begin	August 29	Thursday

Winter Term, 1997

Ann Arbor Campus *(Contact Registrar's Office at 313-764-6280.)*

* Registration	**January 6-7**	**Monday-Tuesday**
Classes begin	January 8	Wednesday
Martin Luther King, Jr. Birthday	January 20	Monday
(University Symposia.	**No Regular Classes)**	
Vacation begins 12:00 noon	March 1	Saturday
Classes resume 8 a.m.	March 10	Monday
University Honors Convocation	March 16	Sunday
Classes end	April 22	Tuesday
Study Day	April 23	Wednesday
Examinations	**April 24-25,**	**Thursday-Friday**
	April 28-May 1	**Monday-Thursday**
Commencement Activities	May 2-4	Friday-Sunday

Dearborn Campus *(Contact Registrar's Office at 313-593-5200.)*

* Registration	December 11-12	Wednesday-Thursday
Classes begin	January 7	Tuesday

Flint Campus *(Contact Registrar's Office at 810-762-3344.)*

* Registration		
Classes begin	January 6	Monday

Spring-Summer Term, 1997

Ann Arbor Campus *(Contact Registrar's Office at 313-764-6280.)*

*	**Registration** (Full Term & Spr. Half)	**May 5**	**Monday**
	Classes begin	May 6	Tuesday
	Memorial Day (Holiday)	May 26	Monday
	Classes end 5 p.m. (Spring Half)	June 20	Friday
	Study Days	June 21-22	Saturday-Sunday
	Examinations	**June 23-24**	**Monday-Tuesday**
	Spring Half Term ends	June 24	Tuesday
*	**Registration** (Summer Half)	**June 26-27**	**Thursday-Friday**
	Summer Half Term classes begin	June 30	Monday
	Independence Day (Holiday)	July 4	Friday
	Classes end 5 p.m.	August 15	Friday
	Study Days	August 16-17	Saturday-Sunday
	Examinations	**August 18-19**	**Monday-Tuesday**
	Full Term & Summer Half Term end	August 19	Tuesday

Dearborn Campus *(Contact Registrar's Office at 313-593-5200.)*

*	Registration	April 14	Monday
	Classes begin	May 5	Monday
	Summer Half Term		
*	Registration	June 23-24	Monday-Tuesday
	Classes begin	July 7	Monday

Flint Campus *(Contact Registrar's Office at 810-762-3344.)*

*	Registration		
	Classes begin	May 5	Monday
	Summer Half Term		
*	Registration		
	Classes begin	June 30	Monday

* **Check School Office for registration dates to avoid late registration fee.**
  This Calendar is subject to change.

General University Offices

Campus Information Center: (313) 763-INFO

Pierpont Commons North Campus Information Center: 764-7544

Academic Affairs (Provost's Office), 3068 Fleming Bldg., 764-9290

Admissions, Undergraduate, 1220 Student Activities Bldg. (SAB), 764-7433

Career Planning and Placement, 3200 SAB, 764-7460

Cashier's Office, 1015 Literature, Science, and the Arts Bldg. (LS&A), 764-8230

Employment:

>   Student, 2503 SAB, 763-4128
>   Hospital, 300 N. Ingalls Bldg. (NIB), Room 8A04, 747-2375
>   Campus, G250 Wolverine Tower, 764-7280

Extension Service, 200 Hill Street, 764-5300

Financial Aid, 2011 SAB, 763-6600

Graduate School, 114 Rackham Bldg.,

>   Domestic Admissions, 764-8129
>   International Admissions, 764-8129

76-GUIDE, 24-hr. Telephone Counseling Svc., SOS Crisis Center, 114 N. River, 764-8433
   (76-GUIDE)

Health Services, 207 Fletcher

>   Appointments, 764-8325
>   Information, 764-8320

Housing, 1011 SAB

>   Residence Halls Assignments, 763-3164
>   Family Housing Assignments, 763-3164
>   Off-Campus Housing, 763-3205
>   Off-Campus Housing (cooperatives),
>   337 E. William, 662-4414
>   Off-Campus Housing (fraternities, sororities),
>   3403 Michigan Union, 936-3686
>   Fees, payment of, Cashier's Office,
>   1015 LS&A Bldg., 764-8230

International Center: Central Campus, 603 E. Madison, 764-9310; North Campus,
   Pierpont Commons Ground Floor, 936-4180

Ombudsman, 3000 Michigan Union, 763-3545

Orientation, 701 E. University, 102 Hayden, 764-6290

President's Office, 2074 Fleming Bldg., 764-6270

Secretary of the University, 2014 Fleming, 763-5553

Student Accounts; Room, Board, and Tuition, 2226 SAB, 764-7447
Student Locator, 764-2330
Student Activities and Leadership, 2209 Michigan Union, 763-5900
Student Legal Services, 2304 Michigan Union, 763-9920
Veterans Affairs, 555 LS&A Bldg., 764-1575

U-M College of Engineering Offices

General Information: (313) 647-7000

Undergraduate Admissions: 1220 Student Activities Bldg., 764-7433

Transfer Admissions and Recruitment: Robert H. Lurie Engineering Center (LEC),
Room 1108, 647-7101 (includes recruitment of first-year and transfer undergradua
students; undergraduate transfer admission—cross-campus, external and foreign,
and admission of students with guest or special status)
Academic Records, 1401 LEC, 647-7111 or 647-7112
Computer Aided Engineering Network (CAEN), 2161 Media Union, 763-3266
Cooperative Education, 2423 EECS Bldg., 763-5086
Engineering Council (UMEC), 1230 EECS Bldg., 764-8511
Engineering Learning Resource Center (ELRC), G264 LEC, 647-7127
Freshman/Undeclared Engineering Student Advising and Career Planning Center,
1009 LEC, 647-7106
Graduate Professional Programs (D.Eng., M.Eng., M.S. in TIDM), 1446 LEC, 647-7024
International Engineering Programs Office, 1105 LEC, 647-7026
Minority Engineering Program Office (MEPO), 1463 LEC, 647-7122
Placement (students and alumni), 201 Stearns Bldg., 764-8483
Scholarships, 1410 LEC, 647-7113
Society of Minority Engineering Students (SMES), 1232 EECS Bldg., 764-7252
Society of Women Engineers (SWE), 1226 EECS Bldg., 763-5027
Withdrawal/Disenrollment, 1401 LEC, 647-7111 or 647-7112
Women in Engineering Office, 1240 LEC, 647-7012

ENGINEERING SHOPS

604   Lyndon '04

History of the College

The University of Michigan College of Engineering was founded in 1853-54, when fewer than a half-dozen other American colleges were providing opportunities for a formal engineering course of study.

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, 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 plain 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 went on to establish itself as a significant engineering school with a number of leadership steps. Michigan established the nation's first program in Metallurgical Engineering (1854), Naval Architecture and Marine Engineering (1881), Electrical Engineering (1890), Chemical Engineering (1898), Aeronautical Engineering (1914), Nuclear Engineering (1953), and Computer Engineering (1965).

Today, the College of Engineering at the University of Michigan is consistently ranked among the top engineering schools in the world. Most of its degree programs are rated in the top ten nationwide. About 900 bachelor's degrees and 700 master's and doctoral degrees are awarded annually. The opportunities for study have expanded so that students may choose from more than 1000 engineering courses.

There were 300 teaching faculty, 88 research faculty, 4,528 undergraduate students and 1,861 graduate students in the College of Engineering in Fall 1995, who took advantage of the College's diverse research and teaching facilities.

The College of Engineering expended about $84 million dollars in research grants for 1994-95—approximately 20% of total University research funds.

The College has more than 150 research laboratories, 45 of which operate with budgets of over a half million dollars, including two National Science Foundation research centers.

The College of Engineering faculty stood before the Engineering Shops building for this 1904 group photograph. Shops housed the forge and foundry; offices, classrooms, and drawing rooms; and laboratories for testing steam engines, water motors, other machines, and materials. The newly-completed West Engineering Building soon incorporated the mechanical, steam, hydraulic, electrical, and physical testing laboratories and a mold loft, in addition to the first enclosed educational naval testing tank in America. (Photo by Lyndon; from College of Engineering archives)
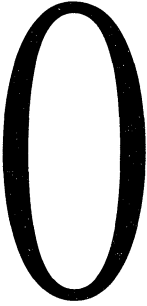
Our world relies on science and technology for prosperity and, increasingly, for survival. Science, in its purest interpretation, is the discovery of nature. Engineering is the technical application for those truths to the benefit of humankind.

Each scientific discovery compels us to search for something better. The relationship between discovery and application of knowledge grows increasingly intimate in the modern era; therefore, the practical art of engineering has become a little less art and a little more science. Yet, the well-being of humanity remains the professional engineer's primary concern.

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. And always, 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? At the dawn of the 21st century, professional engineers must be attuned to these interrelated dynamics.

In many ways, the study of engineering provides students with the true "liberal education" of our technology-based future—

The University of Michigan Engineering Council (UMEC) produces *Springfest*, a North Campus-wide festival on the last day of classes every Winter Term. The *Springfest*-decorated Alice Aycock sculpture, gift of the Class of '33E, is a good backdrop for those who stop to study or chat. (Photo: David Smith)

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.

The University of Michigan College of Engineering is dedicated to preparing our students for the technological leadership of tomorrow. Michigan Engineers have the opportunity to elect courses and to participate in research and co-curricular activities that broaden their knowledge and develop their ability to analyze problems and responsibly apply their knowledge to solutions.
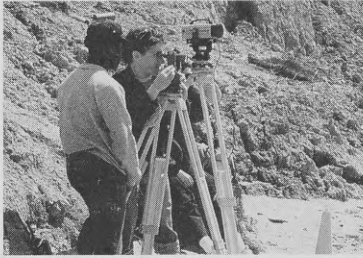
The primary objective of the College of Engineering is the preparation of its students for positions of responsibility commensurate with their talents and interests. Students can prepare for a broad range of professional opportunities. According to their aptitudes and desires, students may become practicing engineers, researchers, administrators, or teachers. Moreover, the knowledge and intellectual discipline of engineering have proven to be excellent preparation for non-engineering careers, particularly in business, law, and medicine. Many graduates of the College choose to earn a master's or doctoral degree in engineering. Another opportunity for growth and professional development is available through registration as a professional engineer; after working as an engineer (usually four years required), new engineers can take qualifying examinations offered by the state in which they seek registration.

At Michigan, engineering students associate with distinguished faculty who have a solid academic base and broad professional involvement. The College believes that ongoing faculty research and industrial consultation in engineering produces an outstanding faculty. Students benefit from the high caliber of our faculty through lectures and discussions in formal and informal settings, through fundamental scientific investigations in the laboratory, and in practicum-based design projects and applications of scientific knowledge to real-world problems. Graduate and undergraduate students in the College have the opportunity to participate in such activities in the classroom, in well-equipped engineering laboratories, and at a variety of field locations.

The University of Michigan College of Engineering undergraduate program consists typically of a four-year schedule leading to a bachelor's degree. There are eleven courses of study that lead to the Bachelor of Science in Engineering degree and two that lead to the Bachelor of Science; these are identified in this *Bulletin* as B.S.E. and B.S., respectively. 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 the College of Literature, Science and the Arts in about one year beyond the time required for a single degree. The Simultaneous Graduate/ Undergraduate Study (SGUS) program is structured for completion of both an engineering baccalaureate and master's degree within approximately five years. For further information, refer to the sections on "Undergraduate Programs" and "Graduate Studies."

Career Choice

In choosing engineering as a career, the main criteria 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.

More and more women are enrolling in this field which offers a satisfying career with a wide variety of employment opportunities. The College has one of the largest female enrollments of any engineering school in the country. Academic advisors and officers 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. A student with questions in this regard may benefit from a leaflet titled "Engineering"—available from the Office of the Assistant Dean for Advising and Career Planning (first year and undeclared students) at the Engineering Advising Center, College of Engineering, 1009 Lurie Engineering Center, Ann Arbor, Michigan 48109-2102.
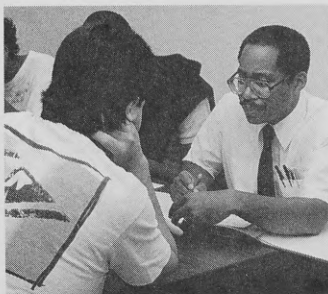
Registration as Professional Engineer

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 degree is awarded within six months after the examina-

tion; and (2) the degree program has been accredited at the College 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.
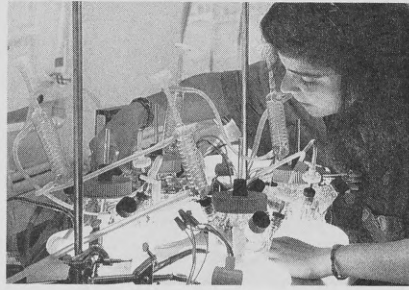
On completion of registration, an engineer establishes professional standing on the basis of legal requirements and receives authority to practice the engineering profession before the public. While state laws may differ in some respects, an engineer registered under the laws of one state will find that reciprocal agreements between states generally make possible ready transfer of privileges to other states.

Anyone wishing to obtain applications for these examinations may do so by contacting:

LGR EXAMINATIONS
ATTN: Michigan Engineer Program
1315 South Allen Street
State College, PA 16801-5992
1-800-877-3926 or 1-814-238-3066

Accreditation

The following degree programs offered on the Ann Arbor campus have been accredited by the Accreditation Board for Engineering and Technology (ABET): Aerospace, Chemical, Civil and Environmental, Computer, Electrical, Industrial and Operations, Materials Science and Engineering, Mechanical, Naval Architecture and Marine Engineering, and Nuclear.
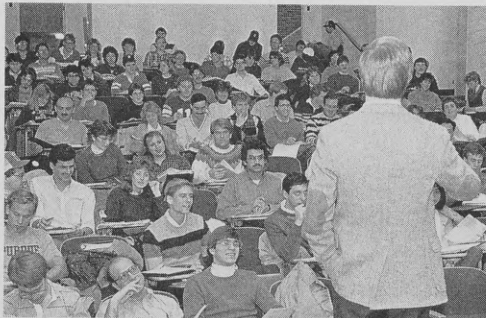
Facilities

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

North Campus Engineering Buildings
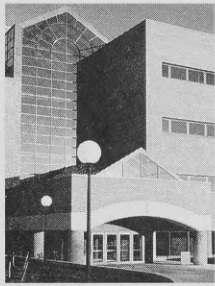
The Electrical Engineering and Computer Science (EECS) Building

Advanced Technology Laboratories (ATL)
Aerospace Wind Tunnel Laboratories
François-Xavier Bagnoud Building (FXB)
George Granger Brown Laboratories (GGB)
Chrysler Center
Mortimer E. Cooley Building
Herbert H. Dow Building
Dow Connector Building
Center for Display Technology and
    Manufacturing Building
Electrical Engineering and
    Computer Science Building (EECS)
Engineering Programs Building (EPB)
Environmental and Water Resources
    Engineering Building (EWRE)
Industrial and Operations
    Engineering Building (IOE)
Institute of Science and
    Technology Building (IST)
Walter E. Lay Automotive Laboratory
Robert H. Lurie Engineering Center (LEC)
Media Union
Naval Architecture and Marine
    Engineering Building (NAME)
Phoenix Memorial Laboratory with the
    Ford Nuclear Reactor
Space Research Building

Central Campus Engineering Facility

West Hall
    Naval Architecture and Marine
    Engineering Towing Tanks

Laboratories and other facilities are described within the sections on Undergraduate Degree Programs, pages 93–164.

The facilities of the University of Michigan College of Engineering rank foremost among the best research and teaching resources in the world. The two new buildings described below complete a major building program designed to comprise the best known technology in each of the College's eleven departments.
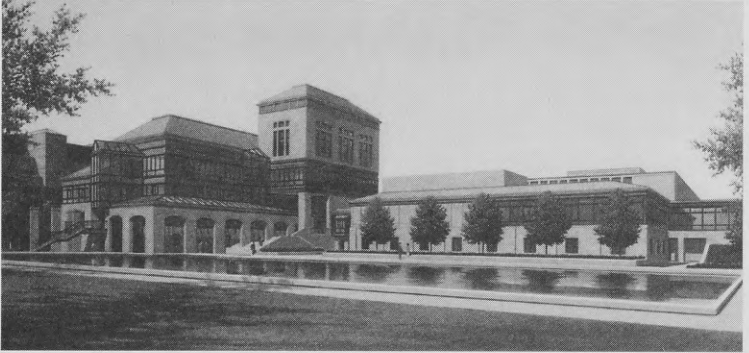
The Robert H. Lurie Engineering Center (LEC)

The Robert H. Lurie Engineering Center, the College of Engineering's new "front door," is the center for College of Engineering undergraduate student support. Most Engineering student services—including central student services, admissions, records, scholarships, freshman and undeclared advising, and specialized academic support such as the Minority Engineering Program Office, the Women in Engineering Office, and the Engineering Learning Resource Center—are in the LEC. 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 the Ann and Robert Lurie Family Foundation. Bob Lurie 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, also is the result of the Lurie Family Foundation's exceptional gift.
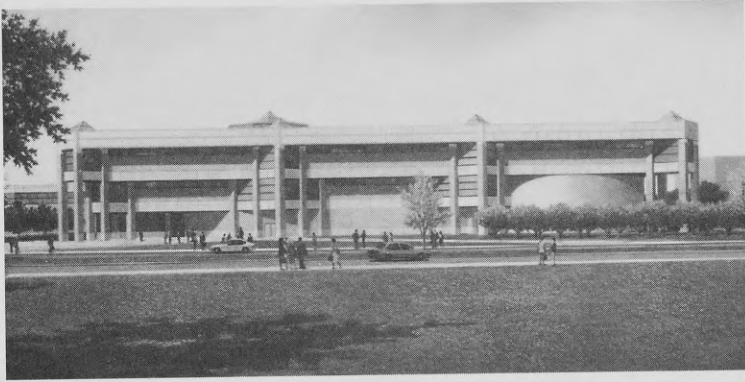
The Media Union

The Media Union is a 225,000 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 Media Union to locate information, to create new artifacts, and to make the results of their own inquiries available to others.

Within the Media Union, 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 Media Union 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. Moreover, the Media Union contains the most advanced networking technologies available today, such as asynchronous transfer mode (ATM). The Media Union also houses the library collections of the College of Engineering, the College of Architecture and Urban Planning, and the School of Art and Design.

Computing Facilities — CAEN

The Computer Aided Engineering Network (CAEN) provides the College of Engineering with one of the world's premier computing environments for engineering-related research and education. Dedicated to the concept of distributed computing since CAEN's inception in 1983, CAEN maintains a fully integrated, multi-vendor network of advanced function workstations and specialized high-performance computers serving the faculty, staff, and students of the College.

The Computing Environment

Comprised of more than 1,300 engineering-class workstations and more than 1,600 advanced microcomputers, the CAEN environment has become one of the largest integrated networks in the academic world. Some of these machines are housed in faculty and graduate offices, others in laboratories for classroom instruction. The rest are spread across the campus in 18 public facilities, conveniently available to the entire Engineering community for unlimited use, 24 hours a day, seven days a week.

A tour of CAEN facilities reveals workstations from many different vendors, including Apple, Hewlett-Packard, IBM, Silicon Graphics, and Sun Microsystems. The College also administrates the *Center for Parallel Computing* (CPC), which contains a 48 node IBM SP/2, a 32 processor HP/Convex SPP-1000, and a 16 processor Silicon Graphics PowerChallenge. The CPC provides assistance in creating, designing, and running parallel models. Access to these parallel systems is available to anyone with a faculty sponsor for parallel computation development. Remote access to a variety of supercomputer centers is also available from CAEN facilities. These varied platforms provide users with tremendous flexibility. They also give exposure to the many industry standards of today, as well as tomorrow.

An Integrated Network

The CAEN network allows users to sit at any workstation, from a Pentium or Apple Macintosh to an HP or Sun, and see an integrated, "single system" image of what is really a heterogeneous physical network. Several distributed file systems—including Sun Microsystems' NFS, Novell's Netware, and AFS—are actively
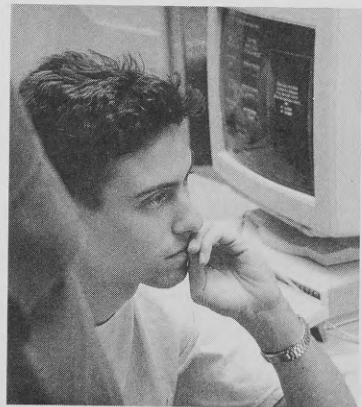
supported. Together they enable CAEN to provide more than 400 gigabytes of centrally administered file storage, all of which can be reached by any computer on the CAEN network.

CAEN's single logical internet is layered over a diverse collection of physical networks. These include Ethernet, fast Ethernet, a high-speed Fiber Distributed Data Interface (FDDI) fiber optic backbone network, and an experimental asynchronous transfer mode (ATM) network.

CAEN's computing environment is fully integrated with other University of Michigan organizations, including the Information Technology Division (ITD), the Medical Center, and the Electrical Engineering and Computer Science department's Departmental Computing Organization (DCO). Michigan's gateways to the Internet—including MCINet, CICNet, and BIT-NET—extend this connectivity across the country and around the world.

CAEN Open Laboratories

CAEN's open lab facilities contain Apple, IBM, Sun, and Hewlett-Packard workstations. All computers have their own hard disks, and all are connected to the CAEN network. Most available software resides either on the computer's hard disk or on networked servers.

In addition to the leading workstations in the industry, CAEN provides access to the top-rated software for engineering and general productivity applications. This software is available for use both in assigned classroom projects, as well as for general use by any CAEN user. Users are encouraged to learn and take advantage of the enormous breadth of software available on the CAEN network to enhance their learning and research efforts at the University. The *CAEN Handbook* and the *CAEN News* articles describe software that is available on the network. Short courses on various packages are announced in the newsletter and on-line, and *Technical Notes* provide introductory material on many packages.

Access to CAEN open labs is available to all College of Engineering faculty, staff, and registered students, and to other students who are majoring in computer science and/or are taking College of Engineering computing courses and who have paid a lab access fee. All of CAEN's open labs are also available 24 hours a day via electronic card-key access, using the standard University photo I.D. or MCard.
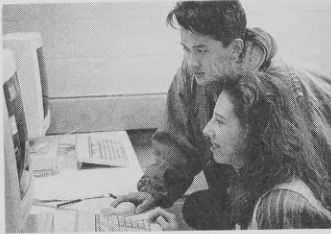
Information and User Services

CAEN's Information and User Services offer a full range of tutorial, instructional, and informational resources to help users more effectively use the computing environment. The *CAEN Handbook* is a detailed overview of services and resources provided by CAEN; *CAEN Technical Notes* provide topical instruction and information on using software, equipment, and services available to CAEN users; extensive on-line help is available via the World Wide Web (WWW) at http://www.engin.umich.edu/; and the monthly *CAEN News* offers technical articles on CAEN systems as well as regular information on changes and updates to the network and services. Classroom instruction ranging from single-session seminars to regular courses for credit are offered on a variety of topics.

The *CAEN News* is available for pickup at most CAEN labs. All other CAEN publications, including the *CAEN Handbook* and technical notes are available at the Media Union/CAEN Hotline, 2320 Media Union. Most CAEN informational material, including the *News* and *Technical Notes*, is available on-line as well. A complete reference collection of manuals for most CAEN software packages is located at the reference desk of the Engineering Library for on-site use. Copies for purchase of many manuals are available at the Art & Architecture Copy Center. Consultants are also located at the Media Union/CAEN Hotline office, 2320 Media Union for both walk-in and phone consultation (763-5041). Hours vary and change over the course of the year.

CAEN Employment Opportunities for Students

Many aspects of the CAEN computing environment are developed, operated, and maintained by student staff. Employment opportunities for students exist in office support, lab maintenance, back-up operations, lab counseling, user services, systems programming, and more. Postings for these positions, including details on how to apply for them, appear regularly in the CAEN *News* and as bulletins in the labs. Job applications are available at the Media Union/CAEN Hotline.

U-M Computing Center

Use of MTS is being phased out, with alternative services being provided in a distributed environment.

Engineering Library

The Engineering Library, located in the Media Union on North Campus, is one of more than 25 divisional libraries in the University Library System. Its collection of approximately 520,000 volumes covers all fields of engineering. The Library subscribes to almost 2,000 serial titles, including popular and scholarly engineering journals, maintains a large collection of technical reports, standards, government documents, U.S. patents, and reserve materials for course work.

The Library uses a wide variety of on-line information services, provides trained staff, course-related instruction programs, and computerized reference searching to help the students, faculty, and researchers make effective use of information resources both on the University campus and around the world.

The Library also provides access to microcomputers in the CAEN Network.
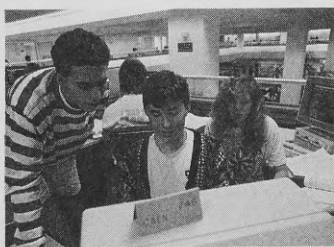
Use of Facilities

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

Student identification cards or MCards are required for entrance to many campus facilities, especially certain laboratories and libraries. These cards are issued by the Housing Office in Room 100, Student Activities Building (SAB) or the Entree Plus Office, Room 1212, on the main floor of the Pierpont Commons on North Campus.

Any student may trade in the Student ID card for the MCard, which has additional features.

Student Health Services

While at the University, students may come to the University Health Service for all their health care needs.

The University Health Service (UHS), located at 207 Fletcher on the Central Campus, offers outpatient services and health education programs. It is funded primarily through a health service fee. Most services provided at UHS that are not covered by a student's private health insurance will be covered by the Health Service fee. Spouses of students may use the UHS on a fee-for-service basis.

Patients are seen by appointment or on a walk-in basis Monday, Tuesday, Wednesday, Friday, 8 a.m.–4:30 p.m.; Thursday, 9 a.m.–4:30 p.m.; and Saturday, 9 a.m.–noon. Urgent care services are available for minor emergency care. For medical emergencies when UHS is closed, you may wish to go to the closest hospital emergency room. Medical care received outside of UHS is not covered by the Health Service fee.

The UHS also offers a wide range of specialty clinics for currently enrolled students. These clinics include: Dermatology, Neurology, Ophthalmology, Orthopedics, Ear-Nose-Throat, Psychiatry, Rheumatology, Audiology, and Sports Medicine. To be seen in one of these clinics, you must be referred by a UHS clinician.

Medical support services include an X-ray department, physical therapy, laboratory, and pharmacy. The UHS also has a nutritionist on staff and an Eye Care Clinic and Optical Shop.

For more information regarding UHS, or to pick up a copy of the UHS brochure, call the UHS Health Promotion and Community Relations Department at 763-1320 or stop in. The Health Service building is wheelchair accessible via its south entrance.

Scholarships

Numerous University of Michigan scholarships, fellowships, prizes, and loan funds are available to qualified Engineering students. 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 scholarship awards.

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, a few Academic or Merit Scholarships are granted by the University of Michigan's Admissions Office and the College of Engineering to incoming students (freshmen and transfer students). Once a student has completed a full term (12 credit hours) in the College of Engineering, it is possible to apply for a Need-Based Scholarship or an Industry-Sponsored Scholarship (see details below). Entering students who are eligible for financial aid should apply for *second term awards during the first term in which they are enrolled*. Applications from first term students will be processed but held until grades are reported.

University Admissions Office Academic Scholarships

The University of Michigan has established a variety of programs to recognize superior academic achievement. Participation in these programs is restricted to citizens of the United States and

persons on Permanent Resident Visas. Nominees are selected or identified from admissions applications or the Admissions Roster and are formally notified of their eligibility. Financial need is not a factor in the selection of scholarship recipients for Academic Awards. The stipends may change from year to year.

College of Engineering Academic Scholarships

Each year, a limited number of incoming freshmen are selected for honorary scholarships. Selection is made from a review of all freshmen students admitted to the College of Engineering and is based on SAT and/or ACT scores, class rank, and grade point average (GPA). An application is not required for consideration. These scholarships are restricted to citizens of the United States and persons on Permanent Resident Visas. For information pertaining to Freshman Merit Awards, entering students should contact the Director of Transfer Admissions and Recruitment in Room 1108 Lurie Engineering Center (LEC) or call (313) 647-7101. The Transfer Student Award is for one term only. For further information on scholarships, contact the Financial Aid Officer in the College of Engineering, 1410 LEC, or call (313) 647-7113.

Continuing Students

Need-Based Scholarships

The majority of scholarships awarded through the College of Engineering are based on financial need. To qualify for a Need-Based Scholarship, students **must** also apply for financial aid through the *University of Michigan Office of Financial Aid*. Other criteria that must be met exist within the various scholarship funds. It is the task of the Engineering Scholarship Office and the Engineering Scholarship Committee to match qualified students with the appropriate fund. Need-Based Scholarships are *not* renewable; students must reapply for scholarships each term and/or terms at which time the applicants' needs are re-evaluated based on new information.

Scholarships are restricted to full-time (12 credit hours) students who have completed one full term in the College of Engineering, have established a grade point average (GPA) of 2.7 or higher, and can demonstrate financial need. Need-Based Scholarships are also restricted to students who are citizens of the United States or have a Permanent Resident Visa. Since Need-Based Scholarships are based on financial need, to qualify, students *must also make an application for financial aid through the University of Michigan Financial Aid Office, 2011 Student Activities Building.* (See "Deadlines" on page 24.)

Industry-Sponsored Scholarships

Several industries offer scholarships to students. Sometimes a summer internship accompanies the monetary award given by industry and often the industry awards are renewable. Recipients are selected based on the criteria established by the donor.

Scholarships are restricted to full-time (12 credit hours) students who have completed one full term in the College of Engineering, have established a grade point average (GPA) of 3.2 or higher, and are citizens of the United States or on Permanent Resident Visas.

Where to Apply

Application forms for Need-Based or Industry-Sponsored Scholarships can be obtained at the Engineering Scholarship Office, 1410 LEC.

When to Apply

Scholarship application is always made one term preceding the term of the award; therefore, entering students should apply during their first term enrolled to be considered for an award during their second term. Scholarship applications from first-term students are held until completion of the term and verification of credit hours and grades.

Limitations

Please be aware that it is the policy of the College of Engineering to not *"over award"* a student, which means, if the sum of your total awards and expected family contribution equals more than the student budget, as established by the University of Michigan, you will not qualify for an Engineering award. Scholarships are given for the term designated only.

Deadlines

Need-Based applications for Winter Term are accepted from September 15 to October 15. Applications for Spring and/or Summer Terms; and Fall only, or Fall and Winter Terms, are accepted from January 15 to March 15.

Industry-Sponsored Scholarships have no deadline for application. An updated application should be filed each September or when new information needs to be added. Awards are made as industry contributions are received.

Students applying for University Financial Aid must have all paperwork, including the Student Aid Report (SAR), submitted to the Financial Aid Office, 2011 Student Activities Building, no later than April 15.

Graduate Students

The graduate student's primary source of financial aid is her/his department of study. Students should contact the graduate office of their department for more information. For information on

College-wide opportunities, contact the Associate Dean for Graduate Studies. Information on graduate study support available from GEM—National Consortium for Graduate Degrees for Minorities in Engineering and Science—may be obtained on the Web at http://www.nd.edu/~gem/.

Foreign Students

Foreign 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. *Scholarship applications are not accepted for foreign students.*

Veterans and Social Security Benefits

Educational benefits are available to students who qualify under the several 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, LS&A Building.

International Programs

The College of Engineering has arrangements with several educational institutions overseas at which our students may choose to study for a prescribed period of time. These agreements offer our students the opportunity to experience the educational, social, political, and professional climate of an outstanding foreign institution. Those students who participate in these programs will learn many new things, including a new level of personal self-reliance. Such experiences, no doubt, will be satisfying in their own right. Moreover, they can serve to meet the requirements for a degree from the College, and should attract the attention of future employers who seek self-confident, imaginative people. Those who desire placement in educational programs at overseas locations should contact Dr. Aparajita Mazumder, Director of International Programs, College of Engineering, 1105 LEC, (313) 647-7026 or Professor Andrzej S. Nowak, Faculty Director of International Programs, College of Engineering, 2370 GGBL Building, The University of Michigan, Ann Arbor, MI 48109-2125, (313) 764-9299, for additional information.

The programs in which the College participates are educationally oriented. Students wishing simply to secure employment outside of the United States are advised to contact the U-M International Center for further information.

Cooperative Education

The Cooperative Education Program offers students the opportunity to seek a co-op position with corporations, government agencies, or small businesses. These positions offer work experience relevant to the student's degree interests and enhance the student's opportunities for future permanent hire.

Work terms can be alternated with school terms, or two terms can be worked consecutively with an option for a third term placement. The program offers experience in manufacturing, design, production, software and hardware development, communications, and other high-tech fields.

Advantages

A variety of progressively challenging jobs and social situations promote both professional and personal growth as well as self-confidence. Co-op students gain valuable experience in their chosen fields, and many have found that they are able to plan their careers more effectively. Because co-op students often qualify for higher starting salaries after graduation, a co-op experience can provide a head start towards financial independence.

How the program works

Employers provide the Cooperative Education Program Office with descriptions of the co-op positions available within their corporations. The co-op office facilitates arrangements for interviews to be held with students either on campus or at the employer's location. On-campus interviews are conducted from October through November and again from mid-January to March.

The Co-op Program Office prescreens qualified applicants and matches them with employer needs. Final selection of a student for a co-op work assignment is a mutual agreement entered into by the employer and the student. When an offer of employment is extended by a corporation or business, and accepted by the student, the student becomes an employee of that company.

> **Note.** The Cooperative Education Program Office does not guarantee placement for every applicant; however, every effort is made to place students in appropriate positions.

While on assignment, students are subject to the rules and regulations of the employer. The employer will rate the student's performance at the end of the work term and forward a report to the Cooperative Education Program Office. Upon returning to the University, co-op students are required to submit an evaluation of their work experience to the Co-op Program Office.

How to sign up

The co-op program is an option within the College of Engineering. Students interested in participating may submit an application, resume, and student audit during the second term of their sophomore year. Opportunities to interview will be available to registered co-op students throughout the semester. To learn more about eligibility requirements, and for more information on the program, write or call the Cooperative Education Program Office, College of Engineering, 2423 EECS Building, The University of Michigan, Ann Arbor, Michigan 48109-2116, (313) 763-5086.

Engineering Placement Services

The College of Engineering considers the proper placement of its graduates to be very important, and recognizes that the first years of professional experience are of great significance in developing the full capabilities of the young engineer. For these reasons, the College provides an engineering placement service for students. This service includes the arrangement of employment interviews on campus (October–November and January–March), the announcement of openings received by mail, and the provision of placement information and career guidance through counseling and published material. Some of these services are available to alumni.

Summer positions are also offered by many employers, especially to students who have completed at least two years of an engineering program. The placement service provides all possible assistance in this area, since such experience is generally considered to be a valuable adjunct to formal technical education.

Foreign students should note that placement services for them are limited. Many companies will interview only U.S. citizens and Permanent Visa holders. Further, companies involved in national defense work will usually interview only U.S. citizens.

The University of Michigan Career Planning and Placement Office in the Student Activities Building on Central Campus conducts lectures, discussion groups, and seminars each fall and winter on a number of career planning and job search topics, including sessions on interviewing and resume writing. The Engineering Placement Office complements these sessions with individual counseling and meetings on how to use the Placement Office facilities and services. The Engineering Placement Office is

located on North Campus in the Stearns Building at 2005 Baits
Drive and Broadway (313) 764-8483.

Minority Engineering Program Office (MEPO)

The U-M College of Engineering's Minority Engineering Program
Office (MEPO) was established to increase the number of under-
represented 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 U-M faculty
and staff; and networks with industry 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 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 engineer-
ing exposure sessions for Detroit Public School students.

At the college level, MEPO provides orientation and profes-
sional development activities, scholarship assistance, career and
academic advising services, and support to the Society of Minority
Engineering Students (SMES). MEPO maintains the Engineering
Learning Resource Center (ELRC), at G264 Lurie Engineering
Center, where reference books and other study materials, tutorial
and study group assistance, and computers are available for
student use.

At the graduate level, MEPO works closely with corpora-
tions to facilitate summer, co-op, and permanent employment
opportunities. MEPO also is actively engaged in the local, region-
al, and national initiatives of GEM (National Consortium for
Graduate Degrees for Minorities in Engineering and Science, Inc.),
which encourages promising minority students to pursue gradu-
ate degrees in engineering.

MEPO's Industrial Advisory Committee provides advice
and support for outreach and retention efforts. The Advisory
Committee also sponsors interview sessions and operates a

Corporate Scholarship Program to facilitate greater industry involvement.

Additionally, MEPO hosts CoE faculty and staff activities that promote an environment conducive to ethnic and cultural diversity.

The MEPO administrative office is located at 1463 Lurie Engineering Center (LEC), (313) 647-7122.

Women in Engineering Office

The Women in Engineering Office at the College of Engineering is dedicated to addressing the University's growing concern for the under-representation of women in engineering disciplines and a national concern about the future pool of engineers in the face of changing demographics. Within the College of Engineering, about 30% of the undergraduate and 16% of the graduate students are women (Fall 1995 data). The Women in Engineering Office staff is committed to working in partnership with University students, faculty, and staff to provide an inviting and supportive environment for women throughout the College of Engineering. Working cooperatively with other University units to serve the needs of its constituents, the Women in Engineering Office staff strive to:

- increase the pool of qualified women who pursue engineering and continue into leadership positions;
- prepare women students for graduate programs and engineering careers;
- provide women undergraduate and graduate students and faculty with resources and services to ensure success in their academic and professional pursuits;
- cooperatively create an environment within the engineering disciplines, as well as the University, that values the contribution of each student, staff, and faculty member; and
- collect, evaluate, and disseminate information on issues faced by women undergraduate and graduate engineering students and faculty.

To meet these goals the Women in Engineering Office supports several on-campus programs for undergraduate and graduate students. The Marian Sarah Parker Scholars Program, developed in collaboration with the U-M Women in Science and Engineering Program, encourages junior-level women to consider and pursue graduate degrees. Parker Scholars attend a series of academic workshops on the opportunities provided by

post-graduate studies and participate in research internships in a university setting.

The Women in Engineering Office also works with graduate students. The office is collaborating with the Center for the Education of Women; the College of Literature, Science and the Arts; and Rackham School of Graduate Studies on a model recruitment and retention program for women graduate students in engineering and the physical sciences. Funded by a grant from the Alfred P. Sloan Foundation, the Graduate Experience Project is a comprehensive, university-wide initiative designed to recruit, retain, graduate, and foster the future successes of women engineering and science students at both the master's and Ph.D. levels.

The Women in Engineering Office advocates for women students by educating the general student body, teaching assistants, faculty, and staff about gender equity—an important contribution to combating gender discrimination and supporting the success of women.

We are committed to responding to the needs of our constituents and promoting our goals to enhance the educational experience of College of Engineering students. For further information, please contact the Women in Engineering Office at (313) 647-7012.

Extracurricular Opportunities

Students at the University of Michigan have an opportunity to participate in a number of extracurricular 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—more than anyone could possibly attend.

The College of Engineering encourages participation in the wide range of activities—University-wide as well as those within the College. Used to advantage, college activities can provide opportunities for self-development and a basis for many friendships and memorable times.

The following is a list of organizations of particular interest to students in Engineering. Those interested in exploring other University-wide opportunities may obtain information at the Student Organizations, Activities, and Programs (SOAP) Office, 2400 Michigan Union, Ann Arbor, Michigan 48109.

Honor Societies

Adara, Michigan senior women's honorary society

Alpha Nu Sigma, national nuclear engineering honor society

Alpha Pi Mu, national industrial engineering honor society

Alpha Sigma Mu, national materials science and engineering honor society

Chi Epsilon, national civil engineering honor society

Epeians, Michigan engineering leadership honor society

Eta Kappa Nu, national electrical engineering honor society

Golden Key, national honor society

Michigamua, Michigan senior men's honorary society

Mortar Board, national senior honor society

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

Phi Lambda Upsilon, national chemical engineering, chemistry, and pharmacy honor society

Pi Tau Sigma, national mechanical engineering honor society

Quarterdeck Honorary Society, honorary technical society for the Department of Naval Architecture and Marine Engineering

Sigma Gamma Tau, national aerospace honor society

Sigma Xi, a national society devoted to the encouragement of research

Tau Beta Pi, the national engineering honor society

Vulcans, Michigan senior engineering honor society

Professional Societies

American Institute of Aeronautics and Astronautics (AIAA), student chapter

American Institute of Chemical Engineers (AIChE), student chapter

American Nuclear Society (ANS), student chapter

American Society of Civil Engineers (ASCE), student chapter

American Society for Engineering Education (ASEE), student chapter

American Society of Mechanical Engineers (ASME), student chapter

Association for Computing Machinery (ACM), student chapter

Engineering in Medicine and Biology Society (EMBS)

Institute of Electrical and Electronics Engineers (IEEE), student chapter

Institute of Industrial Engineers (IIE), student chapter

Michigan Materials Society (MMS), student chapter

Michigan Student Society of Professional Engineers (MSSPE)

National Society of Black Engineers (NSBE), student chapter

Operations Research Society of America (ORSA), student chapter

Society of Automotive Engineers (SAE), student chapter

Society of Hispanic Professional Engineers (SHPE), student chapter

Society of Minority Engineering Students (SMES)

Society of Women Engineers (SWE), student chapter

College Student Government and Judiciary

Engineering Council. The University of Michigan Engineering Council (UMEC) is the student government of the College of Engineering and serves as the representative for Engineering student opinions on College and University issues. The Council's work, done by committees and an executive board, includes efforts in student-faculty and student society relations. Membership is open to all students of the College. The sole requirement for full membership is attendance at two of three consecutive meetings.

The Council welcomes the opinions of all students, from freshmen to graduate students, as well as their active participation in its projects. New ideas are always welcome. Those wishing to express opinions or to bring ideas to the Council should attend a Council Meeting or visit the UMEC Office, 1230 EECS Building, (313) 764-8511.

Honor Council. The Student Honor Council, the student judiciary for the College, has the responsibility of conducting hearings and recommending action to the College of Engineering Discipline Committee in the case of alleged violations of the Honor Code or College rules of conduct.

Honor Societies

The criteria for election to an honor society is based on the rules and regulations of the respective 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.

College Service Activities

IAESTE-US, International Association for the Exchange of Students for Technical Experience, United States, Michigan Chapter

University of Michigan Amateur Radio Club, organization of students interested in radio communications as a hobby

The Society of Minority Engineering Students (SMES)

The Society of Minority Engineering Students (SMES) is a student-run organization whose mission is the recruitment, retention, and successful graduation of its members. The organization acts as a

vehicle to promote unity through programs that encourage academic excellence, personal growth, and professional development, thereby increasing the number of minority professionals who are committed to the development of the minority community.

Founded through the Minority Engineering Program Office (MEPO), SMES assists minority engineering students in areas ranging from personal/social fitness to industry/student relations.

SMES serves as an umbrella organization for two national affiliations: the National Society of Black Engineers (NSBE) and the Society of Hispanic Professional Engineers (SHPE). Within the national affiliations, students discuss the growing engineering field with respect to their particular ethnic community. Each national affiliation holds conferences during the school year where U-M members meet together with affiliation members from other major colleges to discuss minority engineering needs on a national scale.

The Society of Women Engineers (SWE)

The Society of Women Engineers (SWE) is a national organization whose goal is to promote and support women in engineering and engineering-related sciences. The University of Michigan student chapter has identified its function as "an academic and professional support group for women in engineering and technical sciences which provides an opportunity for members to share common experiences, questions, and goals, while also creating an atmosphere in which many friendships develop." Some of the SWE programs and activities include: a speaker series, mentoring for first-year students, annual career fair, annual scholarship banquet, high school outreach, IM sports teams, graduate student program, and pre-interview program. Members of SWE invite all interested students—men and women—to contact them with questions or comments at (313) 763-5027.

Residence Regulations

1. Since normally a student comes to the University of Michigan
    for the primary or sole purpose of attending the University
    rather than to establish a domicile in Michigan, one who
    enrolls in the University as a non-resident shall continue to
    be so classified throughout his attendance as a student,
    unless and until he demonstrates that his previous domicile
    has been abandoned and a Michigan domicile established.

2. No student shall be eligible for reclassification as a resident
    unless he shall be domiciled in Michigan and has resided in
    Michigan continuously for not less than one year immediate-
    ly preceding the first day of classes of the term for which
    reclassification is sought.

3. For purposes of these Regulations, a resident student is
    defined as a student domiciled in the state of Michigan.
    A non-resident student is defined as one whose domicile is
    elsewhere. A student shall not be considered domiciled in
    Michigan unless he is in continuous, physical residence in
    this state and intends to make Michigan his permanent
    home, not only while in attendance at the University but
    indefinitely thereafter as well, and has no domicile or intent
    to be domiciled elsewhere.

4. The following facts and circumstances, although not neces-
    sarily conclusive, have probative value in support of a claim
    for residence classification:
    a. Continuous presence in Michigan during periods when
        not enrolled as a student.
    b. Reliance upon Michigan sources for financial support.
    c. Domicile in Michigan of family, guardian or other
        relatives or persons legally responsible for the student.
    d. Former domicile in the state and maintenance of
        significant connections therein while absent.
    e. Ownership of a home in Michigan.
    f. Admission to a licensed practicing profession in
        Michigan.
    g. Long-term military commitments in Michigan.
    h. Commitments to further education in Michigan
        indicating an intent to stay here permanently.
    i. Acceptance of an offer of permanent employment
        in Michigan.

Other factors indicating an intent to make Michigan the student's domicile will be considered by the University in classifying a student.

5. The following circumstances, standing alone, shall not constitute sufficient evidence of domicile to effect classification of a student as a resident under these Regulations:
   a. Voting or registration for voting.
   b. Employment in any position normally filled by a student.
   c. The lease of living quarters.
   d. A statement of intention to acquire a domicile in Michigan.
   e. Domicile in Michigan of student's spouse.
   f. Automobile registration.
   g. Other public records; e.g., birth and marriage records.

6. An alien who has been lawfully admitted for permanent residence in the United States shall not, by reason of that status alone, be disqualified from classification as a resident, provided, however, that aliens who are present in the United States on a temporary or student visa shall not be eligible for classification as a resident.

7. These Regulations shall be administered by the Office of the Registrar, in accordance with the following residence review procedures:
   a. It shall be the responsibility of the student to register under the proper residence classification, to advise the Office of the Registrar of possible changes in residence, and to furnish all requested information pertinent thereto.
   b. Applications for reclassification shall be filed not later than 20 calendar days following the first day of classes of the term for which such reclassification is sought. Such application shall be filed with the Assistant Registrar for Residence Status (see "f" below for address) and shall set forth in writing a complete statement of the facts upon which it is based, together with affidavits or other supporting documentary evidence. Failure to timely file such an application shall constitute a waiver of all claims to reclassification or rebates for such term.
   c. Any student may appeal the decision of the Assistant Registrar for Residence Status made pursuant to paragraph b, above, by taking the following steps within 20 calendar days after notice of such decision was served upon him, either in person, by mail, or by posting in a conspicuous place at 500 South State Street:

     i.   File with the Residency Appeal Committee a written notice of appeal stating the reasons therefore;

    ii.   File said notice with the Assistant Registrar for Residence Status, together with a written request that all documents submitted pursuant to paragraph b, above, be forwarded to the Residency Appeal Committee. Failure to timely comply with this paragraph c shall constitute a waiver of all claims to reclassification or rebates for the applicable term or terms.

d.   Reclassification, whether pursuant to paragraph b or c above, shall be effective for the term in which the application therefor was timely filed in accordance with paragraph b and for each term thereafter so long as the circumstances upon which the reclassification was based shall remain unchanged. Appropriate refunds shall be made or accounts credited within a reasonable time following such reclassification.

e.   Classification or reclassification based upon materially erroneous, false, or misleading statements or omissions by or in support of the applicant shall be set aside retroactively upon the discovery of the erroneous nature of such statements.

f.   Inquiries should be addressed to: Resident Status Office, Office of the Registrar, 1514 LSA Building, University of Michigan, Ann Arbor, Michigan 48109-1382, phone (313) 764-1400.

Approved by the Board of Regents, March 15, 1974.

Please Note: *The one year continuous presence requirement may not apply to individuals who can clearly demonstrate that they did not come to the state for either their own or a family member's educational pursuits. These individuals must file a residency application for an official determination of their status.*

Admission

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 may be asked to take College Board Achievement Tests or the American College Test. The requirement of a high school diploma may be waived for a few exceptionally gifted students. 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 Notice

The University of Michigan, as an equal opportunity/affirmative action employer, complies with all applicable federal and state laws regarding non-discrimination 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, or admissions. Inquiries or complaints may be addressed to the University of Michigan Director of Affirmative Action and Title IX/Section 504 Coordinator, 4005 Wolverine Tower, Ann Arbor, Michigan 48109-1281, (313) 763-0235, TDD (313) 747-1388. U-M Information Operator: (313) 764-1817.
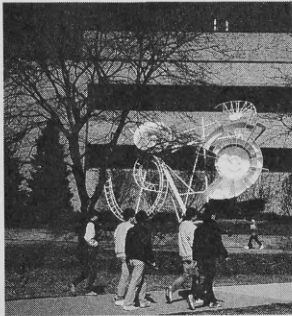
Admission as a Freshman

Freshman students are admitted to the College of Engineering by the Office of Undergraduate Admissions, 1220 Student Activities Building, (313) 764-7433, The University of Michigan, Ann Arbor, MI 48109-1316, from which appropriate forms and instructions are available. Michigan high school students who have begun the senior year may pick up application forms from their high school advisor. Please note that freshmen students are admitted to the College of Engineering and not to a degree program. Declaration of a degree program occurs before the end of the sophomore year.

Freshman applicants are encouraged to apply as early as possible in the fall of their senior year. All applicants should be

aware that some schools and colleges may close admissions before the "equal consideration" date.

February 1 is the deadline for most fall term applicants, which includes all freshman students. This is the date by which you must apply and have all required credentials on file in order to receive equal consideration with other applicants. Allow sufficient time for other offices to process your request and for mail services to deliver your materials to the Undergraduate Admissions office prior to the deadline. Applications will be considered after these dates only if places are available.

Students are encouraged to submit their 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. Admission, when granted to a high school student, 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 freshmen. Contact the College of Engineering to schedule interviews or the Office of Undergraduate Admissions to schedule a place in a prospective freshman group session.

Criteria

The admission requirements are designed to assure that each student who is granted the opportunity to enroll in the College of Engineering has aptitude for the profession of engineering as well as intellectual capacity combined with the necessary 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 College, therefore, takes into account the following criteria in arriving at a decision: subjects studied in high school; scholastic performance; standardized test scores; and in many cases, other information such as high school recommendations and the student's personal statement.

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 required for admission:

Units

3 *English*
(Four units of English are strongly recommended.)

3 *Mathematics*
To consist of a minimum of 1 1/2 units of algebra; 1 unit of geometry; 1/2 unit of trigonometry. (An additional 1/2 unit of algebra and 1/2 unit of analytical geometry are recommended.)

2 *Laboratory Science*
(One unit of chemistry and 1 unit of physics are recommended. Other laboratory sciences are acceptable.)

4 *Academic Electives*
Two units of foreign language are recommended; other acceptable subjects are history, economics, and biological science.

3 *Free Electives*
May include any subjects listed above or any other subjects counted toward graduation by the high school such as art, music, business, shop, mechanical drawing, and computer programming.

15 *Total*

Note: *Students who have not completed the required courses* *can still be considered for admission, and should contact the Director of Admissions for more information.*

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 ability for admission to the study of 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, during their junior or senior year in high school, the College Entrance Examination Board Scholastic Aptitude Test (SAT) or American College Testing (ACT). When a senior desires a decision before the SAT or ACT results are in, preliminary admission may be made if other acceptable test data are submitted with the application. For information and time schedules on the Scholastic Aptitude Test, the student should

consult with the 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, the student should consult with a high school advisor or write to The American College Testing Program, Iowa City, IA 52240.

4. *High School Recommendation.* Though not required, any statement by a representative of the applicant's high school is 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.

5. *Personal Statement.* This brief essay may include your activities, interests, accomplishments, and talents. Such information provides additional background that may not be evident from the other criteria listed above. Applicants to the College of Engineering should include an explanation of their experience and interest in engineering and their education and career goals.

Advanced Placement

Once a student has been accepted for admission to the College of Engineering, it is possible to earn advanced credit toward a degree through the Advanced Placement Program. 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.

For information and time schedules on the Advanced Placement tests, write to College Entrance Examination Board, Box 592, Princeton, NJ 08540, or to Box 1025, Berkeley, CA 94701. All other questions about Advanced Placement should be referred to the Office of the Assistant Dean for Advising and Career Planning (Freshman Advising), 1009 Lurie Engineering Center, College of Engineering, The University of Michigan, Ann Arbor, MI 48109-2102.

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.
(See following list.)

1. *Foreign Languages.* The Foreign Language Placement Examinations are given during Orientation. Students must

take both the reading and listening parts to receive credit. If a student misses the test during Orientation, it can be taken during the next Orientation period. Credit for earned-by-examination first year level courses cannot be used to satisfy the humanities requirement; however, such first year level courses can be used as free electives. Credit for second year level or higher, or advanced placement, or advanced credit for such courses can be used as humanities. These courses will be posted on the student's record unless the student requests otherwise.

2. *Credit By Examination Program.* Advanced credit can be earned through the Credit by Examination Program. Information about this program is available from the Extension Service, 200 Hill Street, Ann Arbor, MI 48109-3297. Advanced credit for Physics 140 and Physics 240 can be earned through this program.

   Note: The purpose of the mathematics examination given during Orientation is to determine if students are prepared to take Math 115. It is not a test for advanced placement. The same is true for the chemistry test.

Admission of Transfer Students

To transfer from an accredited college in the United States, including another unit in the University of Michigan, applicants should contact the Office of Transfer Admissions and Recruitment, College of Engineering, The University of Michigan, Ann Arbor, MI 48109-2102, (313) 647-7101 for application materials and instructions. Applicants are required to submit official transcripts of both secondary school and college course work, together with evidence of honorable dismissal from all previous colleges attended.

Application Deadlines
For equal consideration, applications for admission should be submitted before March 15 for the following spring half-term, summer half-term, or fall term and prior to October 15 for winter term. Applications received after the deadline date for any term will be accepted as space allows.

General Admission Requirements and Information
For admission without deficiencies, an applicant must satisfy the requirements for admission from high school as stated under the section of this *Bulletin* entitled "Admission as a Freshman."

In addition, 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 importance and will be taken into account in making the admission decision. An overall scholastic average satisfactory for good standing at the previous institution may not in itself be sufficient. Admission standards are based on departmental guidelines to specific programs which include meeting the departmental grade point average (GPA) requirements.

While credit is not allowed for work or other experience, a student may be considered proficient in a designated part of the degree requirement if he or she can qualify under provision 1(f) of "Requirements for a Bachelor's Degree."

A student transferring at the junior level has the opportunity to attain a commission in the United States Army, Navy, or Air Force by enrolling in the respective Advanced Course of the Military Officer Education Program. As early as possible, the student should contact the unit on campus to make the necessary arrangements for basic training during the summer. For details and other pertinent information see the section on "Planning the Student's Program" which includes information on the "Military Officer Education Program."

Program with Basic Courses Taken at Another Institution

With a few variations, most programs require the same basic pre-engineering courses for transfer admission. These include mathematics, chemistry, physics, English composition or literature, and a computer course based in either FORTRAN or "C" 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). 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 materials and engineering mechanics if equivalent course content is covered. Computer course requirements vary among degree programs.

A student in another college or university who desires to transfer should examine carefully the program that he or she plans to elect at the College of Engineering and arrange the work accordingly. Questions pertaining to choice of field or program and course elections not answered in this *Bulletin* may be

addressed to the program advisor for the program the student wishes to elect. Other questions of a general nature and those relating to admission requirements should be addressed to the Office of Transfer Admissions and Recruitment, 1108 Lurie Engineering Center, The University of Michigan, Ann Arbor, MI 48109-2102, (313) 647-7101.

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 years by satisfying the requirements for both degrees. Representative institutions providing this opportunity are:

> Adrian College
> Albion College
> Alma College
> Beloit College
> Hope College
> Kalamazoo College
> Lawrence University (Wisconsin)
> Virginia Union University

Normally, 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 years of the requirements of the College of Engineering.

For details on a combined program with the College of Literature, Science, and the Arts of the University of Michigan, refer to "Undergraduate Degree Programs."

Adjustment of Advanced Credit

An appraisal of the previous record of a student transferring from a college or university located in the United States will be made, usually at the time of admission, to indicate tentatively the credit that will be allowed toward a bachelor's degree in the program specified by the applicant. This appraisal is subject to review by representatives of the several teaching departments involved, and by the student's intended program advisor. The adjustment may be revised if it develops that the student is unable to continue successfully because of an inadequate preparation. Credit will not be allowed for a course in which a grade of "C-" or below is received, with the exception of courses taken on the U-M Ann Arbor campus. Class standing is determined by the number of hours transferred. (See "Class Standing.")

Grades earned while enrolled in another college are not recorded and the 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 any questions regarding the adjustment of credit, the Office of Transfer Admissions and Recruitment should be consulted.

Prescribed Program

If an applicant meets the admission standards, and is acceptable to the advisor in the program of the student's choice, the advisor will prescribe a program that meets the requirements for a degree. While the standard evaluation of credits is not required, the general requirements for a degree from this College should be met before the student is recommended for the degree. This would ordinarily apply to students with a degree from another college who could satisfy degree requirements in 30 to 40 credit hours at Michigan (at least 30 of which must be at the 300 or higher level). The student must attain a "C" or better in each course of his/her prescribed program.

Admitting Graduates of Other Colleges

A graduate of an approved college can be admitted as a candidate for a degree in engineering. The official transcript must certify the date of graduation. Upon satisfactory completion of the prescribed courses, covering at least two terms of enrollment and a minimum of 30 credit hours elected in the College of Engineering, Ann Arbor Campus, the student will be recommended for the appropriate degree. (See "Prescribed Program," above.)

Foreign Student Admission

Foreign 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 freshmen to the University of Michigan, College of Engineering, through the Office of Undergraduate Admissions, 1220 Student Activities Building, Ann Arbor, MI 48109-1316.

Foreign students wishing to transfer from an approved accredited college and whose native language is other than English are required to complete the same basic college subjects required of all transfer applicants before applying to the Office of Transfer Admissions and Recruitment. These required courses include English, mathematics, chemistry, physics, and a computer course based in FORTRAN or "C" (computer course requirements may vary based on degree program desired). Foreign applicants must also meet the prescribed standards of proficiency in English. For many students, these requirements may be met

at a minimum of expense by enrolling in a home college for a period of two years. Others may prefer to enroll in a liberal arts or engineering college in the United States for their basic college subjects before seeking a transfer; this provides the advantages to the students of becoming accustomed to the educational system of this country and of improving proficiency in English.

An applicant must submit an official copy in English of the scholastic record of secondary and college education, showing the grade (or mark) earned in each course together with an explanation of the grading system. Foreign students must be prepared to finance their entire education while enrolled in the College of Engineering. The 1995–96 educational cost for a foreign student enrolled as a freshman was approximately $102,000 for four years of study; a junior, $82,000; and a senior, $26,000. A 10 percent increase is estimated in 1996–97. Financial aid is not available to undergraduate foreign students.

Since English is the language of instruction in the United States, a foreign student attends classes with students whose background and education have been in English and must maintain the same scholastic standards. To assure the student that his or her competence in the English language is adequate to carry on studies without serious handicap, 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 (313) 764-2416. For TOEFL registration information, write to CN6154, Princeton, New Jersey, 08541-2416, USA; phone (609) 921-9000. A score of 85 is required on the MELAB test. A TOEFL score of at least 560 is required for admission. Regardless of tests taken previously, the College of Engineering reserves the right to require testing after arrival at the University of Michigan.
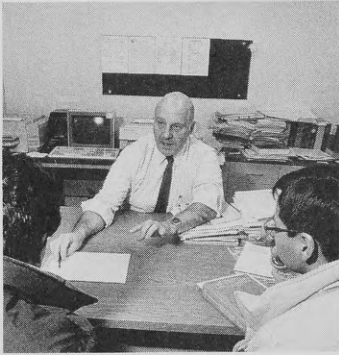
A foreign student granted entry into the United States by virtue of admission to another institution of higher education is expected to complete one academic year of study at that school before seeking transfer. A student who wishes to transfer to this College is encouraged to submit an application for admission with advanced standing during the next-to-last semester or term of enrollment at the institution that issued the initial I-20 Form.

It is generally desirable that a foreign student elect a rather light schedule of studies for the first term enrolled in the College of Engineering because of an unfamiliar environment and a different educational system. To increase the probability of success, a student who observes any irregularity in adjustment or progress should report immediately to the program advisor or to the Office of Transfer Admissions and Recruitment.

All foreign students *must* elect at least 12 semester hours each full semester in order to meet INS regulations and remain "In-status."

English Language Institute

The English Language Institute (ELI) offers advanced instruction in the English language to non-native speakers enrolled in the University. Since the main purpose of this instruction is to help non-native speakers become effective and fully participating members of the academic community, the majority of ELI courses are concerned with English for academic purposes. Most courses address specific areas such as pronunciation, lecture comprehension, or academic grammar, and usually involve no more than 20 contact hours per semester. To assure that students will enroll in the most suitable courses, they may be asked to take an Academic English Evaluation administered by the Testing and Certification Division of ELI. In major areas such as speaking and writing, a sequence of courses of increasing difficulty and specialization is available, including some that carry graduate credit.

ELI operates a Writing Clinic and a Speaking Clinic as one-on-one facilities for those who have taken or are taking ELI courses in the relevant areas, or who are deemed not to need regular classroom instruction.

In addition, ELI runs a Semi-Intensive Program for those who require more assistance in English and who are not, therefore, likely to be carrying a full course load in other subjects.

ELI also offers a Summer Half-Term Intensive Program for non-native speakers who have already received admission to the University but who wish to improve their language and study skills before beginning their academic program. There are two sections: a) English for Academic Purposes, and b) English for Business and Management Studies. Engineering credit is not available for ELI courses.

Finances

When a foreign 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; no financial aid is available from the University for undergraduate foreign students.

International Center

The International Center is housed in a wing of the Michigan Union building, with an entrance on East Madison Street. A second office is located in the Pierpont Commons on North Campus. International Center services are available to United States citizens anticipating travel abroad, and to foreign students arriving in the United States.

For United States citizens planning to travel abroad, there are complete informational services and experienced advisors to help individuals plan recreational, educational, or employment-related trips abroad. An extensive library of materials is available at the Center to all interested individuals.

Foreign students will find assistance at the International Center in dealing with the United States Immigration and Naturalization Service, with their sponsors and governments, with other individuals and organizations. Foreign student advisors are available to discuss personal concerns, housing, adjustment, finances, and other matters. The Center staff also works with community organizations that provide tours, home hospitality, speaking engagements, and assistance for spouses of foreign students. In cooperation with nationality clubs, student associations, and other organizations, the International Center provides, throughout the year, a varied program of cultural and social events. Prospective foreign students may use the International Center as an advance mailing address.

Student Not a Candidate for a Degree (NCFD)

Special Student Status

A qualified college student may be admitted as a "special student" to take engineering college courses for which the student has sufficient preparation. A special student is required to meet the same academic standards as a degree candidate.

Applications for admission as a special student may be obtained from the Office of Transfer Admissions and Recruitment. To apply for special student admission, submit a completed application with official transcript(s) from current and former colleges or universities. Admission and registration is subject to the approval of the instructor of the desired course. The applicant must contact the instructor, obtain written permission to register, and forward this permission to the Office of Transfer Admission and Recruitment.

Admission will be for one term and will be granted only if there is space available after all degree-seeking students have been accommodated. If more than one term is requested, the

student may not register for the subsequent term until his or her academic record for the previous term has been reviewed by a transfer admissions officer and program advisor. If admitted as a non-degree student, registration for classes can only be done on or after the first day of classes for the term of admission.

A student who has graduated from the College of Engineering may request enrollment for one term following his or her graduation as a special student with the approval of the program advisor. The student must abide by the same rules as all special students. A student who wishes to transfer into another academic unit other than the College of Engineering should make an appointment with a representative of the Office of Transfer Admissions and Recruitment concerning the transfer and, if necessary, arrange for an additional term in the College of Engineering as an unclassified student.

A student who is a candidate for a degree cannot transfer to special status.

Guest Students

A student regularly enrolled in another college is permitted to elect appropriate courses as a guest student during the spring and summer half terms only. The guest student must meet the academic qualifications of a student who is seeking admission as a special student. His or her admission must be approved by a program advisor. The applicant must apply for enrollment before the beginning of each term that he or she desires to attend. Guest student admission is offered on a term basis only, depending on availability of space. A student must reapply each time he or she seeks to take courses as a guest student.

Unassigned 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 is advised to report to the Office of the Assistant Dean for Advising and Career Planning at the Engineering Advising and Career Planning Center on effecting a transfer and, if necessary, to arrange for registration for an additional term in the College of Engineering on an "Unassigned" status.

Orientation

All new students, both freshmen and those transferring from other colleges, are assigned to small groups that are guided through the various steps of Orientation: these include testing, student's identification card, consultation with academic advisors, selection of courses, basic computer training, registration, and attendance at the necessary Orientation group meetings. Each transfer student is instructed also on procedures relating to the adjustment of transfer credit from other colleges.

Freshmen entering in the fall term are encouraged to come to the campus during the summer for a three-day orientation. At the same time, parents are invited to attend a program specifically arranged for them.

Transfer students for fall admission are also offered an opportunity to come to the campus during the summer for a one-day orientation.

Each student is expected to assume a high degree of responsibility for his or her own welfare by making proper choices and effectively planning progress toward educational goals. To do this wisely and efficiently, the individual should understand his or her own aptitudes, abilities, and interests, and their relationship to the plans and decisions. A student with some question in this regard, or one who recognizes that a personal problem exists in which the individual might benefit from advice, is urged to consult University resources and people who are qualified to help.

A student who experiences any difficulty in the first term in making a satisfactory adjustment to the studies should report immediately to the academic advisor. Students may also seek advice from the Office of the Assistant Dean for Advising and Career Planning (Freshman Advising) at the Engineering Advising and Career Planning Center, 1009 LEC.

Academic Advising

Academic Advising for Freshmen

Freshmen advisors, consisting of a group of well-qualified faculty from the engineering departments, are available for consultation throughout the fall and winter terms.

Each entering freshman meets with an advisor to determine a schedule of courses for the first term. This is covered in detail in the section "Planning the Student's Program."

Developing self-reliance and the ability to make choices, as well as to appraise one's own performance and intellectual growth, is an important part of the student's education. Nevertheless, each freshman is encouraged to consult with freshmen program advisors any time there is a question relating to career plans, or choice of academic program, or to discuss any matter of interest or concern. Midterm is a particularly appropriate time to examine progress.

Academic Advisor for Continuing and Transfer Students

Academic advisors are assisted by associates on the faculty according to the needs of the respective programs. As academic advisors, they assume responsibility for elections as covered under "Election of Studies" or as specifically delegated.

Program Advisor

At the beginning of each undergraduate degree program description (beginning on page 93) is the name of the member of the faculty designated as program advisor. Upon selecting a degree program, the student is referred to the respective program advisor, who is responsible for the necessary academic advising through graduation. Certain authorities, as covered under "Election of Studies, Grades and Scholastic Standing" and "Requirements for Graduation," are specifically assigned to program advisors.

Counseling Services

Counseling Services offers a variety of personal counseling, workshop, 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.

A 24-hour peer counseling telephone service (76-GUIDE) is available. The staff consists of social workers, psychologists, and psychiatrists; graduate students in psychology, social work, and psychiatry; and trained student counselors. Counseling Services are available at two locations: 3100 Michigan Union, Central Campus, 764-8312; and Pierpont Commons on North Campus, Ground Floor, 763-9658.

Training in reading speed and comprehension is provided for students especially in need of such assistance at the Reading and Skills Center.

Remedial training in speech is offered by the Speech Clinic.

Religious congregations in the Ann Arbor area provide counselors for religious problems.

The Office of Student Services, 3010 Michigan Union, provides counsel and assistance on housing, employment, and other non-academic problems.

The men's and women's residence halls, accommodating freshmen and a few upperclassmen, maintain a staff of advisors and student assistants who help the student make an effective adjustment to the University community.

The Office of Financial Aid similarly provides counsel on financial problems.

Undergraduate Degree Programs

Each of the undergraduate degree programs requires a minimum of 56 credit hours that are common to all Programs. (See "Planning the Student's Program," page 59.) Descriptions are included at the beginning of the section on departmental undergraduate degree programs.

The remaining 72 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; and Technical or Free Electives.

Many of the courses required for one program are readily transferred to meet the requirements of another. This allows students the opportunity to change fields of specialization with a minimum of sacrifice, or to work toward satisfying the requirements for two degrees under the requirements of a minimum of 14 extra hours.

Choosing One of the Degree Programs

While the entering freshman does not need to select a specific field of engineering, there is some advantage in arriving at a decision early. To help the student with a choice, the departments will schedule a series of group meetings that provide information about each of the programs and related career opportunities. If additional help is needed, the student should consult with an academic or program advisor. The degree program in which a student plans to graduate should be selected during the second term.

Admission to a degree program depends on the student being in good standing and having completed the freshmen level mathematics, chemistry, physics and digital computing courses. Transfer to a program involves obtaining the necessary approval forms from the Office of the Assistant Dean for Advising and Career Planning (Freshman Counseling). In addition, the Executive Committee of the College of Engineering, following a request of a particular degree program, may find it necessary to restrict admission to that program, based on grade point averages in mathematics, chemistry, physics, and digital computing courses

elected in the first year. Students should contact the Office of the Assistant Dean for Advising and Career Planning if they have any questions concerning program changes.

Students who have not selected a program by the time they complete 55 credit hours, or who wish to change degree programs after they have reached 55 credit hours, are subject to grade point averages and quotas approved by the Executive Committee of the College of Engineering for admission to the various degree programs.

Dual Baccalaureate Degree Opportunities

Students with interest in more than one program offered by the College may work for two 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. Opportunities to obtain an additional bachelor's degree in the College of Literature, Science, and the Arts, the School of Music and other academic units are also available. (See under "Requirements for Additional Bachelor's Degrees.")

Combined Degree Programs

Simultaneous Bachelor's Degrees from the College of Engineering and the College of Literature, Science, and the Arts

Program Advisors: Gene Smith, 1011 LEC
Katherine McKibben, 1223 Angell Hall

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.) or Bachelor of Arts (B.A.) in LS&A must: (a) satisfy the requirements of one of the degree programs in the College of Engineering; (b) 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 (c) 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: (a) satisfy the requirements of one of the degree programs in the College of Engineering; (b) 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 (c) 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.

Because of the great variety of combinations of programs in the two colleges that might be chosen by students under the Combined Degree Program, it is not feasible to list course requirements in detail. Instead, all students should consult their 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, counselors 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 literature, 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 liaison 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 should consult the College of Engineering Assistant Dean for Advising and Career Planning 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 assistant dean of each college and then 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 and for transmitting to the other college at the end of the term the number of copies of their transcripts needed for advising and other official purposes in that college.
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 and must request their program advisor in each college to submit an appropriate notification of their eligibility for graduation to the records office of that college.

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 freshmen to both units.

The variety of courses which can be elected by students in the joint program makes it impractical to list specific require-ments. Instead, 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 stu-dent is responsible for maintaining contact with the appropriate engineering department (Freshman Advising, if undeclared) in order to receive proper counseling 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 freshmen into both the College of Engineering or 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.

Simultaneous Graduate/Undergraduate Study (SGUS) in Engineering

This program is designed to provide depth and breadth of subject and economies of time to the student. With careful planning, the student will work toward completion of both an engineering baccalaureate and master's degree within a five-year course of study. Admissions and course requirements vary substantially. See the section on "Graduate Studies" for additional information.
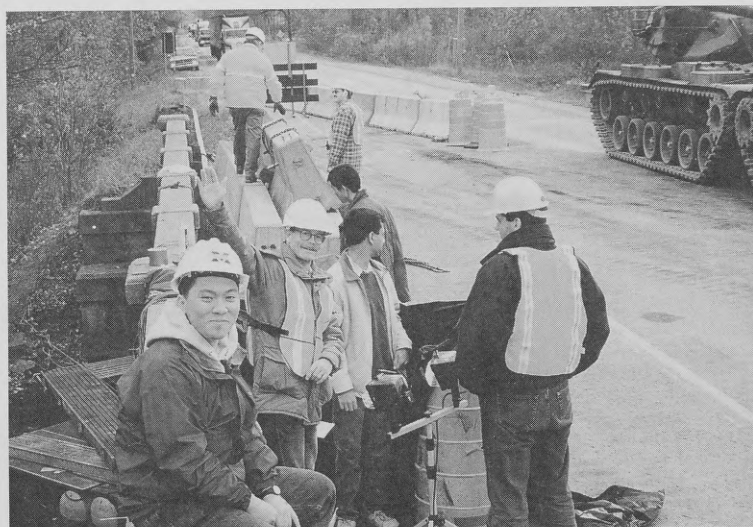
Planning the Student's Program

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 their academic profile, previous experience, and potential for academic success.

Most courses have prerequisites (see "Description of Courses"). 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 13 to 16 hours is considered normal.

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). 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 free electives at the discretion of the program advisors. It should be noted that no engineering program allows more than 12 hours of free electives.

Minimum Common Requirements

Each of the degree programs offered by the College includes the following 54 credit hours that are common to all programs, subject to appropriate adjustment for equivalent alternatives. In addition, Chemistry 125 will be required by most programs; thus, with few exceptions, *the common requirements amount to approximately 56 hours.*

To be scheduled during first four terms as shown below.

Hours
Credit

16	Math 115 or 185, 116 or 186, 215 or 285, and 216 or 286
4	Engineering 160, English 125 or equivalent
3*	Computing: Engineering 103, 104, 106, 107, or EECS 100
5**	Chemistry 130 and 125 or 210 and 211
10***	Physics 140 and 141, and 240 and 241

Additional 18 hours (minimum)

3	Senior Technical Communication *(to be scheduled during senior year)*
17****	Humanities (at least two courses) and Social Sciences *(May be scheduled any term—see "Elective Studies.")*

*EECS 100 is required by Electrical Engineering and Computer Engineering programs.

**Depending upon the degree program, Chemistry 125, or Chemistry 210 and 211, would also be taken.

***In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

****One program requires more than the minimum of 17. For complete information on the requirements of the respective programs, see the individual department degree programs.

Freshman and Sophomore Programs

For each freshman, the advisor will use the student's high school record and the results of various tests to help plan the courses for his/her first term.

At the time of the first advising session, particularly those which occur during summer orientation, all of the high school and advanced placement records may not yet be in the student's file. It is the entering student's responsibility to make certain that all evidence is brought to the attention of the advising office before classes start. With complete information available, the advisor and the student will be able to make carefully considered adjustments in course elections for the first term.

First Year

On the assumption that a student has the necessary academic preparation and no advanced placement credit, he/she will be

expected during the first year to complete courses that include the following:

1. Mathematics 115 or 185 and 116 or 186
2. Chemistry 130 and 125, or, for some, 130, 210, and 211
3. Engineering 160, English 125 or equivalent
4. Physics 140 and 141
5. Engineering 103 or 104, students in EECS take EECS 100 as a requirement
6. The counselor will provide information on a number of courses from which the student may chose to elect approximately 30 credit hours for the year.

Second Year

All students will continue with the mathematics, physics, humanities, and social sciences courses common to all programs marked by * in the Group I listed below. A second-term freshman who has selected a degree program is referred to the respective program advisor for elections counseling for the third term. The student should refer to the description of the program selected for the remainder of the second-year elections. If the program requires additional chemistry, the student must continue chemistry to satisfy prerequisites of later courses and to avoid delays in the schedule.

When a freshman is not ready to select a degree program in the second term, it is possible to define a second-year schedule on an unassigned basis. The courses marked "+" in Group I satisfy requirements in a number of programs or may be applied as electives in other programs. The courses in Group II will be found in the second-year schedule of certain programs and provide the student with an opportunity to continue the schedule with the understanding that, if not used as a requirement in the program the student will select, they may generally be used as electives. The student should consult the course descriptions to help make appropriate selections. If a sophomore is ready to select a program during the third term, the student will be referred to the program advisor for the fourth-term elections.

Hours Credit	*Third Term* Group I	Hours Credit	*Fourth Term* Group I
4	* Math 215	4 or 3	+ Math 216 or 286
4	* Physics 240 with Lab 241	3	+ ME 240
4	+ ME 211	3	+ ME 235
3	+ MSE 250	4	* Humanities or Social Science
4	* Humanities or Social Science		

	Group II		*Group II*
5	Chem 215 and 216	3	Physics 242
3	Aero 200	4	CEE 312
4	ChemE 230	4	EECS 216
3	EECS 250	3	IOE 310, or 333
3	AOSS 304	3	ME 281
3	NA 270	3	NA 302

Also refer to courses listed under Engineering.

Honors-Level Courses

A student whose record indicates qualifications to perform at an advanced level will be given an opportunity to review with a special counselor the eligibility for electing honors-level courses. Among those available to qualified freshmen are Math 185 or Math 195 and Physics 160.

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.

While most freshmen select Math 115 in their first term, it is in the best interest of students to be placed in the mathematics course that most closely matches their previous preparation and ability.

The sequences 175-176-285-286, 185-186-285-286, and 195-196-295-296 are honors sequences. All students with strong preparation and interest in mathematics are encouraged to consider these courses; they are both more interesting and more challenging than the standard sequence. Qualified and interested students should consult their engineering counselor about these options. It is not necessary to be in an honors program to enroll for these courses.

Similarly, qualified and interested students may take Math 217 (Linear Algebra) and Math 316 (Differential Equations) upon completion of Math 215. If elected, this two-course sequence replaces Math 216 and grants an additional 3 credit hours of mathematics. Students should consult with their program advisor

to determine how these 3 additional credit hours might be applied towards their particular degree program.

A student who has completed a full year of calculus in high school and has received a sufficiently high score on one of the College Board Advanced Placement examinations in mathematics is eligible for advanced credit and placement. Likewise, a student who has taken calculus in high school may receive appropriate advanced placement after taking a placement examination administered by the Department of Mathematics; information on this examination may be obtained from the Department of Mathematics Office, 3217 Angell Hall.

The following outline will serve as a guide in determining the proper first elections in mathematics for freshmen:

Those Students Who:

		Hours Credit	Elect
I.	Are deficient in algebra or trigonometry (see note)	4* 2*	Math 105 Math 109
II.	Have no deficiencies and are qualified by high school record and SAT scores	4	Math 115
III.	Qualify for honors level or other honors courses	4	Math 185
IV.	Are allowed 4 hours of advanced placement credit	4	Math 116 or an honors course
V.	Are allowed 8 hours of advanced placement credit	4	Math 215 or an honors course

*__Note__: While these two courses will not provide credit toward the student's degree, the grades will be used in computing grade point averages.

Humanities and Social Sciences

At least 17 credit hours of Humanities and Social Sciences are required in all 13 degree programs offered by the College of Engineering. The complete College requirement is described under *Elective Studies*.

Introductory Composition Requirement

All admitted freshmen will be required to submit a portfolio of their writings for assessment. According to the quality of their performance in this assessment, students will be placed in one of four sequences: (1) required to complete tutorial work (ECB Introductory Tutorial 100-105 or ECB Transfer Tutorial 106-109), then write a post-test which will either place them into Introductory Composition, into another ECB Tutorial, or exempt them

from Introductory Composition; or (2) required to enroll directly in Introductory Composition; or (3) exempted from Introductory Composition but required to attend the ECB Writing Workshop until certified for exemption; or (4) exempted from Introductory Composition.

> **Note**: Students exempted from taking Introductory Composition are granted advanced credit and need no further course work for this requirement.

The Introductory Composition requirement is met when the student has completed one of the four placement tracks described above. Note that Introductory Composition courses include Engineering 160, English 125, University Course 101, Residential College Core 100, and Honors College Great Books 191 or Classical Civilization 101. English 124 or Pilot 165 may be substituted for English 125. Other courses may be substituted with approval of advisor.

> **Note**: A grade of "C-" or lower is not acceptable in any program for the Introductory Composition course.

Transfer students with advanced credit for English composition from another college or university are not required to take the English Composition Board (ECB) writing test. Their advanced credit will be used to satisfy the introductory composition requirement. Transfer students without advanced credit for English composition must elect one of the introductory composition courses listed above. (English 220 is not acceptable.)

Freshmen with advanced credit for English composition from another college or university may use that credit to satisfy the introductory composition requirement.

English Composition Board (ECB): Writing Workshop

ECB lecturers who teach ECB Introductory and Transfer Tutorials also provide consultation and instruction in the Writing Workshop. During the hours that the Workshop is open, two experienced teachers of composition are available for half-hour appointments (on a drop-in or scheduled basis) to discuss writing with any undergraduate in the College. (Any student enrolled in an undergraduate course is eligible to come to the Writing Workshop for help with writing assignments in that course.) Extended appointments are available for students whose immediate needs cannot be met in half-hour sessions.

Instructors in the Writing Workshop do not make assignments and will not work as editors or proofreaders for their student clientele. They will discuss with undergraduates the meaning of, and approaches to, writing assignments made in any course in the College, and then help those same students become

aware of appropriate rhetorical, syntactical, and grammatical choices as they write their papers.

Foreign Languages

Although a foreign language is an important part of the high-school education, it is not required for admission nor does it appear in any program requirement. It is recognized that a number of students are admitted with the equivalent of college-level work in a language. Advanced credit may be requested for foreign language study in high school by one of the following: (a) Advanced Placement Examination, or (b) Foreign Language Placement Examination after arriving at the University. Humanities credit will be granted for all foreign languages not labeled "excluded" that are elected and successfully completed at the University of Michigan. Credit will also be granted for equivalent courses at any other college or university. Humanities credit will not be granted for introductory foreign language courses earned by advanced placement, but such credit may be used as a free elective. Foreign language credit earned by advanced placement or credit by examination at the second year level or higher can be used towards fulfillment of the Humanities requirement. Foreign language or Humanities credit will not be granted in introductory (first and second year level) language and composition courses in the principal language of the country where the student completed high school, or in a second language spoken in his/her home. See *Elective Studies.*)

Technical Communication

A required (3 hour) technical communication course is taken in the senior year. This requirement may be met by electing Technical Communication 486, 492, or 498. (See page 464.)

Engineering

Three or four hours of introductory digital computing or equivalent are required, and the way in which this requirement can be met depends on the particular program, as follows:

1. Students proposing to enter EECS (Electrical or Computer Engineering) should take EECS 100, a 4-credit course specially designed for EECS students.
2. The majority of students proposing to enter *all other* programs *except* EECS should take either of the following 3 credit courses:
   a) Eng 103, *Personal Computing and FORTRAN*
   b) Eng 104, *Personal Computing and "C."*

The Engineering Advising and Career Planning Center in 1009 LEC maintains an up-to-date list of individual department preferences concerning Eng 103 and Eng 104. Although the majority of departments will accept either

course, this list *must* be consulted before enrolling in either
Eng 103 or Eng 104.

3.   Students proposing to enter *all other* programs *except*
      EECS, and who wish to explore digital computing a little
      more deeply, may take either of the following 4 credit
      courses, *providing* that they are acceptable to the stu-
      dent's intended department. Both courses introduce
      computing by using Matlab, before proceeding to "C"
      or FORTRAN.
      a)   Eng 106, *Personal Computing, Problem-Solving,
            and "C."*
      b)   Eng 107, *Personal Computing, Problem-Solving,
            and FORTRAN.*

Again, the list of guidelines maintained by the Freshman
Engineering Advising and Career Planning Center in 1009 LEC
must be consulted before enrolling in either Eng 106 or Eng 107.

Chemistry

The minimum requirement in chemistry for most undergraduate
degree programs is 5 credit hours. The Atmospheric, Oceanic
and Space Sciences, Chemical Engineering, and Materials Science
and Engineering programs require additional chemistry. Students
who enter a degree program requiring only 5 hours of chemistry
would normally elect Chem 130 (3 credit hours.) and Chem 125
(2 credit hours laboratory) during the freshman year. Students
expecting to enter a degree program requiring additional chem-
istry would normally elect Chem 130 (3 credit hours), Chem 210
(4 credit hours), and Chem 211 (1 credit hour laboratory) during
the freshman year. Students who are undecided about a degree
program are advised to defer electing Chem 125 until a decision
is made.

Students can place out of Chem 130 by being at or above
the cutoff percentile (approximately 65%) on the Chemistry
Placement Exam taken during the University of Michigan orienta-
tion or by receiving advanced placement credit for Chem 130.
These students will be given the option to take Chem 210 and
Chem 211 for an advanced 5 credit hour chemistry sequence.
The courses must be taken concurrently. Students who receive
advanced placement credit for Chem 130 and Chem 125 would
not need to take additional chemistry in most programs, but are
encouraged to use the advanced placement credit to acquire a
better chemistry background.

Physics

The usual freshman schedule includes Physics 140 (4) with
laboratory, Physics 141 (1). This course assumes knowledge
of calculus.

A second course, Physics 240 (4), with laboratory, is required by all programs and is normally scheduled in the third term.

> **Note**: Alternate Honors sequence: 160(4); 141(1); 260(4); 241(1); 262(4).

Elective Studies
Each program provides some freedom for the student to elect subjects that satisfy the individual's particular interests and aptitudes. The humanities/social science academic and program advisors are in a position to make helpful recommendations.

Humanities and Social Sciences
To provide a desirable breadth of education, each program in the College of Engineering specifies a certain number of credit hours of elective courses (minimum 17) concerned with human cultures and relationships—generally identified as humanities and social sciences (HU/SS). In general, the humanities include literature (English and others), philosophy, history of art, music history, classical civilization, etc.; the social sciences include economics, history, psychology, anthropology, sociology, etc.

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. Sample cluster themes are contained in a separate document available from the academic program advisors.

Specific requirements for all students (with or without College Board Advanced Placement Program credit or transferred credit) are outlined below. For information on specific courses, see Humanities (HU) and Social Sciences (SS) course offerings in the College of Literature, Science, and the Arts *Bulletin* and *Course Guide*. Courses designated as (N.S.), (N.Excl.), (Excl.), (Experiential), and (Independent) cannot be used to fulfill humanities or social science credits. Foreign language credit will not be granted in a language that is a student's native language or a second language spoken in his/her home.

1. Humanities (6 credit hours)—at least two courses in humanities, totaling at least 6 credit hours, selected from:
    a. Any non-performance course designated as Humanities (HU) in the LS&A *Bulletin*.
    b. Any non-performance course in the School of Music or School of Art.
    c. Any foreign language taken at the University or any other university or college designated FL, LR, or HU.
    d. Advanced placement foreign language credit at the second year level or higher.

2. A set of humanities or social science courses: A set consists of at least two courses in either the humanities or the social

sciences, or both, totaling at least 6 credit hours. The set must be taken from the same department or division (for example, History), one of which must be a 300-level, or higher, course. This requirement may overlap requirement 1.

3. The remaining credit hours may be satisfied with elective courses in either humanities or social sciences as follows:
   a. Any course designated as Humanities in requirement 1.
   b. Any course designated as Social Sciences (SS) in the LS&A *Bulletin*.
   c. Eng 451: Technology and Society (social sciences credit).

   Note: Courses labeled as "NS," "N Excl," "Excl," "Experiential," and "Independent" in the *LS&A Course Guide* may not be used for this requirement.

Other Electives

Subject to the limitations of the student's program and to the approval of the program advisor, a student may also elect courses within the field in which the student is enrolled; courses in other engineering departments; appropriate courses in other colleges or schools of the University such as mathematics, chemistry, physics, astronomy, biology, and the management sciences; and courses in military, naval, or air science.

Free 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, as free electives, a maximum of 3 credit hours of performance courses in the schools of Music or Art, including marching band. Tutorial courses are not acceptable for credit or grade points but will be included on the student's official record.

All undergraduate degree programs in the College of Engineering will accept electives from credits earned (3 credit hours only) by a student in courses for which the requirements include tutoring of other students enrolled in courses offered under the Keller plan or similar plans.

All undergraduate degree programs in the College of Engineering will accept up to 12 credit hours toward free electives from credits earned by a student in 300- and 400-level courses in military, naval, or air science.

It is permissible and generally desirable for a student to elect courses in addition to those required for the degree, provided the student has a clear understanding with the program advisor. This provides an opportunity to explore areas of cultural and professional interests, to augment the student's preparation for continued or professional interest, as well as to enhance the student's preparation for continued or advanced study in a selected field—either in engineering and physical sciences or in other

areas such as business administration, law, medicine, dentistry, or education. Courses not applied to the engineering degree may be elected as pass/fail. (See page 81 for further information on P/F elections.)

Fee Regulations, Expenses, Indebtedness

A non-refundable application fee of $40 for U.S. citizens ($55 for foreign students) will be required of each applicant for admission to the University.

The Total Tuition and Registration Fees for one full term for the 1995–96 academic year were as follows (1996–97 fees were not yet determined at the time of this printing.):

	FALL 1995
Resident Lower Division	$2,945
Resident Upper Division	$3,735
Non-Resident Lower Division	$8,608
Non-Resident Upper Division	$9,658

Students enrolled as special students or guest students in the College of Engineering will be assessed the upper division fees.

The total expenses for upper division students for 1995-96 were approximately:

	FALL 1995
Michigan resident (two terms, academic year)	$13,300
Non-Resident and Foreign (two terms, academic year)	$25,200

Fees are subject to change at any time by the Regents of the University. Cost projections are based on the University Office of Financial Aid guidelines.

Detailed information relating to fees, deposits, payments, and refunds may be obtained in the Engineering Academic Records Office and/or may be found in the first few pages of the current *Time Schedule*.

Class Standing

The number of credit hours accumulated toward graduation at the close of a given term are used to determine a student's class standing for statistical purposes. Questions concerning class-level designations should be referred to the Engineering Academic 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 less 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 published in the *Time Schedule* each term.

Indebtedness to the University

Students shall pay all accounts due the University in accordance with regulations set forth for such payments by the Vice President in charge of Business and Finance.

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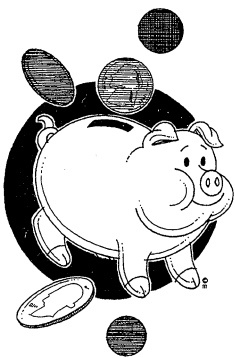
Rules and Procedures

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 unsatisfactory. 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 following statement relating to

ethical conduct is part of the Canon as revised by the Engineers' Council for Professional Development in 1963.

"The Engineer, to uphold and advance the honor and dignity of the Engineering Profession and in keeping with high standards of ethical conduct:

1. Will be honest and impartial, and will serve with devotion his employer, his clients, and the public;
2. Will strive to increase the competence and prestige of the engineering profession, and
3. Will use his knowledge and skill for the advancement of human welfare."

In 1915, several 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 enrollment in the College of Engineering. By observing the Code, students do their work in an environment conducive to establishing high standards of personal integrity and professional ethics.

As a basic feature of the Code, students are placed upon their honor during all examinations and written quizzes, and as required by the instructor, for computer questions, homework, and laboratory reports. Although the instructor is available for questions, the examination may not be proctored. The student is asked to write and sign the following pledge at the end of the examination paper:

"I have neither given nor received aid on this examination."

Either a student or the instructor may report a suspected violation by calling 647-7018. The report is then investigated by the Student Honor Council, resulting in a recommendation to the Faculty Committee on Discipline.

The Honor Council has prepared a booklet that explains the principles and operation of the Honor Code. The Honor Code booklet is available at the Engineering Academic Records Office, 1401 Lurie Engineering Center (LEC).

Independent Study

In general, the principles of the Honor Code also apply to homework when the instructor requires the material turned in to be the student's own work. While independent study is recognized as a primary method of effective learning, some students may find 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 what cooperation between them, if any, is permitted

by the instructor. When independent study and performance are expected, the deliberate attempt to present as one's own work any material copied from another student or from any source not acknowledged in the report is forbidden. In such cases, the instructor may require the signing of the pledge and expect the same high standards of integrity as during examinations. The instructor may report suspected violations.

Attendance and Absences

Regular and punctual attendance at 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 are required to account for their absences to their instructors. An instructor may report to an Assistant Dean when it is considered that the number of absences of an underclassman is excessive; and the instructor may require the student to present a written excuse approved by an Assistant Dean.

A student who has been absent from studies for more than one week because of illness or other emergency should consult the advisor to determine the advisability of reducing elections.

A student with an unresolved problem related to absences may consult an Assistant Dean.

Statement of Student Rights and Responsibilities

All University of Michigan students are responsible for upholding the community standards expressed in the *Statement of Student Rights and Responsibilities* (SSRR) which sets forth standards of non-academic conduct by students and a judicial process for resolving complaints of alleged violations of the standards.

If a student is alleged to have participated in behavior that violates both the professional standards of the College of Engineering and the standards of SSRR, the College of Engineering may choose to resolve the allegations either through the College's procedures or through the procedures outlined in the *Statement*.

On-campus violations of the SSRR include: sexual assault and rape; harassment; physical assault, battery and endangerment; the knowing possession, use or storage of firearms or dangerous weapons; hazing; unlawful possession, use, manufacture,

sale, or distribution of alcohol or other drugs; arson; fraud against the University; theft; intentionally interfering with teaching; property damage; illegal entry into University facilities; false reports concerning fires, bombs, or other emergencies, and misuse of the disciplinary procedures. Off-campus violations include: illegal sale, distribution, or manufacture of drugs; physical assault, battery, and endangerment; murder; arson; hazing; sexual assault and rape; and harassment.

The Judicial Advisor accepts complaints from individuals who believe a violation of the *Statement* has occurred; investigates alleged violations; counsels students, faculty, and staff about the judicial process; assists complainants and accused students prepare for hearings and mediations; enforces sanctions and mediated agreements; and educates the University community about the *Statement.*

The *Statement* is published in the gray sections of T*he Student Handbook of the University of Michigan: Insiders Guide* or *Rounding out A2* and may be obtained on the Internet via UM-GopherBlue. For further information please contact the Office of the Judicial Advisor at (313) 936-6308.

The University of Michigan Policy for Services and Assistance to Disabled Students

The University of Michigan complies with federal and state laws which affect qualified persons with disabilities. It is the policy and practice of the College of Engineering to provide equitable educational opportunities for students with documented disabilities in all programs and activities, including internships or field placements. Students with disabilities who require academic adjustments are encouraged to contact their instructors at the beginning of the semester to discuss their specific needs. The University of Michigan Office of Services for Students with Disabilities (SSD) provides assistance regarding academic, economic, social, and recreational activities to students who have documented disabilities. Specific services available through SSD include counseling, assistance with classroom accommodations, volunteer readers and notetakers, sign language and oral interpreters, peer tutors, accessible transportation, orientation and registration assistance, special scholarships, tape recorders and talking calculators, and aids for reading and studying, such as braille and large print materials, adaptive computer technology, and telecommunication devices for the deaf. SSD staff also serve as intermediaries and advocates for students with disabilities. To find out more about services, or to volunteer as a reader,

notetaker, or tutor, contact Services for Students with Disabilities,
G-625 Haven Hall, Ann Arbor, MI 48109-1045, (313) 763-3000
(Voice/TDD). Students with disabilities may also contact
D. Hansen, 763-3000.

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 estab-
lished by the University.

     Any student absent from an examination is required to
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.

     See "Honor Code" for procedures pertaining to
examinations.

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:

Name of Term	Period	Identification Used in Description of Courses
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:

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

In the following rules and procedures, the word "term" also
applies to half term unless otherwise indicated.

Credit Hour

A credit hour represents, generally, one hour of recitation or lecture per week for a term, or two for a half term; preparation for each credit hour should require normally two hours of study. Generally, one period of laboratory work is considered to be equal to one hour of credit. "Credit hour" or "hours of credit" as used in this *Bulletin* and as reported on the student's academic record are synonymous with "semester hour."

Course Offerings

The appropriate *Bulletin* and the *Time Schedule* prepared for each term, will serve the student as a guide in planning each term's schedule.

The faculty reserves the right to withdraw the offering of any elective course not chosen by at least eight persons.

Registration (Official Enrollment)

All students must go through the registration process to be officially enrolled in classes. This process includes meeting with a departmental advisor so that appropriate classes are selected. This is followed by the actual telephone 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 *Time Schedule.*

Completion of both the advising and registration procedures is required before a student attends any classes or uses any University facilities. Starting the first day of class, a $50 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 through the touch-tone process or at the Engineering Academic Records Office, 1401 LEC and pay the usual disenrollment fee as stated in the current *Time Schedule.*

Change of Elections (Includes Drops and Adds)

During the first three weeks of classes (first two weeks in a half term), students may drop without a "W." The third week through the ninth week of classes (second week through the fourth-and-a-half week in a half term), students must bring Drop/Add forms,

that have been signed by the Program Advisor, to the Engineering Academic Records Office, 1401 LEC. An instructor notification card must also be filled out. After nine weeks students must: **obtain** approval of an Advisor on a Drop/Add form; **fill out** a petition form and instructor notification card; **provide** documentation of extenuating circumstances; **obtain** approval of an Assistant Dean.

The only approved drops will be for those students who present written evidence of extenuating circumstances; i.e., severe health problems, prolonged illness in the family, jury duty, etc. There must be documented evidence that the student was earning a "C" grade or better before the problem occurred. Approved drops will be posted to the official record with a grade of "W." A form for petitioning to drop a class due to extenuating circumstances may be obtained either at the Engineering Academic Records Office, 1401 LEC, or the student's departmental advising office.

The grade for any course dropped without the permission of the Program Advisor or a College of Engineering Assistant Dean will be recorded as "ED" (unofficial drop) and computed as "E" in the averages.

Junior and senior students enrolled in a Military Officer Education Program must also have approval of the Chairman 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.

When a student wishes to drop all courses, the Program Advisor will refer the student to the Engineering Academic Records Office, 1401 LEC. This is the only way to officially withdraw from the College.

Audit

With permission of the advisor and the course instructor, a student may enroll in a course as an auditor. 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 an auditor.

A change in elections from credit to audit must be made during the first six weeks of a term (the first three weeks of a half term). Signed petitions are required after this point.

Program Selection

A student normally selects a program of study during the second term of the freshman year and is referred to the appropriate program advisor. Students who have not selected a program by the time they reach 55 credit hours, or who wish to change degree programs after they have reached 55 credit hours, are subject to grade point averages and quotas approved by the Executive

Committee of the College of Engineering for admission to the various degree programs.

Changing or Adding a Program

When a student desires to change from one program to another, or to elect an additional program, the student must consult the program advisors of the programs involved and obtain the necessary approvals on a form supplied by the Engineering Academic Records Office, 1401 LEC.

Transfer students or continuing students who have earned 55 credit hours or more are subject to grade point averages and quotas approved by the Executive Committee of the College of Engineering for admission to the various degree programs.

Grades 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 Chairman. The final appeal at the College level is by petition to the Executive Committee. Petitions may be obtained from the Engineering Academic Records Office, 1401 LEC.

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.

Electives

See guidelines under "Elective Studies." A student may elect courses in addition to those required for the degree. The student may not register in the College of Engineering and elect courses offered by another college if such elections do not contribute to a goal of a bachelor's degree in this College, except when approved by an Assistant Dean. See "Unassigned Status."

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 general, a student's scholastic standing determines eligibility for admission to other colleges.

Students transferring to LS&A (Literature, Science and the Arts) must complete 30 hours in residence after they have transferred to LS&A.

A College of Engineering Assistant Dean may be consulted for transfer procedures.

Withdrawing

To disenroll after having registered (including early registration), the student must report to the Engineering Academic Records Office, 1401 LEC, to complete a Withdrawal Notice form. A "W" will appear on the transcript when withdrawal occurs after the first three weeks of the full term or the first two weeks of the half term. Withdrawal from the College for a justifiable reason at any time during a term requires the approval of a College of Engineering Assistant Dean.

After the third week of a full term or second week for a half term, a student requesting withdrawal must present evidence of extraordinary circumstances. In any case, the Assistant Dean for Students may specify the conditions for readmission.

Disenrollment fees vary. A fee schedule, including deadlines, is printed in the University *Time Schedule*.

Readmission

A student who is not enrolled for 12 months or more must apply for readmission through the Transfer Admissions and Recruitment office 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 Transfer Admissions and Recruitment office.

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

A student who withdrew for health reasons will be referred to the University Health Service for clearance.

Grades and Scholastic Standing

Academic Record

Each student's "Academic Report" is the cumulative record of courses elected, grades, averages, and other matters relating to

the progress of the student while enrolled at the University of Michigan.

An individual may obtain an official copy of his or her academic record from the Office of the Registrar at no charge. An unofficial copy of the Academic Report may be obtained through Wolverine Access. (See the *Time Schedule* for complete information about Wolverine Access.)

Students electing Study Abroad classes through the U-M Office of International Programs (OIP), will receive credit hours and the appropriate number of grade points (see below). OIP grades will be averaged into the student's overall GPA.

Grade Reports

Unless withheld for infringement of rules, each term's grades are reported to the student. Students may also obtain their grades and class schedules through Wolverine Access.

Good Scholastic Standing

To be in good scholastic standing at the end of any term a student must have a *term and cumulative* grade point average of 2.00 or more. Each course which is graded with "A+" through "E," or "ED," is included in the computations.

Averages

The term grade point average (GPA) and the cumulative grade point average 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**:

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

These items do not affect grade point averages:

P	passed (See Pass/Fail Option)
F	not passed (See Pass/Fail Option)
I	incomplete
W	approved drop

VI   audit
NR   no report

In the remainder of this section of the *Bulletin*, the term "A grade" applies to any of the grades "A+," "A," or "A-;" "B grade" to "B+," "B," or "B-," etc.

The grade point average is computed by dividing the grade points (Michigan Honor Points or MHP), by the 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).

A course elected under pass/fail option does not affect the grade point average.

Pass/Fail Option

Elective courses in Humanities and Social Sciences or courses to be used as Free Electives can be taken pass/fail. The pass/fail total is not to exceed four courses or 14 credit hours and is limited to two courses per term or one in a half term. Any course that is offered only on a pass/fail basis will not be counted in the above totals. The Introductory English Composition and Senior Technical Communication cannot be elected as pass/fail courses. Courses elected pass/fail which exceed the limitations stated above cannot be applied in any way to a degree program. Passed courses, however, will appear in the cumulative totals.

The following regulations will apply:

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 four-and-one-half weeks of a half term). No changes in election as a graded course or as a pass/fail course can be made after the ninth week (or first four-and-one-half weeks) of a 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 lower than "C-" 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 Diploma, a minimum of 45 hours of credit 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

A department or instructor may offer an undergraduate pass/fail course on the following bases:

1. The instructor will report the grade as pass/fail for each student enrolled.

2. The grade will be treated on 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 *Time Schedule*.

Rules Governing Scholastic Standing for Unsatisfactory Performance

Two levels of scholastic deficiency identify a student's unsatisfactory performance: *Probation* and *Enrollment Withheld*.

Scholastic standing is determined by both the term (semester) and cumultative grade point averages. The grade point average (GPA) is based on Michigan Honor Points (MHPs).

Satisfactory completion of each credit hour will yield, minimally, two (2) MHPs. (See "Averages" on page 80.) Scholastic standing is deficient when the student's GPA is less than double the number of credit hours completed.

Scholastic standing action will be determined as follows:

Rule 1. Probation: When a student has a deficiency of 0.001 to 9.999 MHPs on either the term or cumulative GPA, the student is placed on probation. The notation "Probation" will be entered on the Academic Record. A student on probation may continue enrollment but must consult with the academic or program advisor to initiate any adjustments in elections that might be necessary. *Probation is a serious warning that there is a need to improve scholastic performance or further enrollment may be jeopardized.*

Rule 2. Enrollment Withheld: Students on probation for the third time and each time thereafter are put on "Enrollment Withheld."

Rule 3. Enrollment Withheld: When a student has a deficiency of 10 MHPs or more for either the term or the cumulative GPA, enrollment will be withheld. The notation "Enrollment Withheld" will be entered on the Academic Record.

Rule 4. When a student's enrollment is withheld, the following procedure will be employed: A student may petition the Committee on Scholastic Standing and request a review (Rule 5). If reinstated on probation by the Committee, the student may register in the College again.

Rule 5. Reinstatement on Probation: When a student's future enrollment is withheld, the student may present a petition to the Committee on Scholastic Standing. The petition should document reasons for the unsatisfactory performance. If appropriate, the student will meet with the Committee. If the student can show a satisfactory reason for the low record and can provide sufficient and convincing evidence that another opportunity is warranted, the Committee may reinstate the student on probation.

To request a meeting with the Committee, the student must first submit a petition for reinstatement in writing. Petition forms may be picked up in person or obtained by calling or writing the Engineering Academic Records Office, 1401 Lurie Engineering Center (LEC) (313) 647-7112. Appointments for interviews should be made through the same office.

The Committee must receive the petition at least three days prior to the interview. Notice of your meeting with the Committee will be given to your program advisor for comments. On the petition, you will be asked to state the difficulties you have encountered, what you already have done to correct the situation, and what additional plans you have to improve your academic performance. If illness has been a factor, please include supporting information, including a statement (with dates) from your doctor.

All students will be in one of the following classifications:

a. **Good Standing**—better than 2.00 term **and** cumulative average.

b. **On Probation**—0.001-9.999 MHP deficiency on term **or** cumulative.

c. **Reinstated on Probation**—10 or more MHP deficiency but reinstated on grounds of extenuating circumstances surrounding poor record.

Students with academic holds must have written support of their program advisors to early register.

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

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 prerequisite for a later elected course; in this case, the course must be repeated before electing the next course unless waived by the Assistant Dean in the Engineering Advising Center or the program advisor (for students who have selected a program). A grade of "C-" is not a satisfactory level of performance in some programs and is not acceptable in any program for the introductory composition course. 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.

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. As soon as possible the instructor and student should mutually understand the reasons for the "I" mark and agree on methods 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 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 of 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-summer term) 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."

Other Irregularities

Irregularities associated with a failure to submit changes in academic status are identified on the student's Academic Record 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. Unofficial drop ("ED") will be considered the same as an "E" in computing the term and cumulative averages and will affect the scholastic standing.

If there has been an error, the student must consult the Assistant Dean for Students on the necessary procedures for resolving such cases. An "NR" (no report) will be changed to "ED" if the student initially elected the course and takes no action to have it cleared by the end of the next term enrolled.

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 freshmen, the Assistant Dean in 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.

Honors and Awards
for Superior Academic Achievement

The Dean's List

Degree candidates who elect courses and complete a minimum of 12 credit hours with grades (6 for a half term) and earn a 3.50 GPA term average or better, attain the distinction of the Dean's Honor List for the term.

Class Honors

Students who elect a minimum of 28 credits in courses taken on the Ann Arbor campus during a calendar year (January 1 through December 31) including a minimum 20 credits elected on a *graded* basis, and who earn a 3.5 grade point average, are eligible for Class Honors. Incoming freshmen and transfer students who elect a minimum of 14 credits during the fall term, including a minimum of 10 *graded*, and who earn at least a 3.5 grade point average, are also eligible for Class Honors. This distinction is posted on a student's transcript by the University Registrar's Office. Recipients of this honor are invited to attend the annual Honors Convocation.

Angell Scholar

James B. Angell Scholars are students who earn all "A+," "A," or "A-" grades for two or more consecutive terms based on a minimum 12 *graded* credits elected each term; all other grades must be "P," "S," or "CR." Terms of fewer than 12 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. This distinction is posted on a student's transcript by the University Registrar's Office. Recipients of this honor are invited to attend the annual Honors Convocation.

Branstrom Award

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

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 Parker Scholars Program invites those women who have attained a cumulative grade point of 3.0–4.0, or better, 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

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 the Associate Dean for Undergraduate Education.

Society Recognition

Distinguished scholarship and service to the College are also recognized by election to a number of honor societies that are listed under "Extracurricular Opportunities." A student's election to a recognized society will be posted on the Academic Record.

Recognition on Diploma

A student graduating with at least 45 hours of credit completed, with grades, while enrolled in this College (or as directed by the Executive Committee) 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

Time Requirements for a Bachelor's Degree

The time required to complete a degree program depends on the background, abilities, and interests of the individual student. 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 elects a Military Officer Education Program or who is partially self-supporting while at the campus may find it desirable to plan a schedule longer than eight terms. The average length of time for degree completion is four and one-half years.

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 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.

(See additional options available within the "Simultaneous Graduate/Undergraduate Study" [SGUS] program.)

Requirements for a Bachelor's Degree

To obtain a bachelor's degree in the College of Engineering, Ann Arbor campus, a student shall meet the following requirements, subject to approval of the program advisor:

1. The student must achieve a satisfactory level of attainment in those subjects specified by the program of his or her choice. A grade of "D" in a required course may not be considered a satisfactory level of attainment unless approved by the program advisor. A student may be considered proficient in a designated part of the degree requirement and be allowed recognition of the level of attainment in one or more of the following ways:

   a. 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.)

   b. By Advanced Placement Program examination for college-level work completed in high school (See "Advanced Placement," under "Admission.")

   c. By an examination regularly offered by a department of the University (e.g., mathematics and language), or by a recognized testing service

   d. By transfer of equivalent credit from another recognized college (See "Adjustment of Advanced Credit," under "Admission.")

e. By demonstrating qualification for enrollment in a higher-level course or series (e.g., honors-level, in which case a student may achieve a saving in credit hours)

f. 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 Academic Record, 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 complete a minimum of 30 credit hours of advanced level (300 or higher) courses, as required by the degree program while enrolled in the College of Engineering, Ann Arbor campus.

3. The student must complete at least 30 of the last 36 credit hours of work while enrolled in the College of Engineering, Ann Arbor campus.

4. 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.

5. The student must file formal application for the diploma. (See "Diploma" and "Commencement.")

Requirements for an Additional Bachelor's Degree

1. To obtain two bachelor's degrees (including prescribed) in the College of Engineering, a student must complete the requirements of both degree programs. In addition, for the second degree, the student must complete at least a minimum of 14 credit hours in pertinent technical subjects over the number required for the first degree. The credit hours that are used to satisfy each of the two programs also must satisfy the cumulative grade point average requirement of 2.00 or more. 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.

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 Engi-
neering or a second degree in LS&A must file an application for
each.

     The application must be submitted to the student's depart-
ment 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 renew the application at the appro-
priate 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 appro-
priate to the date of graduation. Making all arrangements for
attending is the student's responsibility.

Representative Sample Schedules

In an effort to provide the interested student, both freshman and
transfer, with a sample schedule, 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. Generally, it will be modified for a student elect-
ing Military Officer Education Program or a freshman admitted
with advanced placement.

     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. If this is the case, the student should elect humanities
and social sciences subjects in place of the professional courses
listed in the sample schedule during terms three and four.

In any case, departmental Program Advisors should always be consulted when planning course selections.

Military Officer Education Program courses are not included in the sample schedules. A student who elects and completes the advanced program for a commission should consult the program advisor on the use of a maximum of 12 credit hours of advanced (300- and 400-level) courses for free elective credit.
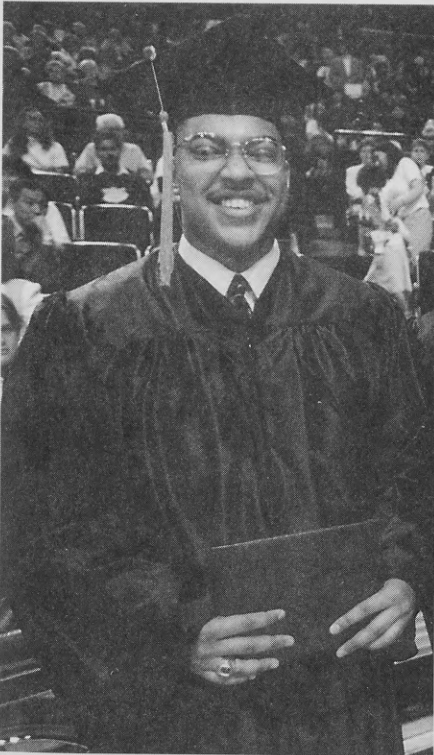
Cornelius Langston Henderson IV received his B.S.E. in M.E. at the 1995 College of Engineering Commencement, 84 years after his great-grandfather, Cornelius Langston Henderson, Sr., received his B.S.E. in Civil Engineering. The senior Henderson was the second Michigan Engineering African-American alumnus; the first was Fred B. Blackburn (B.S.E. 1887 Civil).

Undergraduate

Degree Programs

Twelve of the programs first listed are offered
under the jurisdiction of a particular department
of the College. Following these is one program
that is interdisciplinary in nature and is adminis-
tered on a College-wide basis. See "Contents"
at front of this *Bulletin* for listing.

Jose Rico III and Maria Zamora, members of the Society of Hispanic Professional
Engineers (SHPE) U-M student chapter, celebrate their victory at the 1995 SHPE
National Career Conference. The U-M team won the National Academic Olympiad.

UNITED STATES OF AMERICA
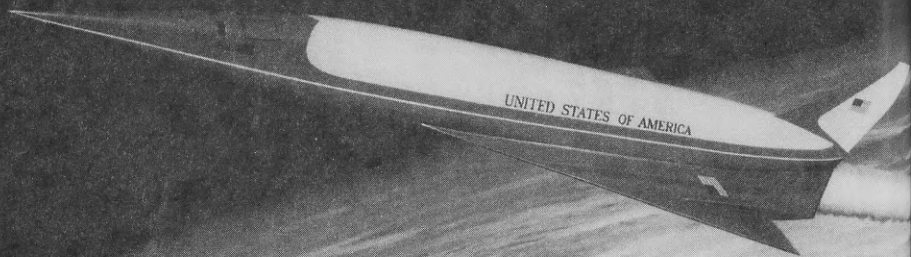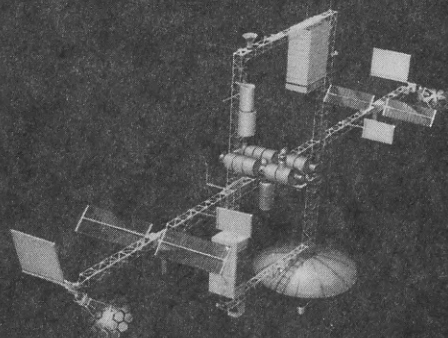
Aerospace Engineering

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 ground-effect machines and helicopters to aircraft and spacecraft. Design of such vehicles has always been challenging, not only because of the requirement that they operate in a hostile environment but also because of the high premium placed on lightweight vehicles performing efficiently and with great reliability. 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

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engineering. Real-life problems in aerospace and related areas are emphasized in the applications of the theory. In the senior year the 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 an overall system.

Aerospace Engineering Program

The degree program gives the student a broad education in engineering by requiring basic courses in aerodynamics and propulsion (sometimes collectively referred to as "gas dynamics"), structural mechanics, flight dynamics and control systems. These courses cover fundamentals and their application to the design and construction of aircraft, space-

In this computer enhanced image of Aerospace Engineering at the Millennium, a space vehicle is launched toward a United States manned space station. (NASA photo adapted by Marie Howard.)

craft and other vehicular systems and subsystems. Courses in gas dynamics treat fluid and gas flow around bodies and through turbojet engines and rocket nozzles; also involved is the study of large- and small-scale air motion in the atmosphere and its relationship to environmental and noise problems. In courses on structural mechanics, lightweight structures are studied not only from the strength point of view but also in their elastic dynamic behavior. Flight dynamics and control systems 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 this material takes place in the design course in which the student has a wide choice of design topics. The aerospace engineering program offers considerable flexibility through technical and free electives in which the student has an opportunity to study in greater depth any of the basic areas mentioned earlier. In addition, there are other technical elective areas which the aerospace engineering students are encouraged to consider, 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.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Aerospace Engineering "Combined Degrees Program" and "Department Laboratories" are described on pages 98–99.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Aerospace Engineering)—(B.S.E. Aerospace E.)—must complete the program listed on the next page. *The sample schedule is an example of one leading to graduation in eight terms.*

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	–	–	–	–
English 125, Intro Comp	4	4	–	–	–	–	–	–	–
*Computing	3	3	–	–	–	–	–	–	–
**Chemistry 130	3	–	3	–	–	–	–	–	–
**Chemistry 125	2	–	–	2	–	–	–	–	–
Physics 140 with Lab 141; 240 with Lab 241	8	4	4	–	–	–	–	–	–
(See Physics Note below)									
Senior Technical Communication	3	–	–	–	–	–	–	–	3
Humanities and Social Sciences (see pages 63, 67)	17	–	4	4	4	–	–	2	3
Related Technical Subjects (16 hrs.)									
ME 211, Intro to Solid Mech	4	–	–	4	–	–	–	–	–
ME 235, Thermodynamics I	3	–	–	–	3	–	–	–	–
ME 240, Intro to Dynamics	3	–	–	–	3	–	–	–	–
MSE 250, Prin of Eng Materials	3	–	–	–	3	–	–	–	–
EECS 314, Cct Analy and Electronics	3	–	–	–	–	3	–	–	–
Program Subjects (40 hrs.)									
Aero 200, Intro to Aero Eng	3	–	–	3	–	–	–	–	–
Aero 301, Laboratory I	3	–	–	–	–	3	–	–	–
Aero 302, Laboratory II	3	–	–	–	–	–	3	–	–
Aero 314, Structural Mech I	3	–	–	–	–	3	–	–	–
Aero 320, Intro to Gas Dyn I	3	–	–	–	–	3	–	–	–
Aero 330, Intro to Gas Dyn II	3	–	–	–	–	–	3	–	–
Aero 340, Mechanics of Flight	3	–	–	–	–	–	3	–	–
Aero 350, Aero Analysis	3	–	–	–	–	3	–	–	–
Aero 414, Structural Mech II	3	–	–	–	–	–	3	–	–
Aero 420, Aerodynamics I	3	–	–	–	–	–	3	–	–
Aero 430, Aerospace Propulsion	3	–	–	–	–	–	–	3	–
Aero 471, Automatic Control Sys	3	–	–	–	–	–	–	3	–
Aero 481, 483, or 484, Design **(Note A)**	4	–	–	–	–	–	–	4	–
Technical and Free Electives (16 hrs.)									
Technical Electives **(Note B)**	9	–	–	–	–	–	–	3	6
Free Electives	7	–	–	–	–	–	–	2	5
Total	**128**	**15**	**15**	**17**	**17**	**15**	**15**	**17**	**17**

*Eng 103 (3 hrs), Eng 104 (3 hrs), Eng 106 (4 hrs), or Eng 107 (4 hrs) are acceptable; Eng 106 or Eng 107 preferred, 1 hour counting as free-elective credit.

**Students who qualify are encouraged to take Chem 210 (4 hrs) and Chem 211 (1 hr) as replacements for Chem 130 (3 hrs) and Chem 125 (2 hrs).

Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

Note A. Aero 481, Airplane Design; or Aero 483, Space System Design; or Aero 484, Computer Aided Design

Note B. Technical electives (9 hrs) are to be chosen from the following groups:

Science/Mathematics elective (3 hrs): Stat 311, Aero 452, Math 371, Math 419, Chem 365, Physics 242, Adv Physics (e.g., 401, 402, 405, 406)

Aerospace Vehicle Systems elective (3 hrs): Aero 440, 443, 535, 545

Other technical elective (3 hrs): Upper division engineering, mathematics or physical science

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. Favorite second degree areas of concentration among aerospace engineers are Mechanical Engineering and Applied Mechanics and Naval Architecture and Marine Engineering, but combined degrees with other departments can be arranged.
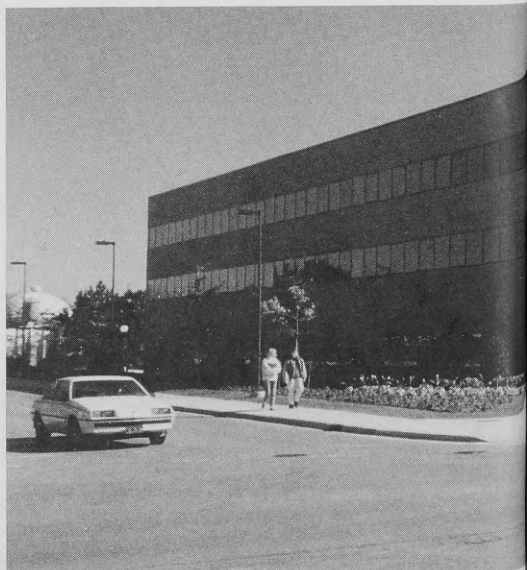
The François-Xavier Bagnoud Building
In 1993, the new home of the Department of Aerospace Engineering was inaugurated in the memory of François-Xavier Bagnoud (B.S.E. Aero '82), who died in a helicopter mission in 1986. (Photo: Marie Howard)

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 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; structural 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 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.
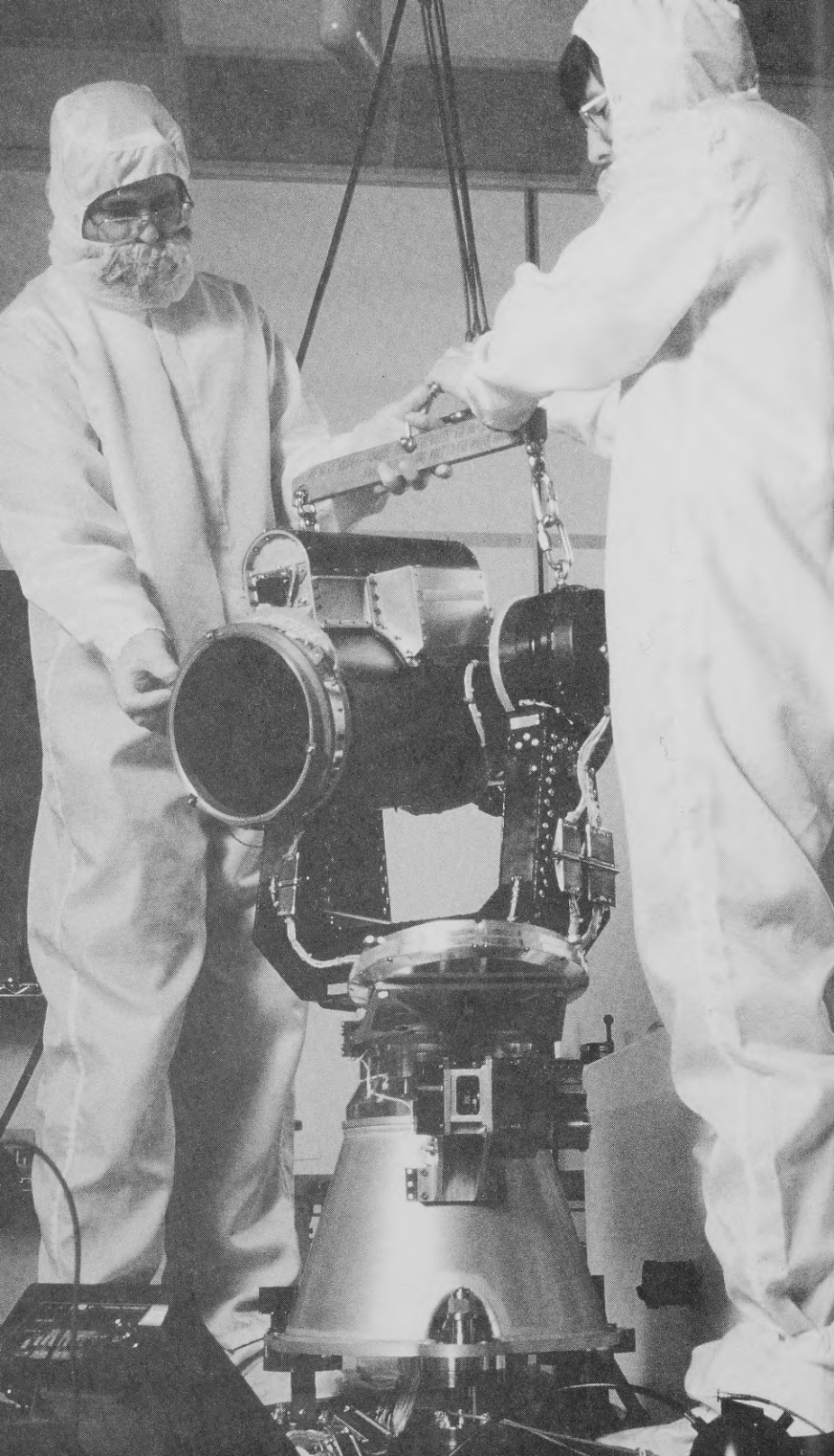
Atmospheric, Oceanic and Space Sciences

Atmospheric, Oceanic and Space Sciences (AOSS) is concerned with the description and explanation of phenomena in the atmosphere and oceans of the Earth and other planets. Both theoretical and applied problems are treated.

The increased recognition of the importance of the Earth's atmosphere and oceans in a wide range of human activity has created a demand for atmospheric scientists, oceanographers, and space scientists with a broad knowledge of the many processes that take place in the earth-ocean atmosphere system, ranging from the sea floor to the altitude of orbiting satellites. This knowledge is necessary to understand and manage weather and climate changes caused by natural and anthropogenic modifications of our environment.

The sub-disciplines treated within AOSS cover a wide range of activities and interests. The atmospheric scientist is concerned with solving problems relating to forecasting, air pollution, industrial plant location and processes, the design of structures and

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the wind loading of them. Many important decisions on transportation, whether by land, water, or air, depend critically on meteorological factors. The oceanographer is concerned with solving problems relating to water supply and control, water pollution, wave action on structures and beaches, and many other oceanographic and ocean engineering problems. Areas of interest in space science include the construction of satellite platform instruments for the observation of earth-atmosphere-ocean system. The B.S. degree in AOSS will prepare graduates for employment in the National Weather

The High Resolution Doppler Imager telescope in the Department's clean room facilities is prepared for flight prior to launch on the Upper Atmosphere Research Satellite. (Photo: David Koether)

Service, private weather forecasting companies, air and water quality management firms, or NASA; and for continued studies in graduate school.

Degree Program in Atmospheric, Oceanic and Space Sciences

The course of study leading to the B.S. is designed to be flexible and to accommodate a wide variety of interests. All students in the undergraduate program take a sequence often required courses (30 credit hours) that introduce the various aspects of atmospheric, oceanic, and space sciences, emphasizing the interactions between the various disciplines and the scientific bases of the phenomena that are observed.

An additional 32 credit hours, split between technical and free electives, are selected by the student with the advice and consent of the program advisor to allow the student to specialize in a particular subdiscipline, such as weather forecasting or air quality. The technical electives are to be at the 300 level or above. Some examples of electives are shown below.

Program meeting the requirements of the American Meteorological Society and the National Weather Service for weather forecasting: Math 217(3), Aero 350(3), AOSS 310(1), 311(2), 401(3), 411(3), 434(3), 454(3), 479(3).

Program leading to graduate study in Atmospheric Science: AOSS 412(3), 401(3), 451(4), 454(3), 479(3), Math 454(3), Stat 412(3), and Eng 451(3).

Preparation for graduate studies in Physical Oceanography: ME 240(3), 325(3), Stat 412(3), AOSS 401(3), 425(4), NA 455 (3), AOSS 528(3).

Preparation for a nontechnical profession, such as law, business, or medicine: AOSS 412(3), 479(3), Stat 412(3), Nat Res 310(4), Eng 451(3), Econ 400(4), Pol Sci 412(3), Phil 356(4), Geol Sci 123(2).

Facilities

Laboratories include Air Pollution Meteorology; Meteorological Instrumentation; a Synoptic Meteorology Laboratory weather station where current weather data including satellite information are received over a satellite link; and a dynamic Meteorology Laboratory where numerical simulations of various atmospheric and oceanic phenomena are performed. The Weather Underground and the Weather Net provide current weather information and forecasts to users of the World Wide Web (http://groundhog. sprl.umich.edu). It ranks in the top 10 most visited Web sites in the world. The department also operates a Radiation Measurement Analysis Facility, which includes comprehensive solar and infrared radiation measuring devices with automatic

data acquisition. The Space Physics Research Laboratory houses teaching and research activities for studies of all regions of Earth's atmosphere and space probe studies of the atmospheres of other planets. Other facilities include laboratories for the study of atmospheric chemistry and for field measurements of atmospheric constituents, as well as modeling of the transport and dispersion of pollutants. Remote sensing of the atmosphere and ocean from satellites and other platforms is a strong area of research in the department. In the space sciences there is an emphasis on the upper atmosphere, the atmosphere of the planets, the interplanetary medium, and the study of comets. Facilities for the construction and testing of

satellite instruments are part of the laboratory. Undergraduates are encouraged to participate in research programs in one of the areas discussed above. Additionally, state of the art classroom facilities and several computer labs are located in the department.

More information on the department may be found on the World Wide Web http://www.engin.umich.edu/dept/aoss.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/ Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the B.S. degree must complete the 120 credit hour program listed on the following page. *The sample schedule is an example of one leading to graduation in eight terms.*

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8

Subjects required by all programs (58 hrs.)

(See under "Minimum Common Requirements," page 59, for alternatives.)

	Hours	1	2	3	4	5	6	7	8
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125 or equivalent, Intro Composition	4	4	-	-	-	-	-	-	-
Computing	3	3	-	-	-	-	-	-	-
Chemistry 125 and 130, or 210 and 211	5	3	2	-	-	-	-	-	-
Physics 140 with Lab 141	4	-	4	-	-	-	-	-	-
Physics 240 with Lab 241	4	-	-	4	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Science	17	-	4	4	6	3	-	-	-

AOSS Core Courses (30 hrs.)

|	Hours	1	2	3	4	5	6	7	8
304 Atmos and Ocean Environment	3	-	-	3	-	-	-	-	-
305 Intro to Atmos and Ocean Dynamics	3	-	-	-	3	-	-	-	-
335 Space Science and Spacecraft Applics	3	-	-	-	3	-	-	-	-
407 Math Methods in Geophysics	3	-	-	-	-	-	-	3	-
408 Environ Prob Solv with Computers	3	-	-	-	-	-	-	3	-
414 Weather Systems	3	-	-	-	-	-	3	-	-
430 Thermodynamics of the Atmosphere	3	-	-	-	-	3	-	-	-
432 Environmental Radiative Processes	3	-	-	-	-	-	3	-	-
462 Instrumentation for Atmos and Space Sci	3	-	-	-	-	-	3	-	-
475 Earth-Ocean-Atmos Interactions	3	-	-	-	-	-	-	-	3

	Hours	1	2	3	4	5	6	7	8
Additional Humanities and Social Sciences	2	2	-	-	-	-	-	-	-
Technical Electives (16 hrs.)	16	-	-	-	-	3	3	4	6
Free Electives (16 hrs.)	16	-	-	-	-	6	3	4	3

	Hours	1	2	3	4	5	6	7	8
Total	**120**	**14**	**16**	**15**	**16**	**15**	**15**	**14**	**15**

Physics Note: In Academic Years 1995-96 and 1996-97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.
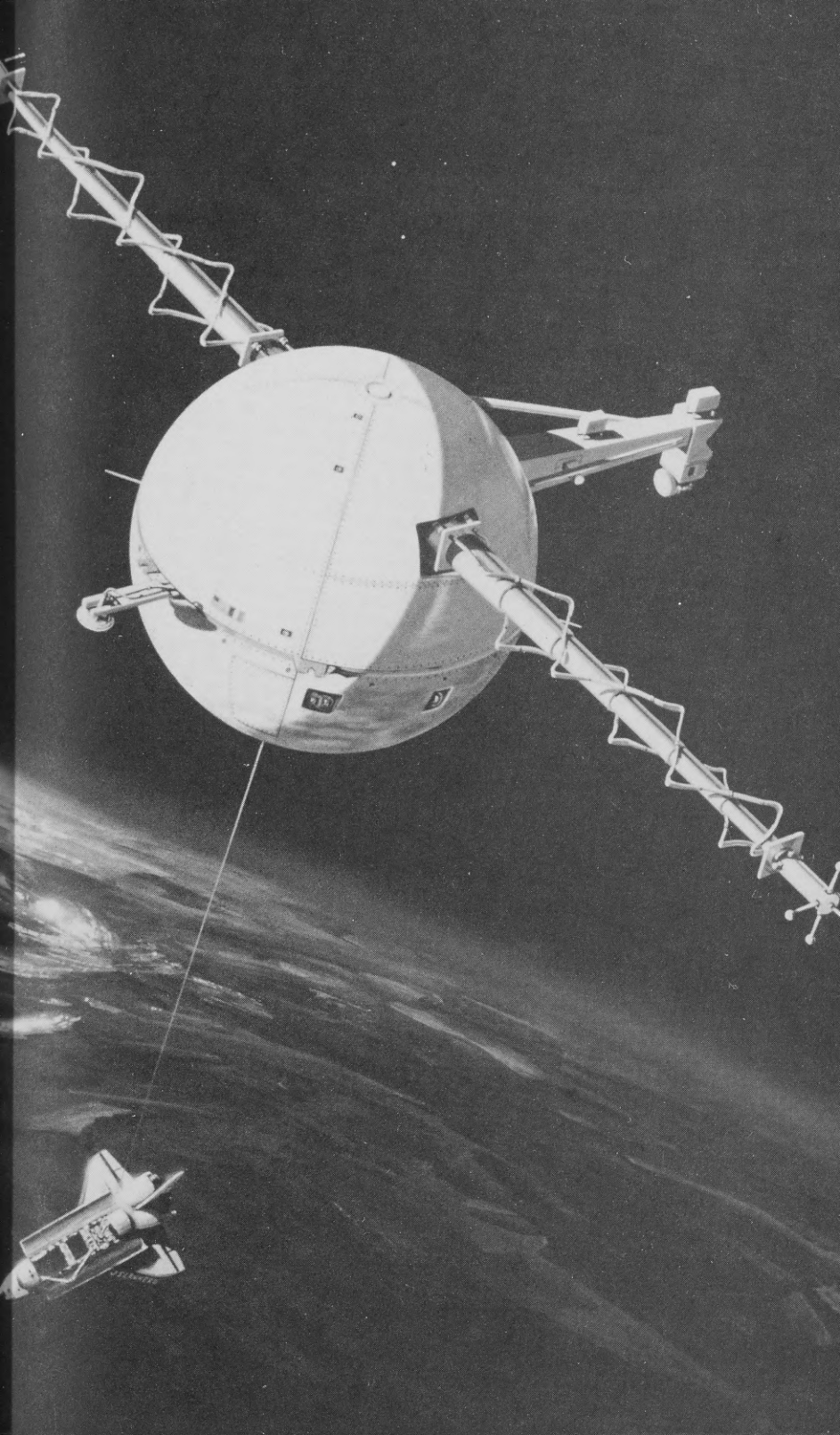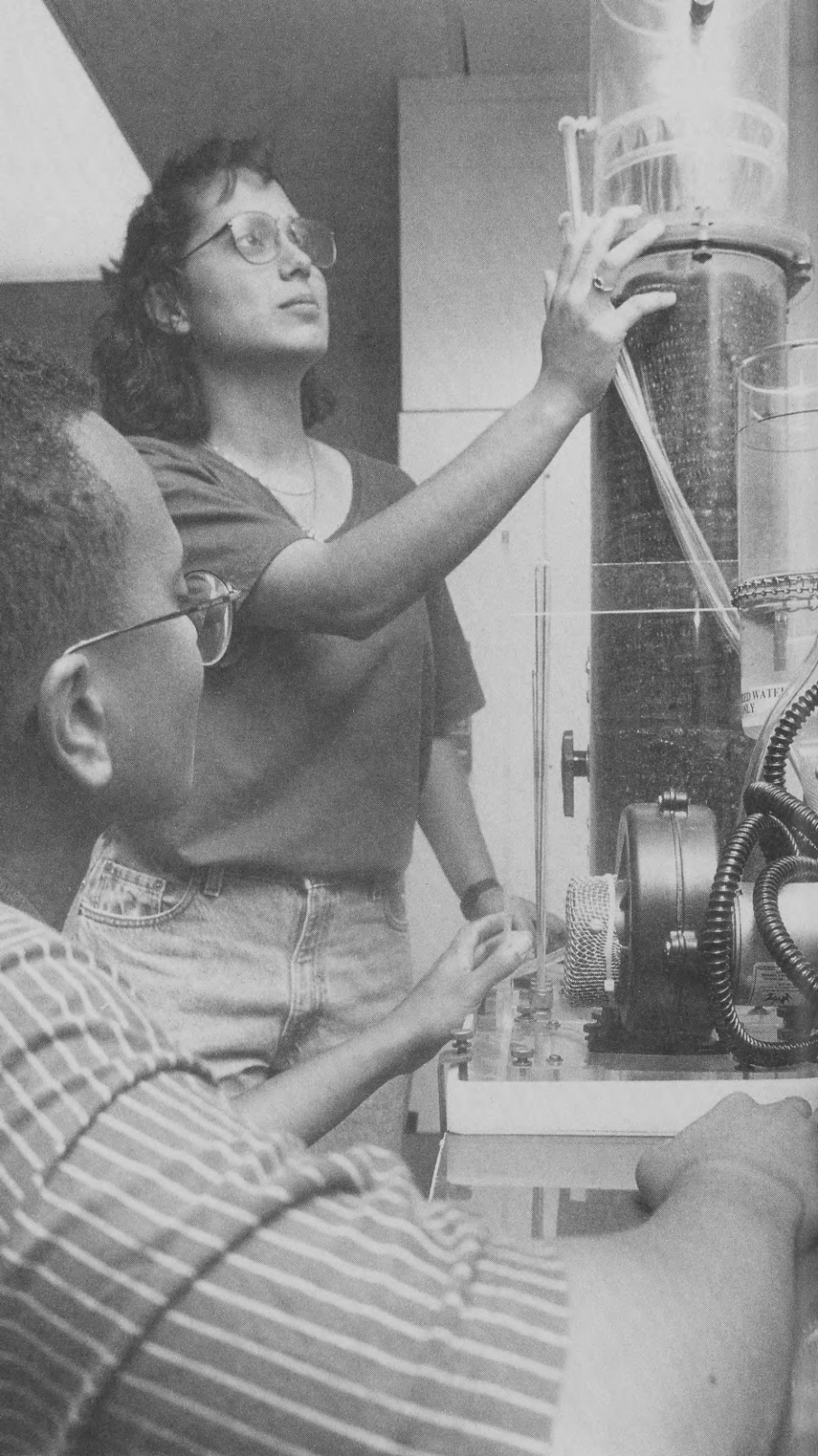
Chemical Engineering

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 physical 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, plant operation, marketing, sales, and corporate or government administration.

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Professor Dale E. Briggs
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Program Office
3086 H.H. Dow Building
(313) 764-7413

The work of the chemical engineer encompasses many industries, from the manufacture of chemicals and consumer products and the refining of petroleum, to biotechnology, nuclear energy, and space technology. Because of this breadth, there are many special fields in which chemical engineers may concentrate.

The program allows 8 hours of free electives and 9 hours of engineering 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 petroleum, polymers, environmental engineering, chemical reaction engineering, control systems,

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Damon Prather and Michelle Moceri use a cooling tower apparatus in a Chemical Engineering undergraduate instructional lab. (Photo: D.C. Goings)

computers, nuclear energy, biochemical processes, solar energy, and natural resource usage.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Facilities

The facilities located in the H. H. Dow Building include biochemical engineering, catalysis, energy logistics, eco-system simulation, electrochemical, heat transfer, light scattering and spectroscopy, petroleum research, polymer physics, process dynamics, real-time computing, and surface science laboratories; and in the G. G. Brown Laboratories Building, large and pilot scale heat transfer, mass transfer, kinetics, and separations processes equipment.

Combined Programs in Chemical and Materials Science and Engineering

A combined degree may be obtained in chemical engineering and materials science and engineering. Chemical engineering students who choose a second degree in the metallurgical option will take a minimum of 14 additional hours in the field of process, physical, and mechanical metallurgy. Those who choose the materials option will take at least 14 additional hours in physical metallurgy, physical ceramics, and polymers.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Chemical Engineering)— B.S.E. (Ch.E.)—must complete the program listed on the next page. *The sample schedule is an example of one leading to graduation in eight terms.*

Note: Transfer students may require a program different from that printed. Details of such programs are not shown here, but may be obtained from the program advisor.

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216 +	16	4	4	4	4	–	–	–	–
English 124 or 125 or equivalent, Intro Comp	4	4	–	–	–	–	–	–	–
*Engineering 103, Computing	3	3	–	–	–	–	–	–	–
Chemistry 130	3	3	–	–	–	–	–	–	–
Physics 140 with Lab 141; 240 with Lab 241	10	–	5	–	5	–	–	–	–
(See Physics Note below)									
Senior Technical Communication	3	–	–	–	–	–	–	–	3
Humanities and Social Sciences (see pages 63, 67)	17	3	3	3	–	4	4	–	–
(to include a course in economics)									
Advanced Science (19 hrs.) (Note A)									
Chem 210, 211, Struct and Reactiv I and Lab +	5	–	5	–	–	–	–	–	–
Chem 215, 216, Struct and Reactiv II and Lab	5	–	–	5	–	–	–	–	–
Chem 302, Inorganic Chem	3	–	–	–	–	3	–	–	–
Chem 461, Physical Chemistry	3	–	–	–	–	–	3	–	–
Chem 463, Physical Chemistry	3	–	–	–	–	–	–	3	–
Related Technical Subjects (9 hrs.)									
Elective Courses in Engineering *(Note B)*	9	–	–	–	–	3	–	3	3
Program Subjects (36 hrs.)									
ChemE 230, Thermo I +	4	–	–	4	–	–	–	–	–
ChemE 330, Thermo II +	4	–	–	–	4	–	–	–	–
ChemE 341, Fluid Mechanics +	3	–	–	–	3	–	–	–	–
ChemE 342, Heat and Mass Transfer +	3	–	–	–	–	3	–	–	–
ChemE 343, Separation Processes +	3	–	–	–	–	3	–	–	–
ChemE 344, Reaction Eng and Design +	3	–	–	–	–	–	3	–	–
ChemE 360, ChemE Lab I	3	–	–	–	–	–	3	–	–
ChemE 460, ChemE Lab II	3	–	–	–	–	–	–	–	3
ChemE 466, Process Control and Dynamics +	3	–	–	–	–	–	–	3	–
ChemE 486, Chem Proc Sim and Design I +	3	–	–	–	–	–	–	3	–
ChemE 487, Chem Proc Sim and Design II	4	–	–	–	–	–	–	–	4
Free Electives (8 hrs.)	8	–	–	–	–	–	2	3	3
Total	**128**	**17**	**17**	**16**	**16**	**16**	**15**	**15**	**16**

*Students may elect Eng 103 (3 hrs), Eng 104 (3 hrs), Eng 106 (4 hrs), or Eng 107 (4 hrs).
If Eng 106 or Eng 107 is elected, 1 hour will be counted as free elective credit.
"D+" rule: Students must earn a "C-" or better in prerequisite courses indicated by the (+)
symbol; anything less must be repeated.
Note A. An advanced natural science course may be substituted for Chem 461 or Chem 463.
Note B. The courses are to be at the 200 or higher level. At least one course must be out-
side of Chemical Engineering. Courses in AOSS are not considered engineering
courses for this purpose.
Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141;
240, 241 will count for 10 total credits, 2 of which will be applied according to
individual program directives.
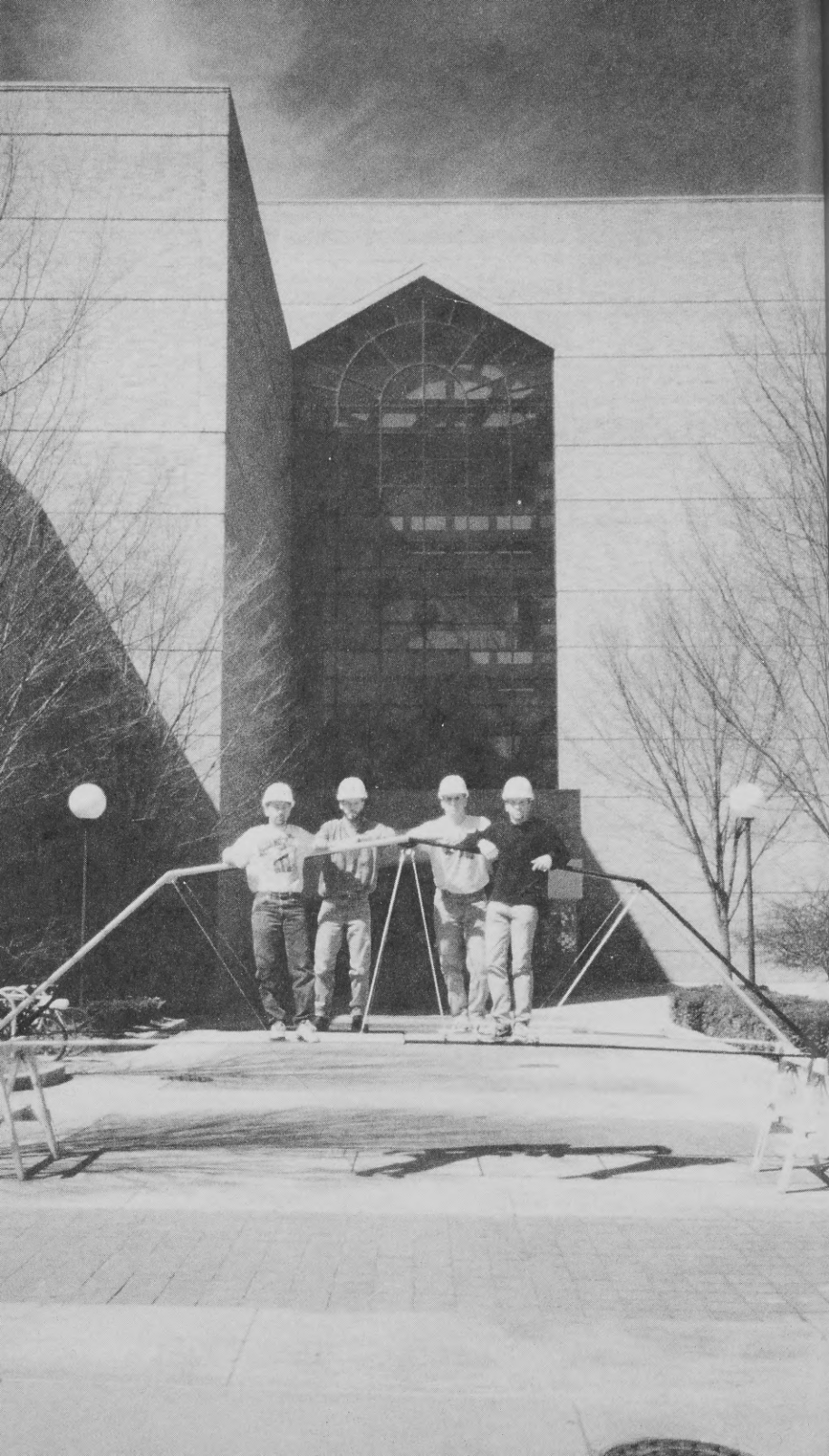
Civil and Environmental Engineering

Civil engineers have always had the unique opportunity to touch the everyday lives of those around them. They design, plan, and construct the buildings in which we live and work, the roads, highways, and bridges upon which we travel, the transit and transportation systems we use, and much more. As the world population grows and society becomes more technologically complex, the issues facing civil and environmental engineers will be even more important and the challenges more exciting. Civil and environmental engineers will be involved in environmental and public health issues as they examine the disposal of newly generated wastes and the handling of contaminated sites. New technologies for the control of water and air quality, and computer models to predict the movement and dispersion of wastes in ground and surface waters, will be developed. Advances in the construction industry will allow civil engineers to design and build new facilities more efficiently. As new materials are developed,

Program Advisor
Professor E. B. Wylie
Program Office
2342 G.G. Brown Building
(313) 764-9412

innovations in all constructed facilities, from buildings to space stations will be possible. Computer technology, including machine learning, will also play a larger role. In all of these areas, civil and environmental engineers are given the rare opportunity to improve the environment and to have a direct impact on society's life style. The following are areas of concentration within Civil and Environmental Engineering at Michigan.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Construction Engineering and Management

Planning, estimating, scheduling, and managing the construction of engineered

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U-M received First Place in the 1996 North Central Regional Steel Bridge Competition. Team members include Civil and Environmental Engineering undergraduate students Rick Hutter (captain), Jon Galow, Tim Jones, and Brian Keeler. (Photo: CEE department)

facilities using modern construction methods, materials, and equipment. Business and legal principles of construction contracting.

Environmental Engineering

Municipal and industrial water distribution and waste collection, water quality and water pollution control, the improvement and regulation of natural waters for municipal, industrial, and recreational use; water resources development and management, the analysis and design of water resource systems; environmental design for control of solid wastes and air and water pollution, management of engineering problems in the urban environment.

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.

Hydraulic and Hydrological Engineering

The application of the fundamental principles of hydraulics and hydrology to the optimum development of surface water and groundwater resources. The area includes the study of flood prediction and flood control, flow and contaminant transport in surface and ground waters, transients in pipe lines and channels, coastal engineering, and hydraulic design of involved structures.

Materials and Highway Engineering

The analysis, engineering, and testing of civil engineering materials pertaining to infrastructure renewal and high performance structures. The area encompasses 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/structures.

Municipal Engineering

The design, construction, maintenance, and management of the water, wastes, and transportation systems of the urban population along with consideration of the many other factors which affect the urban environment so as to maintain safe and wholesome physical conditions within the city.

Structural Engineering

The theory, analysis, design, and construction of structures such as bridges, buildings, chimneys, tanks, and towers, involving the use of steel, reinforced concrete, aluminum,

timber, and other materials; studies of inelastic behavior of materials and structures; studies of dynamic forces and their effects on structures.

Facilities
The Civil and Environmental Engineering departmental offices are in the G. G. Brown Building.

The George Granger Brown Laboratories Building on the North Campus houses the construction engineering and management laboratory, the structural research laboratory, hydraulic engineering laboratory, the soil mechanics laboratory, and the civil engineering materials laboratory.

The Environmental and Water Resources Engineering Building, a wing of the G. G. Brown Building, contains laboratories for Environmental and Water Resources Engineering. Equipment is available for physical and biological studies, analytical determinations, and data analyses in environmental science and water quality engineering.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Civil and Environmental Engineering)—B.S.E. (C.E.E.)—must complete the program listed on the next page. *The sample schedule is an example of one leading to graduation in eight terms.* Electives should be carefully planned in consultation with advisors so that the complete program includes the equivalent of two terms of engineering science and one term of engineering design.

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125, Intro Composition	4	4	-	-	-	-	-	-	-
Engineering 103 or 104, Computing	3	3	-	-	-	-	-	-	-
Chemistry 130 and 125	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241	8	-	4	4	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences (**Note A**)	17	-	3	3	-	4	4	3	-
Advanced Electives (6 hrs.)									
Advanced Mathematics (**Note B**)	3	-	-	-	-	3	-	-	-
Advanced Sciences (**Note C**)	3	-	-	-	-	-	-	3	-
Engineering Sciences (19 hrs.)									
ME 211, Intro to Solid Mechanics	4	-	-	-	4	-	-	-	-
ME 240, Introduction to Dynamics	3	-	-	-	3	-	-	-	-
CEE 280, Intro to Environ Eng	3	-	-	3	-	-	-	-	-
ME 235, Engineering Thermodynamics (**Note D**)	3	-	-	-	3	-	-	-	-
MSE 250, Prin of Eng Materials	3	-	-	3	-	-	-	-	-
CEE 325, Fluid Mechanics	3	-	-	-	-	3	-	-	-
Program Subjects (19 hrs.)									
CEE 303, Computational Methods	3	-	-	-	3	-	-	-	-
CEE 312, Theory of Structures	4	-	-	-	-	4	-	-	-
CEE 315, Design of Structures	3	-	-	-	-	-	3	-	-
CEE 400, Contracts and Eng Legal Rel	2	-	-	-	-	-	-	-	2
CEE 401, Prof Issues in CEE	1	-	-	-	-	-	-	1	-
CEE 421, Hydraulics	3	-	-	-	-	-	3	-	-
CEE 445, Eng Properties of Soil	3	-	-	-	3	-	-	-	-
Technical Electives (18 hrs.) (Note E)	18	-	-	-	-	-	6	6	6

Option A (3 credit courses)
CEE 351, Civil Eng Materials
CEE 413, Design of Metal Structures
    or CEE 415, Design of R/C Structures
CEE 431, Construction Contracting
CEE 446, Engineering Geology

Option B (3 credit courses)
CEE 420, Hydrology
CEE 428, Intro to Ground Water Hydrology
CEE 480, Dynamics of Environ Systems
CEE 485, Water Supply and Wastewater Eng

General Courses (3 credits each)
CEE 332, Eng Surveying and Measurement Applications
CEE 405, Civil Eng Systems
CEE 470, Transportation Engineering

	Hours	1	2	3	4	5	6	7	8
Design Concentration (6 hrs.) (Note F)	6	-	-	-	-	-	-	3	3
Free Electives (4 hrs.)	4	-	4	-	-	-	-	-	-
Total	**128**	**16**	**15**	**17**	**17**	**17**	**16**	**16**	**14**

Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141;
240, 241 will count for 10 total credits, 2 of which will be applied according to
individual program directives.

Note A. At least 3 hours must be in economics.

Note B. The elective in advanced mathematics may be satisfied with any course in
mathematics, probability, statistics, operations research, mathematical programming, or
computer science that has the equivalent of at least Math 215 as a prerequisite.

Note C. Select one of the following: Biol 152 (4), Chem 210 (4), Chem 230 (3), or
Physics 242 (3).

Note D. ChemE 230 (3) may be substituted for ME 235 (3).

Note E. Technical electives (18) must include at least five of the courses listed. Of these
five, a student must take three (3) in Option A or B, two (2) outside of this option, but no
more than one (1) of the general courses listed.

Note F. The design concentration will be composed of an approved sequence of
courses in some area of civil engineering practice. As early as possible, a student
should select a particular area of interest and confer with the advisor in that field regard-
ing the electives required for the completion of the program. A student must elect one
set of two courses that will provide the required minimum of 3 units of design. Group-
ings of courses that meet the technical concentration requirements are available in the
following areas:

> Construction Engineering — Advisor: Professor Carr
> Environmental Engineering — Advisor: Professor Demond
> Geotechnical Engineering — Advisor: Professor Gray
> Hydraulic and Hydrological Engineering — Advisor: Professor Wright
> Materials and Highway Engineering — Advisor: Professor Li
> Municipal Engineering — Advisor: Professor Woods
> Structural Engineering — Advisor: Professor Goel

Electrical Engineering and Computer Science

Modern electrical engineering is,, itself, a broad and diverse field. The closely related area of computer science and engineering has now achieved its full role as a profession and rivals all engineering disciplines in its impact on society. The expanding roles of both electrical and computer engineers and scientists in today's society reflect the variety and scope of these exciting professions. In recognition of the distinct qualifications required of engineers and scientists entering these fields, the Electrical Engineering and Computer Science department offers three undergraduate programs: the electrical engineering program leads to a Bachelor of Science in Engineering (Electrical Engineering) B.S.E. (E.E.); the computer engineering program leads to a Bachelor of Science in Engineering (Computer Engineering)— B.S.E. (Comp. E.); and the computer science program leads to a Bachelor of Arts or Bachelor of Science degree in Computer Science (consult the LS&A *Bulletin*).

Throughout each program, students work with modern laboratory equipment and are exposed to the most recent analytical techniques and technological developments in the field. Students have many opportunities to associate with outstanding faculty, most of whom are actively engaged in research or professional consulting. Such interaction serves to acquaint students with the opportunities and rewards available to practicing electrical or computer engineers and scientists. Students are encouraged to seek an advanced degree if further specialization and a higher degree of competence in a particular area is desired. The advanced degrees available are described under the section, "Graduate Studies."

Facilities

The departmental facilities include modern instructional laboratories and research laboratories in the areas of communications and signal

Microwave and millimeter-wave test laboratory for characterization of devices up to 350 GHz (Photo: Courtesy of EECS department)

processing, bioelectrical science, systems engineering, radiation, solid-state electronics, optical science, vehicular electronics, advanced computer architecture, computer vision and cognitive science, artificial intelligence, robotics, and software systems. The instructional laboratory facilities available to the student provide access to many types of digital computers, logic design modules, and modern instrumentation for the design of discrete analog and digital circuits and systems. In addition, there are specialized facilities for communications and signal processing, integrated circuit and solid state device fabrication, image processing, electromagnetics and optics, VLSI design, distributed systems, computer vision, and artificial intelligence.

Computer Engineering

Program Advisor
**Professor Kevin J.
     Compton**
Program Office
3415 EECS Building

CSE Undergraduate
Computer Engineering Option
(College of Engineering Degree)

The program in Computer Engineering provides the 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 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 of the first two years) gives the essential material in electronic circuits, digital logic, discrete mathematics, computer programming, data structures, and other topics. Following completion of this work, the student is free to select courses in a wide range of subject areas. These include operating systems, programming languages and compilers, database systems, software engineering, computer graphics, computer architecture, computer aided design and VLSI, fault-tolerant computation, artificial intelligence, robotics, control engineering, and computer networking, among others. A broad selection from these areas is recommended for most undergraduate students with specialization in particular areas being more typical of graduate programs of study.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Advising

Appointments with program advisors are scheduled at 3415 EECS Building or by calling 763-2305.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Computer Engineering)—B.S.E. (Comp. E.)—must complete the program listed below.

The sample schedule is an example of one leading to graduation in eight terms.

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (55 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro Comp (see page 63)	4	4	-	-	-	-	-	-	-
*Chemistry 130 and 125	5	5	-	-	-	-	-	-	-
Physics 140, with Lab 141; 240 with Lab 241	10	-	5	5	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences (see pages 63, 67)	17	-	4	-	4	3	3	3	-
Program Subjects (48 hrs.)									
**Computing	4	4	-	-	-	-	-	-	-
EECS 210, Elec Engin I	4	-	-	-	4	-	-	-	-
EECS 211, Elec Engin II	4	-	-	-	-	4	-	-	-
EECS 270, Intro to Logic Design	4	-	-	4	-	-	-	-	-
EECS 280, Prog and Intro Data Structures	4	-	4	-	-	-	-	-	-
EECS 303, Discrete Structures	4	-	-	4	-	-	-	-	-
EECS 360 or 476 or 477 or 478, Sys Comput Sci	3	-	-	-	-	-	3	-	-
EECS 370, Intro to Comp Organization	4	-	-	-	-	4	-	-	-
EECS 373, Des of Microproc Based Systems	3	-	-	-	-	-	3	-	-
EECS 380, Data Struc and Algorithms	4	-	-	-	4	-	-	-	-
EECS 400 or Math/Stat 419, Lin Spaces	3	-	-	-	-	-	3	-	-
EECS 401 or Math/Stat 425, Probabilistic Methods	3	-	-	-	-	-	-	3	-
EECS 482 or 483, Oper Sys or Compiler Const	4	-	-	-	-	-	-	4	-
Technical Electives (13 hrs.) (Note A)	13	-	-	-	-	4	-	3	6
Free Electives (12 hrs.)	12	-	-	-	-	-	4	3	5
Total	**128**	**17**	**17**	**17**	**16**	**15**	**16**	**16**	**14**

*Students who qualify are encouraged to take Chem 210 (4), Chem 211 (1) as a replacement for Chem 130 (3), Chem 125 (2).

**EECS 100 or the equivalent is a prerequisite for EECS 270 and EECS 280. Students are strongly advised to take this course.

Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

Note A. Must include courses only at the 300 level or higher. Must include 10 hours of courses whose primary orientation is in computer-related areas such as those listed on succeeding pages, and must also include 3 hours of courses whose primary orientation is engineering sciences and design not in CSE.

Electives should be carefully planned in consultation with advisors so that the complete program includes the equivalent of two terms of engineering science and one term of engineering design. If a fourth credit is earned from the group requirement EECS 360, 476, 477, 478, the free electives will be reduced by (1). No more than 4 hours of EECS 499, Directed Study, may be taken to fulfill the technical elective requirement.

Engineering Sciences and Design (not in CSE) Technical Electives (3 hrs.)
Courses can be selected with the approval of the counselor from EECS, IOE, ME, NERS, Aero, and AOSS. Communications Signals and Systems, EECS 451, 453, and 455. Control Systems, EECS 360 and 460.

Computer-Oriented Technical Electives (10 hrs.)
A broad selection from the following areas is recommended.

    Algorithms: EECS 477, 586, 587
    Artificial Intelligence: EECS 492, 545, 547, 592, and 595
    Communications Signals and Systems: EECS 453 and 455
    Computer Graphics: EECS 487 and 588
    Computer Vision and Image Processing: EECS 442, 542, and 543
    Database Management Systems: EECS 484, 584, and 585
    Digital Design and Computer Architecture: EECS 470, 473, 478, 570, and 577
    Networks: EECS 489, 557
    Operating Systems: EECS 482, 582, and 682
    Programming Languages and Compilers: EECS 483, 486, and 583
    Robotics: EECS 467 and 567
    Software Engineering: EECS 481, 581, and 681
    Theoretical Computer Science: EECS 476, 477, 574, 575, and 586
    VLSI and Computer-Aided Design: EECS 426, 427, 527 and 627

Electrical Engineering

The program in Electrical Engineering is designed to provide students with a fundamental background in the basic theoretical concepts and technological principles that constitute the foundations of modern electrical engineering and, at the same time, the opportunity to emphasize subject areas in which they have a particular interest. The curriculum requirements are flexible enough to allow students to design their academic program to achieve a variety of objectives, with the assistance and approval of the program advisor. Students may emphasize the applied and experimental aspects of electrical engineering or may concentrate on subjects requiring analytical or theoretical treatment.

Students are expected to pursue a coherent course of study. Nine areas of concentration are possible under Technical Electives. Electives should be carefully planned in consultation with advisors so that the complete bachelor's program includes the equivalent of two terms of engineering science and one term of engineering design. Detailed programs for each major area are available at the program office.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Program Advisor
Professor S.L. BeMent
(Chief Advisor)
Program Office
3415 EECS Building
(313) 763-2305

Requirements

Candidates for the Bachelor of Science degree in Engineering (Electrical Engineering)—B.S.E. (E.E.)—must complete the program listed on the following page. *The sample schedule is an example of one leading to graduation in eight terms.*

The requirements described in this *Bulletin* differ significantly from those described in previous years. Generally speaking, students who have already begun their B.S.E. (E.E.) program should satisfy the requirements described in the appropriate previous editions of the *Bulletin*. **Please read "Important Notes" on page 123.**

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (57 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125 Intro Composition	4	4	-	-	-	-	-	-	-
*Chemistry 130 (3 hrs) and Chem 125 (2 hrs)									
OR Chem 210 (4 hrs) and Chem 211 (1 hr)	5	5	-	-	-	-	-	-	-
Computing	3	-	3	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241	10	-	5	5	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Sciences (see pages 63, 67)	16	4	4	-	4	-	4	-	-
Program Subjects (35 hrs.)									
EECS 210, Elec Engr I	4	-	-	4	-	-	-	-	-
EECS 211, Elec Engr II	4	-	-	-	4	-	-	-	-
EECS 270, Intro to Logic Design	4	-	-	4	-	-	-	-	-
EECS 280, Prog and Intro Data Structures	4	-	-	-	4	-	-	-	-
EECS 316, Signals and Systems	4	-	-	-	-	4	-	-	-
EECS 317, Solid State Devices and Digital Electronics	4	-	-	-	-	4	-	-	-
EECS 320, Intro to Semiconductor Device Theory	4	-	-	-	-	4	-	-	-
EECS 331, Electromagnetics I	4	-	-	-	-	4	-	-	-
EECS 401, Probabilistic Methods in Engineering	3	-	-	-	-	-	3	-	-
Technical Electives (28 hrs.)									
Technical Electives (see next page)	28	-	-	-	-	-	4	12	12
Free Electives (8 hrs.)	8	-	-	-	-	-	4	-	4
Total	**128**	**17**	**16**	**17**	**16**	**16**	**15**	**15**	**16**

*EECS 100 (4 hrs), Eng 103 (3 hrs), Eng 104 (3 hrs), and Eng 106 (4 hrs) are all acceptable. For students committed to Electrical Engineering, EECS 100 is preferred. In the case of the 4 hour courses, the fourth credit hour counts as a technical or free elective credit.

Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

Technical Electives Description

1. Technical electives may come from EECS, from other engineering programs, from physical or biological sciences, and from mathematics or statistics. Certain courses in other areas, such as business and economics, are also acceptable, when approved by a Program Advisor.

2. Technical electives must be 300-level or higher, except for Physics 242, and 200-level courses that are program subjects in other engineering programs. Additional exceptions may be approved by a Program Advisor.

3. Technical electives must include:

   a. at least 8 hours of EECS courses including at least one at the 400-level or higher

    b. at least one of the following laboratory courses: EECS 373, 423, 425, 437, 458, 467
    c. at least one course of 3 or more credits from an engineering department other than EECS.

4. The combination of program subjects and technical electives must include at least 16 credit hours of design, including at least one senior level major project design experience. The latter course does not count as the 400-level EECS technical elective in 3a (above) nor as the non-EECS engineering technical elective in 3c.

5. Up to 4 hours of independent study are permitted.

Areas of concentration in which technical electives may be selected include:

Bioelectrical Sciences	Computers	Optics
Circuits and Electronics	Control (and Robotics)	Signal Processing
Communications	Electromagnetics	Solid-State Devices and Integrated Circuits

Important Notes

The B.S.E. (E.E.) degree requirements described in this *Bulletin* differ significantly from those described in previous years. Generally speaking, students who have already begun their B.S.E. (E.E.) program should satisfy the requirements described in the appropriate previous edition of the *Bulletin*. The following notes give details.

1. Students who have not completed EECS 216 or the equivalent prior to the 1996 fall term must satisfy the requirements described in this *Bulletin*.

2. Students who have completed EECS 216 prior to fall 1996 are generally expected to satisfy the requirements described in a previous *Bulletin*—usually the *Bulletin* for the year in which they entered the B.S.E. (E.E.) program. A combination of the requirements of this *Bulletin* and a previous one will be permitted only with the permission of the Chief Program Advisor.

3. Transfer students who begin their program in fall 1996 and who have completed a course similar to EECS 216 (as described in previous *Bulletins*) at another university will be given transfer credit for that course. The policies in item 2 (above) apply. Those who have not completed a course similar to EECS 216 must satisfy the requirements described in this *Bulletin*.

   Transfer students who begin their program in winter 1997 or later must satisfy the degree requirements described in this *Bulletin*. Those who have completed a course similar to EECS 210 or EECS 216 (as described in previous *Bulletins*) at another university will be given transfer credit for that course and will proceed to EECS 211.

4. Significant changes to some program subjects are planned. It is anticipated that such changes will be made by the time these courses are needed by students who begin their B.S.E. (E.E.) program with EECS 210 in fall 1996 or later. Students who are pursuing the B.S.E. (E.E.) under the requirements of a previous *Bulletin* are advised to take their program subjects during the 1996–1997 academic year, i.e., before significant changes are made.

5. Students are strongly urged to consult a program advisor for the latest details about course changes and for advice on planning the best possible program of study.
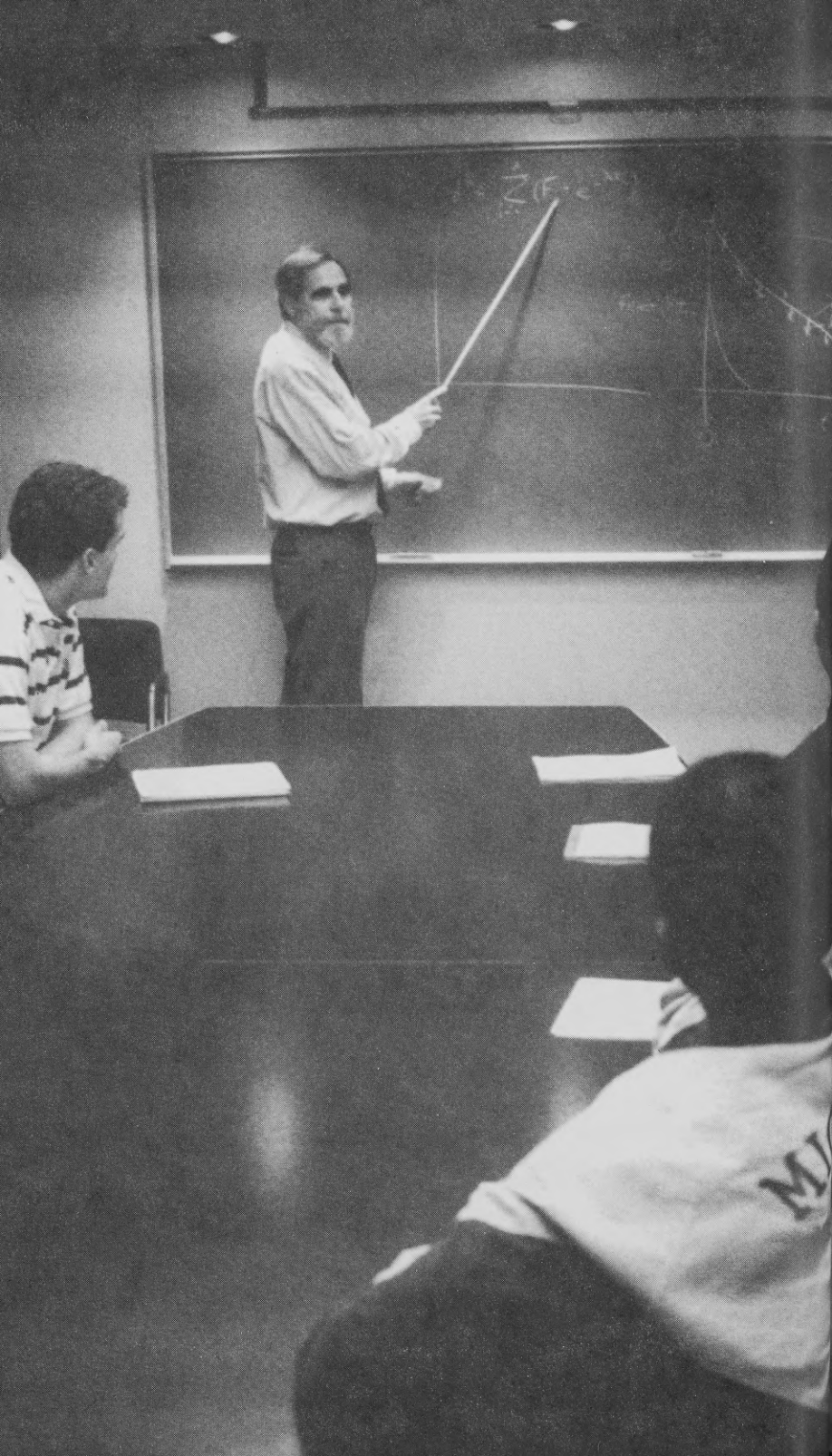
Industrial and Operations Engineering

Industrial and operations engineering is concerned with the efficiency in which work is performed by machines, people, and computers. An industrial engineer deals with the design, improvement, and installation of integrated systems drawing upon specialized skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis, for specifying, predicting, and evaluating the results to be obtained from such systems. Some integrated working systems arise in industry and manufacturing while others are found in a variety of non-industrial settings, ranging from health care and education to financial centers and government.

The wide range of tasks an industrial engineer may be called upon to perform in different settings necessitates knowledge of the five following areas: operations research, human factors, management engineering,

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manufacturing engineering, and computer and information processing.

Operations Research

Operations research is an applied science devoted to describing, understanding, and predicting the behavior of human-machine systems operating in natural environments and guiding them towards better performance. Courses in this area are designed to teach the use of mathematics in constructing models to analyze and design operational systems. The student studies known model structures and their application in real-world processes such as production, maintenance, inspection, resource allocation, distribution, and scheduling.

Professor Stephen M. Pollock of the Department of Industrial and Operations Engineering is shown teaching the final course requirement for IOE undergraduates in their senior year.

Human Factors

In the human factors area, emphasis is placed on the technical knowledge necessary to analyze and predict the performance of humans in human-machine systems. Basic courses cover the capabilities and limitations of the 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. Courses emphasize the role of people acting as individuals and as part of a group in operating systems. Theories of administration, group dynamics, and human motivation are applied to specific managerial problems in the establishment, clarification, and modification of an organization's objectives and in the design, evaluation, and improvement of human-machine systems for accomplishing these objectives.

Manufacturing Engineering

Manufacturing engineering is concerned with determining how to manufacture engineered products with minimal capital investments and operating costs in facilities safe to both workers and the environment. Students study methods for evaluating production and inventory systems, facility layout, and material handling systems and are prepared to aid in the daily operation of a manufacturing facility while evaluating operations for the future.

Computer and Information Processing

Computers and information systems are important components in most modern human-machine systems. In this area, students are introduced to the basic terminology and concepts of information system design, construction, and usage. The objective is to provide a sense of both the value and the limitations of computing capabilities. Emphasis is placed on the role of computer hardware and software systems as used in information processing and on their interface with management in helping to achieve the objectives of an organization.

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 one-half of the courses required for the B.S.E. degree consist of the common College of Engineering core requirements, comprised of studies in mathematics, basic physical

sciences, digital computing, humanities, and social sciences, along with a broad base in engineering fundamentals, specifically courses in mechanics, thermodynamics, manufacturing processes, and electronic circuits. The fundamentals required for study in industrial engineering are provided by the seven 300-level IOE courses. A solid foundation in the areas of interest described above is obtained through 12 credits of departmental IOE electives in which students select one course from four of the six areas of interest. 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 6 credits of IOE technical electives, 9 credits of non-IOE technical electives, and 8 credits of free electives. The goal of the non-IOE technical electives is to provide a background in areas related to industrial and operations engineering. This freedom of electives not only allows students to deepen their knowledge in specific areas of industrial and operations engineering but also provides the opportunity to prepare for advanced studies in other engineering disciplines, medicine, law, or business.

The IOE program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering Technology (ABET).

Engineering Global Leadership Honors Program

The EGL Honors Program is a five year, 158-hour program leading to B.S.E. I.O.E. and M.S.E. I.O.E. degrees. It seeks to educate leaders of engineering practice for the global economy of the next century. EGL combines the traditional industrial engineering core with a minor in some technology area, a core in the School of Business, and a cultural core in the College of Literature, Science, and the Arts.

The program requires two years of a foreign language. Admitted students must maintain a minimum GPA of 3.200, and at least 15 credit hours per semester. A listing of program requirements is available in the Undergraduate Program Office, 1603 IOE Building.

Facilities

As an aid to the student's education, the department has well-equipped laboratories in the following areas: human performance, industrial systems, plant flow analysis, 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.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Industrial and Operations Engineering)—B.S.E. (I.O.E.)—must complete the program listed below. *The sample schedule is an example of one leading to graduation in eight terms.*

Required Programs

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro Composition	4	4	-	-	-	-	-	-	-
Engineering 104, Computing	3	3	-	-	-	-	-	-	-
*Chemistry 130	3	3	-	-	-	-	-	-	-
*Chemistry 125	2	-	2	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241	8	-	4	4	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication 498	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	3	3	-	3	4	-	-	4
Related Technical Subjects (13 hrs.)									
ME 211, Intro to Solid Mech	4	-	-	-	4	-	-	-	-
ME 235, Thermodynamics I	3	-	-	-	-	3	-	-	-
MSE 250, Prin of Engr Materials	3	-	-	-	3	-	-	-	-
EECS 314, Circuit Analysis and Electronics	3	-	-	-	-	-	-	3	-
Program Subjects (36 hrs.)									
IOE 301, Indust and Oper Mgmt	3	-	-	3	-	-	-	-	-
IOE 310, Intro to Optim Methods	3	-	-	-	-	3	-	-	-
IOE 315, Stochastic Industrial Proc	3	-	-	-	3	-	-	-	-
IOE 333, Ergonomics	3	-	-	3	-	-	-	-	-
IOE 334, Ergonomics Lab	1	-	-	1	-	-	-	-	-
IOE 365, Engineering Statistics	4	-	-	-	-	4	-	-	-
IOE 373, Data Processing	4	-	-	-	-	-	4	-	-
IOE Senior Design Course (see note next page)	3	-	-	-	-	-	-	-	3
IOE Electives (12 hrs., see note next page)	12	-	-	-	-	3	3	6	-
Technical Electives (15 hrs.)									
(6 hrs. must be IOE)	6	-	-	-	-	-	-	3	3
(9 hrs. must be non-IOE)	9	-	-	-	-	-	6	-	3
Free Electives (8 hrs.)	8	-	3	-	-	-	2	3	-
Total	**128**	**17**	**16**	**15**	**17**	**17**	**15**	**15**	**16**

Sample Schedule by Term

*Chem 210 (4 hrs) and Chem 211 (1 hr) may be substituted for Chem 130 and
Chem 125.
Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141;
240, 241 will count for 10 total credits, 2 of which will be applied according to
individual program directives.

Note on Departmental IOE Electives

Within the 12-hour elective requirement, the student must elect one course from four of
the following six IOE core groups shown below:

1. IOE 441 (Production and Inventory Control)
    IOE 447 (Facility Planning)
    IOE 449 (Material Handling Systems)

2. IOE 465 (Design and Analysis of Industrial Experiments)
    IOE 466 (Statistical Quality Control)

3. IOE 473 (Information Processing Systems)
    IOE 474 (Simulation)
    IOE 484 (Database Management Systems)

4. IOE 436 (Human Factors in Computer Systems)
    IOE 439 (Safety Management)
    IOE 463 (Work Measurement and Prediction)

5. IOE 416 (Queueing Systems)
    IOE 460 (Decision Analysis)

6. IOE 421 (Work Organizations)
    IOE 425 (Manufacturing Strategies)
    IOE 451 (Engineering Economy)
    IOE 452 (Capital Budgeting and Financial Engineering)

Note on IOE Senior Design Requirement

During the senior year, each student must elect one of the following design courses:

1. IOE 424 (Practicum in Production and Service Systems)
2. IOE 481 (Practicum in Hospital Systems)
3. IOE 499 (Senior Design Projects)
4. Other IOE courses satisfying the design requirement, if approved by the
    undergraduate program advisor and with the consent of the course instructor.
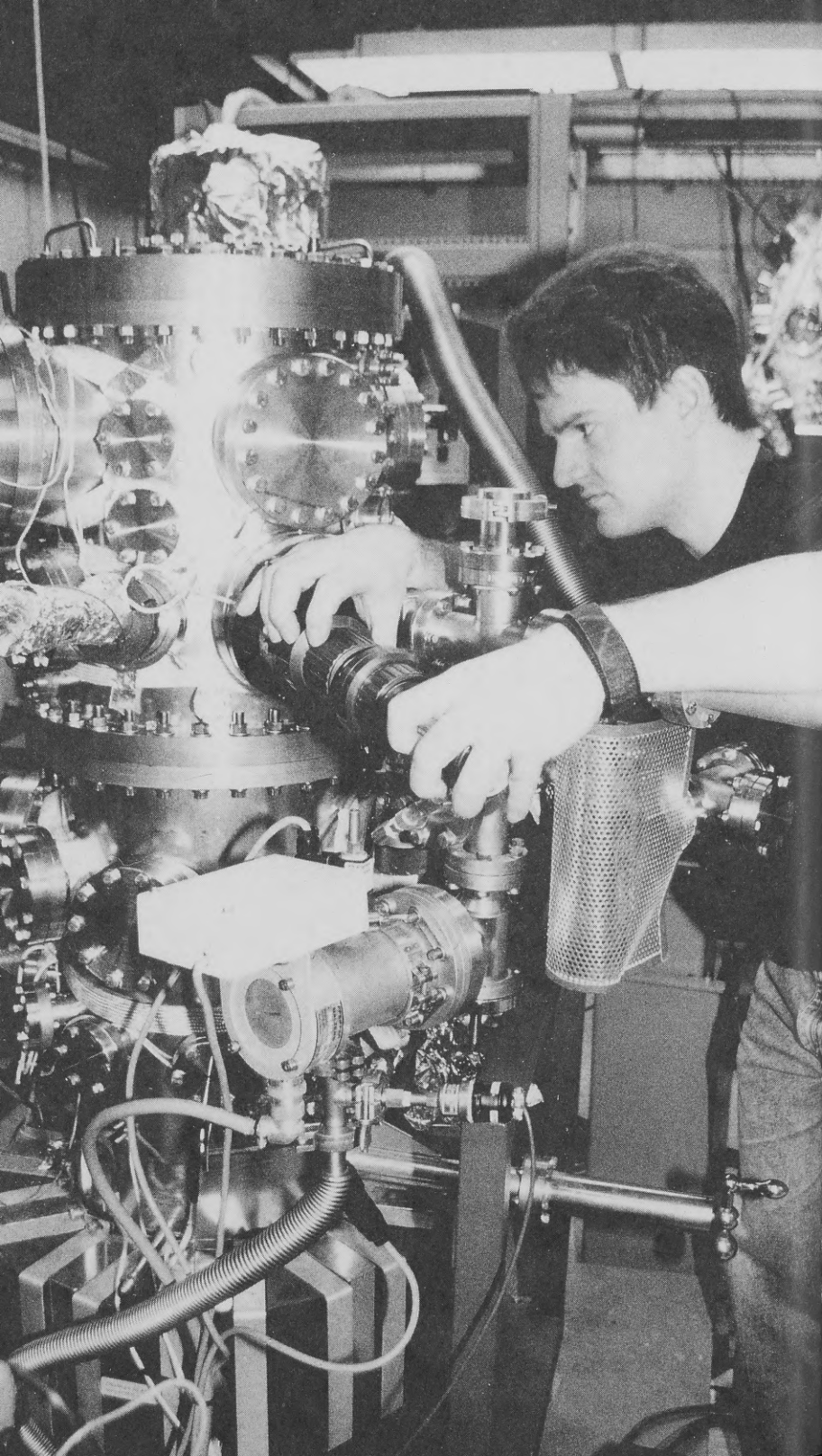
Materials Science and Engineering

Materials science and engineering is widely recognized as one of the most promising technical fields of the '90s and beyond.

Materials scientists and engineers specialize in the characterization, development, production, and use of the metallic, ceramic, polymeric, and electronic materials that are employed in all fields of technology.

Engineering materials have been crucial to the development of civilization since the dawn of history as evidenced by the identification of the Stone Age, the Bronze Age, and the Iron Age with the most advanced materials then available for constructing tools and weapons. More recently, materials scientists and engineers have developed a variety of important materials to meet the needs of our modern technological society, including high temperature superconductors; ultra-high-purity semiconductor materials for solid state electronic devices; high-strength alloys for use at

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**Professor
William F. Hosford**
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the extreme temperatures encountered in jet and rocket engines; strong, light alloys 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 we are facing a crucial energy shortage and there is great public concern about waste disposal problems. To conserve our dwindling natural resources and to protect our natural environment, methods

MSE graduate student Oleh Karpenko manipulates a sample from the surface analysis system to the ultra-high vacuum scanning tunneling micrscope. (Photo: Judy Hyde)

must be developed for recycling many materials that are now discarded. New materials will be needed to replace current materials that are being depleted. In addition, new and better materials will be required to meet the needs of our advancing technology. New processing methods are often needed to manufacture products made of these new materials. Materials scientists and engineers of the future will continue to be at the forefront of all of these important and challenging activities.

In addition to these newly developing fields, materials scientists and engineers are in constant demand for a number of more traditional, but equally important and rewarding activities. These include processing basic materials into forms suitable for use in various manufacturing processes; managing manufacturing processes that critically involve the manipulation of materials properties; modifying existing materials and the development of new materials to meet advanced design requirements; 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. The tremendous range of materials science and engineering opportunities apply equally in metals, polymers, ceramics and electronic materials. Applications range from the manufacture of basic tools and machines to the development of high-temperature superconductors and components of space probes.

The program in materials science and engineering at the University of Michigan has been carefully designed to prepare students for all the types of activities described above, or for continuing their academic work to acquire a masters or doctoral degree. A foundation in principles relating to all classes of materials

is provided by two courses (MSE 250 and MSE 350) that are normally taken in the fourth and fifth terms; however, students who enter with an interest in materials can take a special course (MSE 150) in their second term to get an earlier start on their professional course work. A broad base in engineering fundamentals is provided by required courses in mechanics, electronic circuits, physical chemistry, thermodynamics, and transport phenomena. Two senior design courses ensure a high level of professional competence.

Two required laboratory courses give our students a working knowledge of equipment 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.

To give students an opportunity to tailor their courses to meet individual interests, the program provides 5 credits of free electives, 11 credits of electives in engineering, science and technical subjects, and 6 credits of electives in advanced program subjects. The program also provides a choice among three senior level courses that are devoted to specific types of materials and three that deal with different phenomenological topics.

This unusual elective freedom allows students to take materials-oriented courses in other departments such as chemical, electrical, and mechanical engineering, and also facilitates obtaining a second degree in these departments.

Materials science and engineering students are required to take at least one course in economics due to the importance of this subject. They are also urged to select other humanities and social sciences courses to obtain a sound basis for the future enjoyment of, and participation in, the cultural, political, economic, and social aspects of modern society.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Combined Degrees

Materials are critically involved in most fields of engineering; therefore, it is often 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, and aerospace engineering. As early as possible, students interested in combined degree programs
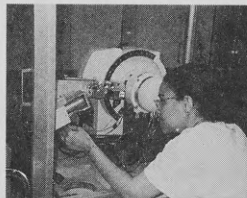
should consult with the program advisors in both programs to work out optimum combinations of courses.

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 corrosion and electrochemical processes, 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.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Materials Science and Engineering)—B.S.E. (Matl. Sci. & E.)—must complete the program listed at the right. *The sample schedule is an example of one leading to graduation in eight terms.*

Notes for Required Programs Sample Schedule

*Eng 103 (3 hrs), Eng 104 (3 hrs), Eng 106 (4 hrs), or Eng 107 (4 hrs) acceptable; Eng 106 or Eng 107 preferred, 1 hour counting as free-elective credit

**Chem 210 is required for the MSE Program. It may be taken either to fulfill the common engineering requirement or as a science and technical elective.

Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (58 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125 or equivalent, Intro Composition	4	4	-	-	-	-	-	-	-
*Computing	3	3	-	-	-	-	-	-	-
**Chemistry 130 and 125 or 210 and 211	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241	10	-	5	5	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Science, including									
Economics (see pages 63, 67)	17	-	3	3	3	-	4	-	4
Free Electives (5 hrs.)	5	-	3	-	-	-	2	-	-
Science and Technical Subjects (25 hrs.)									
Physics 242	3	-	-	-	3	-	-	-	-
ME 211, Intro to Solid Mechanics	4	-	-	-	4	-	-	-	-
MSE 250, Prin of Eng Materials	3	-	-	-	3	-	-	-	-
EECS 314, Cct Analys and Electronics	3	-	-	-	-	3	-	-	-
EECS 315, Cct Analys and Electronics Lab	1	-	-	-	-	1	-	-	-
*Science and Technical Electives	11	-	-	4	-	4	-	-	3
Program Subjects (40 hrs.)									
MSE 350, Prin of Eng Matls II	4	-	-	-	-	4	-	-	-
MSE 356, Matls Lab I	2	-	-	-	-	2	-	-	-
MSE 430, Thermodynmics of Matls	4	-	-	-	-	-	-	4	-
MSE 435, Transport Phenomena	4	-	-	-	-	-	4	-	-
MSE 456, Matls Lab II	2	-	-	-	-	-	2	-	-
MSE 480, Matls Eng Design	3	-	-	-	-	-	-	3	-
MSE 489, Matls Process Design	3	-	-	-	-	-	-	-	3
Elect 2 of the following 3 courses:	6	-	-	-	-	3	-	3	-
MSE 400, Elec, Mag and Opt Prop of Matls (3)									
MSE 420, Mech Behavior of Materials (3)									
MSE 460, X-ray Methods and Crystallography (3)									
Elect 2 of the following 3 courses:	6	-	-	-	-	-	3	-	3
MSE 412, Polymeric Matls (3)									
MSE 440, Ceramic Matls (3)									
MSE 470, Physical Metallurgy (3)									
Electives in Program Subjects (6)	6	-	-	-	-	-	-	3	3
Total	**128**	**16**	**15**	**16**	**17**	**17**	**15**	**16**	**16**

Mechanical Engineering and Applied Mechanics

The scope of mechanical engineering includes all aspects of the mechanics of equipment and processes used in the rapidly developing technical era in which we live. Mechanical engineers play a major role in the national space program, in energy utilization and conservation, in solar energy, in the design of both conventional and nuclear power plants, in heating, air conditioning, and refrigeration, in the transportation and automotive fields, and in the fields of automation, fluid machinery, production and processing machinery including the petroleum and chemical fields, and consumer goods and appliances.

Mechanical engineers have responsibility for research, design, development, testing, control, and manufacture in these many and diverse fields. Many mechanical engineering graduates assume positions of management, while others

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prefer a career along technical lines.

Because a mechanical engineer might work in any one of these fields, the academic program has been planned to offer a challenging and basic education. It is designed to provide a knowledge of the basic physical sciences, and to encourage the development of ingenuity for the purpose of creating well-engineered solutions to technological problems.

A basic science program in physics, chemistry, and

Students spend many hours in the MEAM student machine shops preparing their final projects for the ME 450 Design Expo. The metal lathe is one of the many machine tools that ME students must learn to use to complete their studies.
(Photo: Sandy Ackerman/MEAM Communications)

mathematics, an engineering science program in thermodynamics, fluid mechanics, heat transfer, solid mechanics, dynamics, materials, and electronics integrated with laboratory experiences in measurement, and studies in design and manufacturing, will prepare the student equally well for any of the fields of application. The program includes a number of technical and non-technical electives that permit the student to undertake further studies in an area of particular interest. Technical electives may be grouped under one of three specialized technical option areas— Energy and Power, Materials and Manufacturing, or System and Design—or may be a mixture of these areas.

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 Office of the Department of Mechanical Engineering and Applied Mechanics.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Facilities

The laboratories of the Department of Mechanical Engineering and Applied Mechanics, located in the George Granger Brown Laboratories and Walter E. Lay Automotive Laboratory buildings on the North Campus, provide facilities for both instruction and research.

The George Granger Brown Laboratories Building contains the thermodynamics, heat transfer, and fluid mechanics laboratories; a drop-tower for zero-g heat transfer studies and a large centrifuge for high-g investigations; a two-phase flow loop; holographic measurements laboratory; and thermal systems research. Also located in this building are the biomechanics laboratory; robotics 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, friction and wear, 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, as well as a number of single cylinder engines.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Mechanical Engineering)—B.S.E. (M.E.)—must complete the program listed on the following pages. *The sample schedule is an example of one leading to graduation in eight terms.*

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (58 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
+Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125,	4	4	-	-	-	-	-	-	-
Engineering 103 or 104, Computing	3	-	3	-	-	-	-	-	-
Chemistry 130 and 125	5	5	-	-	-	-	-	-	-
+Physics 140 with Lab 141; 240 with Lab 240	10	-	5	5	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Sciences	17	3	4	-	-	3	3	-	4
(to include one course in micro or macro economics) (see pages 63, 67)									
Advanced Mathematics (3 hrs.) (Note 1)									
Elective	3	-	-	-	-	3	-	-	-
Related Technical Subjects (6 hrs.)									
+MSE 250, Princ of Eng Materials	3	-	-	-	3	-	-	-	-
EECS 314, Cct Anal and Electronics	3	-	-	-	-	3	-	-	-
Program Subjects (41 hrs.)									
+ME 211, Intro to Solid Mechanics	4	-	-	4	-	-	-	-	-
+ME 235, Thermodynamics	3	-	-	-	3	-	-	-	-
+ME 240, Intro to Dynamics	3	-	-	-	3	-	-	-	-
+ME 250, Intro to Design and Manufacturing	4	-	-	4	-	-	-	-	-
+ME 281, Mech Behav of Eng Mtls	3	-	-	-	-	3	-	-	-
+ME 320, Fluid Mech I	3	-	-	-	-	-	3	-	-
+ME 350, Mech Design I	4	-	-	-	-	-	4	-	-
+ME 360, Model, Anal, and Cntrl of Dynam Sys	4	-	-	-	-	4	-	-	-
ME 370, Heat Transfer	3	-	-	-	-	-	3	-	-
ME 395, Thermal-Fluids Lab	3	-	-	-	-	-	-	-	3
ME 396, Mechanical Sciences Lab	3	-	-	-	-	-	3	-	-
ME 450, Mech Design II	4	-	-	-	-	-	-	4	-
Technical Electives (15 hrs.)									
(See opposite page for courses within specific areas of interest.)	15	-	-	-	-	-	-	6	9
Free Electives (5 hrs.)	5	-	-	-	2	-	-	3	-
Total	**128**	**16**	**16**	**17**	**15**	**16**	**16**	**16**	**16**

"D+" rule: Students must earn a "C-" or better in prerequisite courses indicated by the (+) symbol; anything less must be repeated.

"D-" rule: no grade less than "D "shall be earned in any course used for degree credit.

Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

Technical Electives (15 hours)

Program Advisor:

Professor William W. Schultz

Associate Advisors:

V. Arpaci, J. Holmes, B. Karnopp, N. Kikuchi, H. Merte, and R. Sonntag

The 15 hours of pertinent technical subjects (300 level courses) are listed by area of interest solely for convenience. While it is encouraged, students are not required to select courses within a specific concentration. **(Note 2)**

Energy and Power Concentration

ME 336, 420, 432, 435, 436, 438, 458, 471, 490, 491

Materials/Manufacturing Concentration

ME 311, 381, 401, 402, 412, 451, 452, 456, 476, 482, 487, 490, 491

Systems/Design Concentration

ME 305, 311, 381, 412, 441, 442, 443, 451, 452, 454 or Aero 484 , 458, 461, 463, 467, 490, 491

Note 1: A mathematics course (other than Math 216) that requires at least Math 215 as a prerequisite should be elected within two terms of completing Math 216. See department for a listing of appropriate courses.

Note 2: Pertinent technical subjects (Concentration Courses) begin at the 300 level. These courses will be revised from time-to-time. See department for most current information. There is a limitation of 6 credit hours outside of Mechanical Engineering for Technical Electives courses.

Note 3: Mechanical Engineering supports several dual and multiple dependent degree programs such as, Aerospace Engineering and Mechanical Engineering; Literature, Science and the Arts and Mechanical Engineering; Industrial Design and Mechanical Engineering. Students may obtain a handout from the department on these established programs.
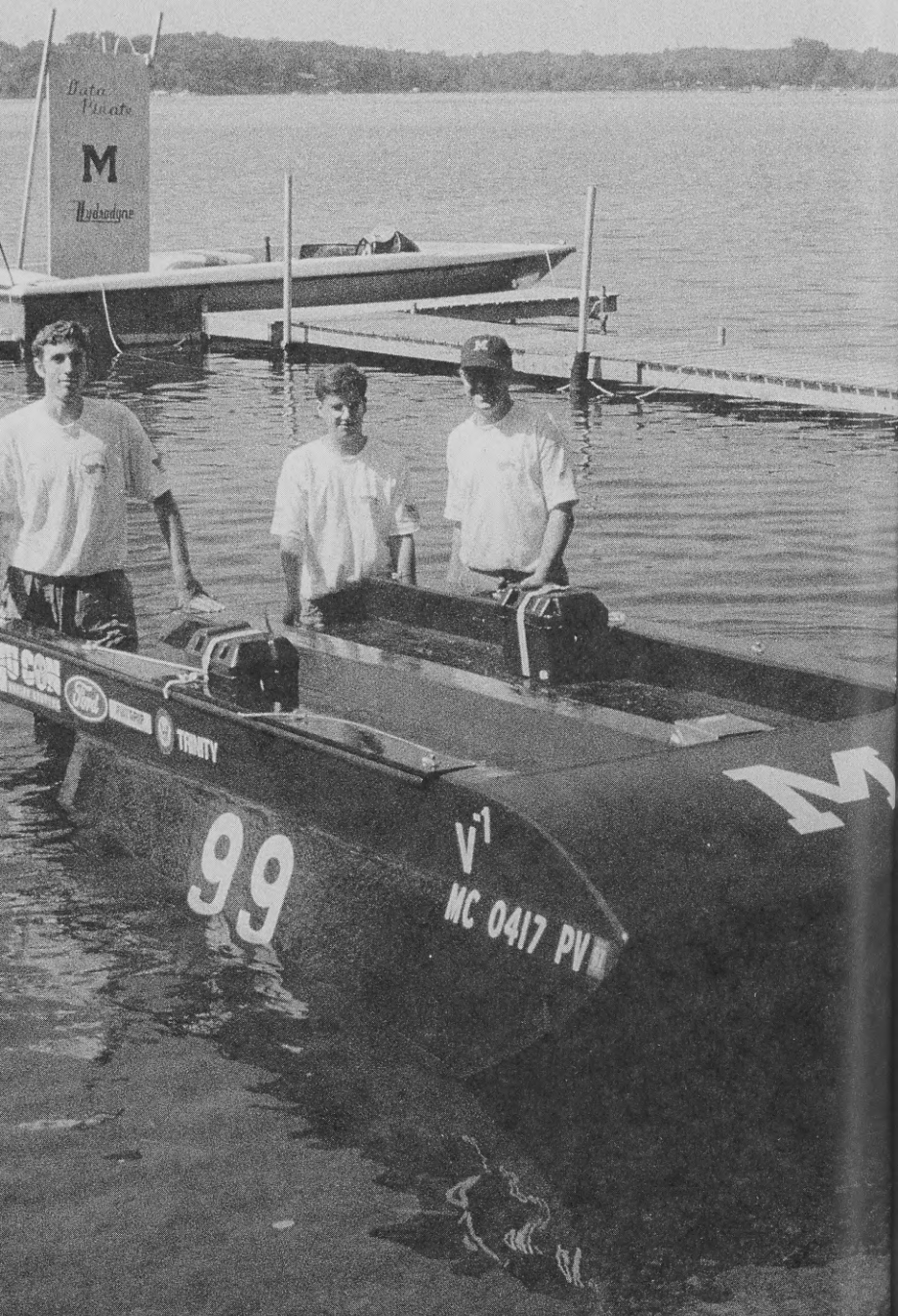
Naval Architecture and Marine Engineering

More than 70 percent of our planet is covered by water. The exciting field of marine engineering covers the design of all types of systems to operate successfully in this harsh and demanding environment. In addition to traditional naval architecture and marine engineering, the department offers courses in offshore engineering, coastal engineering, and marine environmental engineering. Recent graduates are active in design and research related to giant offshore oil and gas exploration and production platforms. Others are involved in water-borne pollution transport in the Great Lakes and the oceans, and coastal erosion predictions, as well as traditional ships, submersibles, high-speed vessels and recreational craft. A number of our alumni have leading roles in the design process for 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

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professional responsibilities. Therefore, the program includes training 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; graduate work is therefore often encouraged.

Ship and offshore structure design requires a knowledge of hull geometry, vessel

The University of Michigan team won technical achievement first place in the mechanical division of the 1994 Solar-Electric Boat Regatta. (Photo: Bob Kalmbach)

arrangements, hydrostatic stability, structures, resistance, propulsion, maneuvering, and seakeeping. Other areas of concern are the economic aspects of ship design and operation, ship production, ship model testing, maneuvering and other control considerations, propeller 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 building of marine vehicles and systems. Courses in marine strength deal with the design and analysis of marine structures including static strength, fatigue, dynamic response, safety, and producibility. 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, the rigid body responses of the vessel to wind and waves, and the

dynamics of subsurface vessels. An integration of all this material 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 Whitbread Around the World racing yacht, high-speed ferry boats, a fishing trawler, a LASH ship, a high-speed LPG carrier, a large cruise ship, a small deep-submergence submarine, 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 must be 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 department, 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. (See "Undergraduate Degree Programs" in this *Bulletin* for requirements and restrictions.)

The department operates the Marine Hydrodynamics Laboratory (MHL) located on Central Campus. The laboratory houses a 110 x 6.7 x 3.2 meter towing tank, a low turbulence-free surface water channel, a gravity-capillary water wave facility, a 35 meter-long gravity wave tank, and a propeller tunnel for student use. The laboratory is equipped with appropriate shops and state-of-the-art instrumentation, much of which was developed in-house. Undergraduate students are required to take at least one laboratory course that uses the model basin. The MHL also hires students on a part-time basis to help with ongoing research.

In addition to the MHL, the department also has an Ocean Engineering Laboratory and a Computer Aided Marine Design Laboratory. The Ocean Engineering Laboratory (OEL) is involved in full-scale field measurements such as beach erosion measurements, measurements of thermal fronts and pollution transport on the Great Lakes, and active remote sensing of the ocean surface from satellites and aircraft. In addition, the OEL is the home of the University's new under-water Remote Operated Vehicle (ROV), the M-ROVER. M-ROVER is used for submerged vehicle/dynamics studies in the undergraduate curriculum and for exploration and research of the Great Lakes. The Computer Aided Marine Design Laboratory is equipped with several types of high-end graphics work stations in order to develop computer aided design tools and scientific visualization techniques. Both facilities are used for teaching and student and faculty research.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Dual Degrees

For students with special interests, combined 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, materials science 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.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Naval Architecture and Marine Engineering)— B.S.E. (Nav. Arch. & Mar. E.)— must complete the program listed at the right. *The sample schedule is an example of one leading to graduation in eight terms.*

Notes for Required Programs Sample Schedule

*Eng 103 (3 hrs), Eng 104 (3 hrs), Eng 106 (4 hrs), or Eng 107 (4 hrs) acceptable; Eng 106 or Eng 107 preferred, 1 hour counting as free-elective credit.

Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, College Writing	4	4	-	-	-	-	-	-	-
*Computing	3	3	-	-	-	-	-	-	-
Chemistry 130 and 125 or 210 and 211	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241	8	-	4	4	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences (see pages 63, 67)	17	-	6	-	3	-	-	4	4
Advanced Mathematics (3 hrs.)									
Mathematics 350	3	-	-	-	-	3	-	-	-
Related Technical Subjects (16 hrs.)									
MSE 250, Prin of Eng Materials	3	-	3	-	-	-	-	-	-
ME 211, Intro to Solid Mechanics	4	-	-	4	-	-	-	-	-
ME 240, Intro to Dynamics	3	-	-	-	3	-	-	-	-
ME 235, Thermodynamics I	3	-	-	-	3	-	-	-	-
EECS 314, Cct Analy and Electronics	3	-	-	-	-	-	3	-	-
Program Subjects (38 hrs.)									
NA 270, Marine Design	3	-	-	3	-	-	-	-	-
NA 275, 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 330, Marine Power Systems I	4	-	-	-	-	4	-	-	-
NA 340, Marine Dynamics I	4	-	-	-	-	-	4	-	-
NA 391, Marine Lab	3	-	-	-	-	-	3	-	-
NA 470, Ship Design or NA 471, Offshore Eng Design	3	-	-	-	-	-	-	3	-
NA 475, Design Project	3	-	-	-	-	-	-	-	3
NA 481, Probal Meth in Marine Sys	3	-	-	-	-	-	-	3	-
Technical Electives (9 hrs.)									
These must include at least two of the second courses in the four areas of concentration— NA 410, Marine Struc II; NA 425, Envir Ocean Dynamics; NA 430, Mar Power Systems II; or NA 440, Mar Dynamics II	6	-	-	-	-	-	-	3	3
Another Technical Elective	3	-	-	-	-	-	-	-	3
Free Electives (6 hrs.)	6	-	-	-	-	-	3	3	-
Total	**128**	**16**	**17**	**15**	**16**	**15**	**17**	**16**	**16**

Nuclear Engineering and Radiological Sciences

Unlike most other engineering disciplines, with roots that go back hundreds or even thousands of years, nuclear engineering has its foundation in twentieth century discoveries. The nucleus of all matter contains a vast potential, for good and ill, that requires manipulation of events occurring on tiny scales of length and over tremendous ranges of energies which do not typically occur in the other branches of engineering; hence the existence of a separate engineering discipline. And while nuclear engineering is founded on the properties of the nucleus, it goes beyond that origin to touch on the use of high-energy fundamental particles whatever their source and technological purpose.

Nuclear engineering practice is concerned with a broad range of activities touching on a number of other fields of human endeavor. Nuclear processes and radiation are used in manufacturing technology, household products,

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power generation, food preparation, medicine, and in other areas as well.

The most visible application is certainly nuclear-electric power, which provides almost 20% of the electric power in the United States, and much larger fractions in countries such as France and Japan. The effective use of nuclear processes for large-scale power generation requires careful attention to questions of safety and economics. The nuclear engineer, when maintaining existing nuclear power facilities and when designing new ones, must consider

NERS student Adam Airhart and Visiting Professor Yuni Dewaraja read the position of the control rod on the nuclear reactor in the Nuclear Reactor Laboratory. (Photo: Cheri Smith)

nuclear fuel loading, control system parameters, water chemistry, materials behavior, and radiation effects on equipment and people in order to achieve an electricity production cost that is as inexpensive as possible within the constraints of safety. In the United States, the current generation of nuclear plants is now complete. Nuclear reactor vendors such as Westinghouse and General Electric are actively engaged in the design and construction of a new generation of reactors which build upon the knowledge of mistakes and accomplishments in previous reactor designs.

Nuclear power is in an enviable position relative to other large-scale power production methods: it is the first such method that produces no greenhouse gases, and the first method in which the volume of waste is sufficiently small that we can afford to prevent its release into the environment. This opportunity provides the nuclear engineer with a host of technical challenges. Other countries have pioneered techniques for extracting valuable materials from used power plant fuel and then encapsulating nuclear wastes in glass and placing the packaged waste into deep geological repositories. The ongoing analysis of this approach to waste disposal in the United States requires an understanding of the various nuclear species that need to be packaged, the effect of radiation on the packaging materials,

a knowledge of the heat transfer mechanisms, a knowledge of the chemistry of the system, and an understanding of the geology of the proposed repository. The nuclear engineer is an invaluable member of the team required to assess, develop, and advance this technology.

After nuclear power, the second most visible application of nuclear processes is in radiation medicine and medical imaging. Radioactive materials and radiation are used for medical diagnosis in a variety of ways, ranging from the now humble x-ray machine to the high technologies of NMR (nuclear magnetic resonance) imaging and PET (positron emission tomography) imaging systems. But nuclear medicine does not stop with diagnosis; fundamental particles such as electrons and neutrons are used in cancer therapy. Nuclear engineers are involved in many aspects of this work, from studying the mathematics of image reconstruction in tomographic machines, to the development of neutron sources for therapy.

The reverse side of nuclear medicine is radiation protection: the use of nuclear materials in industrial facilities and hospitals requires engineers who can design solutions to radiation protection problems. This work includes shielding of radiation sources, estimations and measurements of radiation doses, the modeling of the transport of radionuclides in the environment, and the

design of advanced radiation detection systems.

Nuclear technology is an invaluable addition to the kit of tools available to better our lives, in ways simple and complex. For instance, it has been used to power all the space probes to other planets and to manufacture non-stick cookware. It is used to study and modify materials, explore human history, generate electric power, and improve human health in preventative care, diagnosis, and treatment. This breadth of impact requires engineers with an interdisciplinary perspective, and with excellent analytical skills that are applicable in a wide range of disciplines.

The Program

In order to use the vast potential of the nucleus for the benefit of all people, nuclear engineers require a sound foundation in classical and modern physics, mathematics, basic engineering, and specialized engineering knowledge. In the Nuclear Engineering program (see the requirements below) students are required to take basic courses in mathematics, physics, general engineering, and a sequence of intermediate and advanced nuclear engineering courses to achieve the common foundation necessary for the field. In addition, students then elect 9 hours of nuclear engineering and radiological sciences electives, 9 hours of technical electives, 17 hours of Humanities and Social Sciences and 7 hours of free electives to increase both their

breadth across different areas of human thought and their depth in technical matters.

Within the Department of Nuclear Engineering and Radiological Sciences, all aspects of nuclear technology are of interest, but a few areas of concentration provide a common framework to help students achieve breadth and depth.

Fission Reactor Engineering: This area focuses on the basic analytical and computational tools and techniques for the modeling and design of nuclear reactors, and on nuclear power plant systems and safety.

Radiological Health Engineering: This area, sometimes called health physics, is the application of engineering and scientific principles to the solution of problems concerned with radiation protection involving individuals, populations, or the environment.

Radiation Measurements: The measurement of radiation is of fundamental importance to all aspects of nuclear technology. This area focuses on the fundamental physics and practical techniques whose understanding is essential to the measurement of radiation and nuclear properties.

Materials Studies: Radiation can damage materials, can be used to study materials, or can be used to tailor their properties. Materials studies within Nuclear Engineering are concerned with all three of these aspects of nuclear technology.

Plasma Physics: Plasmas and high-energy charged particle beams have a range of uses from semiconductor manufacture to compact particle accelerators. Plasma physics is also the basis for current work to harness thermonuclear fusion reactions for power production.

The B.S.E. (Nuclear Engineering) program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET).

Facilities

The Department of Nuclear Engineering and Radiological Sciences occupies the Mortimer E. Cooley Building, which contains departmental offices, a computer lab, faculty offices, classrooms, and several of the labs listed below. 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:

Ford Nuclear Reactor
Glow Discharge Laboratory
High Temperature Corrosion Laboratory
Intense Energy Beam Interaction Laboratory
Materials Preparation Laboratory
Metastable Materials Laboratory
Michigan Ion Beam Laboratory
Nuclear Data Laboratory
Radiation Detection Laboratory
Radiation Imaging Laboratory
Radiological Health Engineering Laboratory

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Notes for Required Programs Sample Schedule

*Acceptable substitutions for Eng 103 include EECS 100, Eng 104, Eng 106, and Eng 107. Credits that exceed the required 3 hours will be used as free electives.
**Math Electives must be 300 level or higher. Suggested courses are: Math 371, 404, 417, 454, 471; Eng 303, 371; CEE 303.
***Within these electives, a senior nuclear engineering capstone design course must be elected (e.g., NERS 442).
****Electives should be carefully planned in consultation with a faculty advisor so that the complete program includes the equivalent of one term (16 hours) of engineering design.
Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

Requirements

Candidates for the Bachelor of Science degree in Engineering (Nuclear Engineering)—
B.S.E. (N.E.)—must complete the program listed at the right. *The sample schedule is
an example of one leading to graduation in eight terms.*

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125 or equivalent, Intro Comp	4	4	-	-	-	-	-	-	-
*Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 130 and 125 or 210 and 211	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241	10	-	5	5	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	-	4	4	3	-	3	3	-
Advanced Mathematics and Science (7 hrs.)									
Math 450, Adv Math for Eng I	4	-	-	-	-	4	-	-	-
**Math Elective	3	-	-	-	-	-	3	-	-
Related Technical Subjects (20 hrs.)									
MSE 250, Princ of Eng Materials	3	-	-	-	-	3	-	-	-
ME 211, Intro to Solid Mech	4	-	-	4	-	-	-	-	-
ME 235, Engr Thermodyn	3	-	-	-	3	-	-	-	-
ME 240, Intro to Dynamics	3	-	3	-	-	-	-	-	-
EECS 314, Cct Analy and Electronics	3	-	-	-	-	3	-	-	-
EECS 315, Cct Analy and Electronics Lab	1	-	-	-	-	1	-	-	-
CEE 325, Fluid Mechanics	3	-	-	-	-	3	-	-	-
Program Subjects (29 hrs.)									
NERS 211, Intr to Nuclear Eng and Rad Sci	3	-	-	-	3	-	-	-	-
NERS 311, Elements of Nuclear Eng I	3	-	-	-	-	3	-	-	-
NERS 312, Elements of Nuclear Eng II	3	-	-	-	-	-	3	-	-
NERS 315, Nuclear Instr Lab	4	-	-	-	-	-	4	-	-
NERS 441, Fiss Reactors and Power Plants I	4	-	-	-	-	-	-	4	-
***NERS Electives	9	-	-	-	-	-	-	3	6
NERS Laboratory (above NERS 315)	3	-	-	-	-	-	-	-	3
****Technical Electives (9 hrs.)	9	-	-	-	3	-	-	3	3
Free Electives (7 hrs.)	7	-	1	-	-	-	3	3	-
Total	**128**	**16**	**17**	**17**	**16**	**17**	**16**	**16**	**15**

Engineering Physics

Physics is a traditional, integral part of the engineering curriculum. However, in many areas of engineering the sophistication of a particular field, coupled with the tremendous rate of technological advances, has created a need for engineers with stronger backgrounds in physics — people who can work in an engineering environment and who are capable of applying advanced physics concepts to their jobs. For example, the development of the computer closely followed the invention of the transistor and is representative of a considerable number of recently discovered physical phenomena (lasers, nuclear reactors, particle accelerators, etc.) that have been successfully applied and utilized by engineers.

There is also a need to accommodate those students who wish to attend graduate school but who have not decided on a particular field of specialization. An advanced physics and mathematics background, coupled with an engineering curriculum, is excellent preparation for many graduate engineering

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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 must take in a narrow field of engineering design and analysis. 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/nuclear

Teaching Assistant Rami Kishek demonstrates a radio-frequency plasma to NERS 575 student Shefali Kaul. (Photo: Cheri Smith)

fusion, computational methods, optics, and radiological health, to name a few. This permits the student a high degree of flexibility yet provides an opportunity for specialization in a field of the student's interest.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree in Engineering (Engineering Physics)— B.S.E. (Eng. Physics)—must complete the program listed to the right. *The sample schedule is an example of one leading to graduation in eight terms.*

Required Programs

Sample Schedule by Term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125 or equiv, Intro Comp	4	4	-	-	-	-	-	-	-
*Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 130 and 125 or 210 and 211	5	3	2	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241	10	-	5	5	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Sciences	17	3	3	3	4	-	4	-	-
Advanced Mathematics (6 hrs.)									
Mathematics Electives	6	-	-	-	-	3	-	3	-
Related Technical Subjects (16 hrs.)									
MSE 250, Princ of Eng Materials	3	-	3	-	-	-	-	-	-
ME 211, Intro to Solid Mech	4	-	-	4	-	-	-	-	-
ME 320, Fluid Mech	3	-	-	-	-	-	3	-	-
ME 370, Heat Transfer	3	-	-	-	-	-	-	-	3
EECS 314, Cct Analy and Electr	3	-	-	-	3	-	-	-	-
Program Subjects (17 hrs.)									
Physics 242, Gen Phys III	3	-	-	-	3	-	-	-	-
Physics 401, Int Mech	3	-	-	-	-	3	-	-	-
Physics 405, Int Elect and Mag	3	-	-	-	-	-	3	-	-
Physics 406, Stat and Thermal Phys	3	-	-	-	-	3	-	-	-
Physics 453, Quantum Mechanics	3	-	-	-	-	-	-	3	-
Physics Lab Elective or Directed Study with	2	-	-	-	-	-	-	-	2
Research Lab Component									
Program Electives (30 hrs.)									
**Engineering Electives	15	-	-	-	-	7	4	-	4
**Engineering Technical Electives	12	-	-	-	-	-	-	6	6
**Laboratory Elective (400 level)	3	-	-	-	-	-	3	-	-
Free Electives (3 hrs.)	3	-	-	1	2	-	-	-	-
Total	**128**	**17**	**17**	**17**	**16**	**16**	**17**	**15**	**15**

Notes:

*Acceptable substitutions for Eng 103 include EECS 100, Eng 104, Eng 106, and Eng 107. Credits that exceed the required 3 hours will be used as free electives.

**The engineering and technical requirements 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 faculty advisors.

Physics Note: In Academic Years 1995–96 and 1996–97 only, Physics 140, 141; 240, 241 will count for 10 total credits, 2 of which will be applied according to individual program directives.

Interdisciplinary Undergraduate Degree Program

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.

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The program, however, is suited only for those students who have clearly defined career goals. Because the degree is undesignated (i.e., non-departmental), the program does not automatically provide the routine and typical 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 solid engineering background for either an engineering career or a graduate program in engineering should consider a departmental B.S.E. program.

Interdisciplinary Areas

Students with interdisciplinary goals devise a program option based on the course offerings of two or three engineering departments, if the goals of such programs cannot be attained by pursuing one of the departmental B.S.E. degrees. These programs will 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 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.

Students also 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.

Program Design

Each student is asked to define his or her own educational goals and to design a program with the advice of one of the program advisors. 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.

For information regarding Combined and/or Dual Degrees see page 54 in "Undergraduate Degree Programs." For information regarding the Simultaneous Graduate/Undergraduate Study (SGUS) program, see page 167 in "Graduate Studies."

Requirements

Candidates for the Bachelor of Science degree (Engineering)—B.S. (Engineering)—must complete the program listed at the right. *The sample schedule is an example of one leading to graduation in eight terms.*

Required Programs

Sample Schedule by term

	Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 59, for alternatives.)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125 or equiv, Intro Comp	4	4	-	-	-		-	-	-
*Computing	3	3	-	-	-	-	-	-	-
Chemistry 130 and 125, or 210 and 211	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 241	8	-	4	4	-	-	-	-	-
(See Physics Note below)									
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	-	2	3	3	3	3	3	-
***Engineering Science (18-20 hrs.)**	18-20	-	-	3	6	6	3	-	-
Program Subjects (40-42 hrs.)									
***Engineering Concentration	20-22	-	-	-	3	4	6	6	3
****Program Option Courses	20	-	-	3	-	3	4	4	6
Free Electives (12 hrs.)	12	-	6	-	-	-	-	3	3
Total	**128**	**16**	**16**	**17**	**16**	**16**	**16**	**16**	**15**

*Eng 103 (3 hrs), Eng 104 (3 hrs), Eng 106 (4 hrs), Eng 107 (4 hrs) are acceptable.

**See guidelines for Engineering Science courses, page 164.

***See guidelines for Engineering Concentration courses, page 163.

****See guidelines for Program Option Courses, page 162.

Note: The combined hours for Engineering Science and Engineering Concentration courses must total at least 40 hours.

Physics Note: The student will earn 5 credit hours upon completion of each Physics course. Contact your Program Advisor to determine distribution of credits in excess of those shown.

Program Option Courses

This group of courses is selected by students to provide a unified program of study oriented to their 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 an engineering department is a viable pre-law alternative.

Pre-Medicine

Students choose this option to become physicians or to go into biomedical research where they can use their technical training. However, a chemical engineering degree is also an appropriate pre-medical degree.

Pre-Bioengineering

Students choose this option to prepare for a graduate program in bioengineering, a field related to medical research in which analytical methods are 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

Some students combine business courses with engineering courses to prepare for a career in business. Some students earn an M.B.A. (Master of Business Administration) 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 among technical communication programs in the United States because its graduates combine engineering skills with communication skills. It is good preparation for a graduate program in technical communication, such as the College of Engineering's M.S. in Technical Information Design Management (see "Graduate Studies," page 165 in this *Bulletin*).

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 this list in at least four of the six areas:

Area	Course
Electrical	EECS 210 (4) or EECS 314 (3) and EECS 315 (1), EECS 331 (4)
Materials	MSE 150 (4) or MSE 250 (3), ME 281 (3)
Mechanics	ME 211 (4), ME 240 (3), Aero 314 (3), ME 320 (3)
Nuclear	NERS 311 (3), NERS 312 (3)
Systems	IOE 310 (3) or CEE 405 (3), IOE 315 (3), IOE 373 (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.

A Unique Feature: Educational Goals Statement

For the Interdisciplinary Engineering program, students are asked to write out 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.

Graduate
Studies

Graduate Studies

Upon completion of their baccalaureate, many students find continued study for at least one additional year a decided advantage. It offers an attractive opportunity to pursue their special interests and to acquire a more thorough preparation for their first employment. The University of Michigan has always maintained a leading position in postgraduate engineering education and provides excellent facilities in many fields.

Students who are candidates for the M.S. and M.S.E. degrees, the post-Master's Professional Engineer 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, the Master of Science degree in Technical Information Design and Management, and the Doctor of Engineering degree in Manufacturing are offered through the College of Engineering.

Anyone contemplating graduate work should consult with the program advisor or the advisory committee for the desired program.

Electing courses approved for graduate credit

Credit, not to exceed 15 hours (limited to 10 hours for a graduate student in Civil Engineering) earned with a grade of "B" or better in graduate level (400 or 500) courses while enrolled as an undergraduate with senior standing, and not used to meet bachelor's degree requirements, may be used to partially satisfy the requirements for a degree in the School of Graduate Studies. The student should consult the Graduate School for the regulation pertaining to the transfer of this pre-graduate credit.
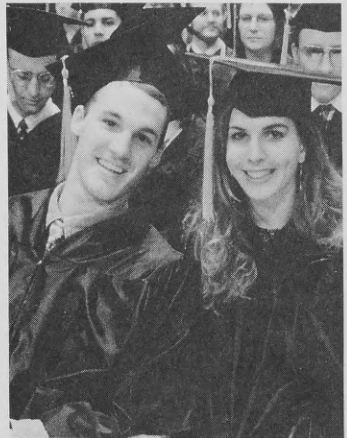
Simultaneous Graduate/Undergraduate Study (SGUS)

The master's degree is rapidly becoming the leading technical level at which engineers practice their profession. The University

of Michigan, therefore, offers a five-year Simultaneous Graduate/ Undergraduate Study (SGUS) program that permits outstanding students who enter the program in the second term of their junior 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. Students apply early in the second semester of heir junior year. Recommendation from the appropriate Under- graduate Program Advisor is required, and the standard depart- ment 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.

SGUS (Rackham)

M.S.E. in Aerospace Engineering/B.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 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 complete program information.

M.S.E. in Civil Engineering/B.S.E. in Civil and Environmental Engineering

This program permits outstanding Civil and Environmental Engineering students to receive the B.S.E. and M.S.E. degrees after completing a minimum of 149 credit hours. 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.

Please contact the Civil and Environmental Engineering department for more complete program information.

M.S.E. in Construction Engineering and Management/B.S.E. in Civil and 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. Students who do not meet the GPA requirement may petition the Civil and Environmental Engineering Graduate Committee for admission by providing additional credentials such as letters of recommen- dation from faculty or other evidence of special accomplishment.

B.S.E. and M.Eng.) degrees after completing a minimum of 149 credit hours. The student benefits from continuity of study, and the inefficiencies of transferring from an undergraduate to a graduate program are eliminated.

The program allows junior year students with a 3.1 or better GPA to apply early in the second semester of their junior year for a simultaneous graduate/undergraduate program which allows them to maximize 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.

Master's Degrees (Rackham)

Master of Science in Engineering

A candidate for the degree M.S.E.—Master of Science degree in Engineering—must meet the requirements for the degree Bachelor of Science in Engineering at the University in the student's field of specialization, or essentially the equivalent of these requirements, with sufficient evidence that the scholastic requirements of study can be met at an advanced level.

Master of Science

Qualified students who have attained an undergraduate degree in mathematics or an appropriate field of physical science are offered opportunities by the faculty of the College of Engineering in several instances to pursue their studies that will lead to an M.S. degree—Master of Science.

M.S.E. and M.S. Admission Requirements: In general, an applicant must have earned a "B" average in undergraduate work to be accepted by the School of Graduate Studies into a master's degree program. If the preparation of an otherwise acceptable candidate is not adequate, the candidate will be required to take the necessary preparatory courses without graduate credit.

M.S.E. and M.S. Degree Requirements: The requirements for a master's degree include the completion of at least 30 credit hours of graduate work approved by the advisor or advisory committee for the program elected, with an average grade of at least "B" covering all courses elected as a graduate student.

A student must satisfactorily complete a minimum of 4 hours of graduate-level course work in a department other than the department of the student's specialization, selected with the approval of the advisor.

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

A superior student who is well prepared may complete the requirements for a master's degree in two terms.

The M.S. and M.S.E. degrees offered are designated in the titles of the graduate program descriptions that follow.

M.S. in Aerospace Science and M.S.E. in Aerospace Engineering

Advisory Committee: Consult departmental office.

Because of the broad nature of study in Aerospace Engineering, a B.S.E. in any of a variety of engineering fields is suitable preparation for entrance to the M.S.E. program. Admission and setting of degree requirements are approved by the departmental graduate committee. Candidates for the M.S.E. degree will include in their program at least five courses in aerospace engineering at the 500 level or higher, excluding directed study courses, and at least two approved courses in mathematics beyond advanced calculus. Up to 4 credit hours of non-technical studies and up to 6 credit hours of directed study may be elected. The courses in aerospace engineering may be selected to emphasize one or more of the following technical areas: gas dynamics, flight dynamics and control systems, and structural mechanics.

A candidate for the M.S. degree in aerospace science must present substantially the equivalent of the four-year program in physics or mathematics at the University. The requirements for the M.S. degree are otherwise the same as the requirements for the M.S.E. degree described above.

M.S.E. in Applied Mechanics

Graduate Chair: Professor Christophe Pierre
2206 G. G. Brown Building, (313) 936-0406

A total of 30 hours of graduate study is required for the master's degree. These must include 18 hours of graduate credit in applied mechanics courses, AM 441(ME 441), AM 511(ME 511), and AM 520(ME 520), or their equivalent; and at least 6 hours from graduate courses concerned with advanced mathematics. A master's thesis, subject to departmental approval, may be substituted in place of 6 of the 12 credit hours which are not specific course requirements. Details of admissions and specific course requirements will be furnished by the department upon request.

M.S. in Atmospheric and Space Sciences and M.S. in Oceanic Science

Advisors: Professor William Kuhn and Professor Stanley Jacobs

Candidates for the M.S. in Atmospheric and Space Sciences or Oceanic Science must present the substantial equivalent of a bachelor's degree in engineering, physics, mathematics, or some other physical science. Each candidate will follow a special program arranged in conference with an advisor and may be required to make up deficiencies.

A total of 30 credit hours is required, including 15 hours of atmospheric, oceanic and space sciences, and 4 hours of mathematics, engineering, or natural science, but not in the area of specialization. A master's thesis or research essay is optional.

Thesis or Research Essay: Subject to approval of a faculty advisor, students may write a master's thesis or research essay. Satisfactory completion of the thesis or essay will account for 6 credit hours of the total 30 hours required for the master's degree. A student must register for the master's thesis or research essay under AOSS 701. A master's degree is not a prerequisite for obtaining a Ph.D. degree in atmospheric and space or oceanic sciences.

There is also an interdisciplinary M.S. program in earth geoscience and remote sensing that leads to a combined degree in electrical engineering and atmospheric, oceanic and space sciences and space and planetary physics. See separate listing.

M.S. in Atmospheric, Oceanic and Space Sciences and in Electrical Engineering—Interdisciplinary Degree Program

Co-Chairs: Professor Anthony England (EECS) and
Profesor John Vesecky (AOSS)

The EECS/AOSS Interdisciplinary Graduate Program in Geoscience and Remote Sensing leads to a combined Master of Science degree in Electrical Engineering and in Atmospheric, Oceanic and Space Sciences, or to a Doctor of Philosophy degree from the Rackham School of Graduate Studies with combined specialties in Electrical Engineering and in Atmospheric, Oceanic and Space Sciences.

Students who apply to the program choose one of three sub-fields—Electrical Engineering, Atmospheric and Space Sciences, or Physical Oceanography. Those who choose the electrical engineering sub-field will take at least 50% of their courses in the EECS department. These who choose either Atmospheric and Space Sciences or Physical Oceanography will take at least 50% of their courses in the AOSS department.

At the core of both the M.S. and the Ph.D. academic plans are four graduate level courses—one in the interactions among

atmosphere, ocean, land (AOSS 475), and three in the underpinnings of remote sensing science—EM Theory (EECS 530), Probability and Random Processes (EECS 501), and Inversion Theory (AOSS 585). In addition, each individual academic plan will include courses from the approved list of sub-specialties, or from general EECS/AOSS course offerings. Each student's academic plan is subject to program advisor approval and to the requirement that at least 50% of planned courses lie within their sub-field department.

Each M.S. student will complete an academic program of 30 credits based upon the four core courses, one math course, one directed study or thesis course, two sub-specialty courses from the student's sub-field department, and one sub-specialty course from the other department.

M.S. in Biomedical Engineering

The Department of Biomedical Engineering at the University of Michigan is a graduate program in the Rackham School of Graduate Studies granting the M.S. and Ph.D. degrees in Biomedical Engineering. The Department and the Center for Biomedical Engineering Research are jointly supported by the College of Engineering and the Medical School.

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 and the Center for Biomedical Engineering Research.

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 organic chemistry

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 asanatomy, 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 problems 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 five (5) curriculum options available:

Bioelectrical option
Biomaterials option
Biomechanics option
Biotechnology option
Rehabilitation option

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.

Directed Research and Thesis Research Opportunities

The Department of Biomedical Engineering provides a wide range of research opportunities and thereby affords students a variety of choices. The major thrust of the program is in the use of engineering analysis, science, mathematics, and instrumentation to formulate a basis for understanding or predicting the performance of living systems. The environment of the clinic and the research laboratory is particularly important to students in this program. The conception and development of new instrumentation and advanced data systems frequently moves hand in hand with research investigations.

The following are examples of the types of research efforts in which biomedical engineering are participating:

The engineering analysis of the performance of different parts of the nervous system. This work includes dynamic analysis and modeling of receptor systems, determination of skeletal muscle transfer characteristics, signal analysis of the electromyogram and of compound action potentials, and modeling of signal transmission and coding in neurons. Improved bioelectric electrodes are being developed to facilitate some of this work. Studies of neurosensory systems include the neurophysiology of the auditory and vestibular systems, the electrical biophysics of the peripheral auditory system, and detailed characterization of the electroretinogram, and quantitative studies of the somatosensory system.

The properties of biological tissues and materials used to replace and repair natural tissue are a significant consideration in many engineering analyses of biological problems. Tissue studies include the mechanical properties of bone, and the factors involved in fracture and healing of bone. Studies of artificial materials used as implants include mechanical property analysis and bio-compatibility under various conditions of material-tissue interaction. The results of these fundamental studies are being applied directly to practical problems such as traction treatment of spinal curvature, improved protection of automotive vehicle occupants, and the design of prosthetic devices such as total knee replacements.

Several research activities have as their goals the ***application of engineering principles to the solution of clinical problems***. The work may be in the form of instrumentation development to enable new measurements to be made, or in the use of systems analysis and optimization theory techniques for better diagnosis and treatment. Examples of instrument development include smaller and more responsive electrodes for blood gas measurement, a device for continuous monitoring of the degree of cervical dilation during labor, and an ultrasonic particle measuring instrument. Growth and physical development of children are being assessed more accurately through improved measuring devices and computer controlled anthropometry.

Diagnostic applications of signal processing and parameter estimation techniques include the early detection of lung disease, quantitation of the degree of arteriovenous shunting in patients with congenital hearing defects, and prediction and prevention of complications in heart attack patients. Examples of therapeutic applications of engineering systems theory are the optimization of therapy with drugs such as anticoagulants, determination of the proper timing and amount of blood transfusion or intravenous infusion, and computer control of treatment with the artificial kidney to reduce the incidence of low blood pressure reactions. These projects rely on the results of other investigations involving fundamental research on pharmacokinetics,

transport of materials across natural and artificial membranes, and the mechanisms of cardiovascular control.

The facilities available for student research include well-equipped laboratories in the 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 working in the laboratories and clinics have access to modern on-line data acquisition equipment and the flexibility of both large and small scale computational capacity. A medium scale computer system housed in the Electrical Engineering and Computer Science department is largely devoted to medical imaging problems. This machine is part of a network that links several systems in the Medical School and other campus locations.

The student's education in the laboratory or clinic of his/her choice is enhanced by seminars, clinical conferences, and informal discussion with faculty members.

M.S.E. in Chemical Engineering

Advisor: Professor Brice Carnahan
Program Office, 3074C H. H. Dow Building

The minimum requirement for the M.S.E. degree 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 a 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), Chemical Reactor Engineering (ChemE 528), Chemical Engineering Research Survey (ChemE 595), and a chemical engineering course in heat and mass transfer and a math/modeling elective. Each student is encouraged to develop a program to fit his or her professional objectives and should consult with the graduate advisor concerning a plan of study.

A student wishing to pursue a combination of the M.S.E. and B.S.E. program in the senior year should contact the undergraduate program advisor.

M.S.E. in Civil Engineering

Advisory Committee: Professors Robert I. Carr, Kevin R. Collins, Donald H. Gray, Kim F. Hayes, Victor C. Li, Steven, J. Wright (Chair)
Program Office, 2340 G. G. Brown Building

Regular admission is normally open to students holding a bachelor's degree in civil engineering or its equivalent.

However, students in other branches of engineering, physical science, or related fields may have achieved the technical background needed to pursue advanced work in a special field of civil engineering. Conditional admission may be granted to students not meeting these requirements.

Graduate study programs leading to the M.S.E. may be arranged in the following areas of specialization: construction, geotechnical, hydraulic and hydrological, materials and highway, municipal, solid waste, and structural engineering. The basic requirements to receive the M.S.E. are 30 hours of acceptable graduate credit courses, of which at least 18 hours are 500 level or above. At least 15 hours must be in civil and environmental engineering, of which no more than 9 hours can be 400 level. A student should take at least 8 hours in an area of specialization but cannot apply more than 21 hours in one area of specialization to the 30 hour requirement. Two courses of at least 2 hours each must be from outside the department, and one of these must be in mathematics, probability, statistics, or mathematical programming.

Students who do not have an undergraduate degree in civil engineering are expected to fulfill substantially all of the two-year core undergraduate engineering program. In addition, they are expected to demonstrate competence by examination or election (without graduate credit) of certain basic undergraduate civil and environmental engineering program courses or subjects, which will include at least three of the following four: Theory of Structures (CEE 312), Contracts and Engineering Legal Relationships (CEE 400), Hydraulics (CEE 421), and Engineering Properties of Soil (CEE 445).

M.S. and M.S.E. in Computer Science and Engineering

A student must satisfy both the General Master's Degree Requirements of the Rackham School of Graduate Studies, as specified in the Rackham *Bulletin,* and the College of Engineering Regulations as specified in the College of Engineering Bulletin. In addition, the student must satisfy the requirements listed below.

1. Credit hour requirements include:
   a. at least 24 credit hours in **technical coursework**
   b. at least 15 credit hours of **CSE coursework at the 500 level** or higher: Credit hours earned in other departments or universities and credit hours earned in individual study, research or seminar courses cannot be counted towards this requirement. Three hours of 599 may be counted and certain EECS 598 courses that are intended to become regular courses may be used to satisfy this requirement. (These must have prior approval.)

    c. A maximum of 6 credit hours of **individual study**, research and seminar courses (EECS 598, EECS 699 and similar courses).

2. The program requires a GPA in CSE coursework of *at least* 5.0 based on a 9.0 scale. An individual course grade of "B-" or better (4.0/9.0) is required for any course counted toward any CSE master's degree.

3. Courses of insufficiently advanced level, or which substantially duplicate a course level and content already completed by the student, may not be counted as meeting any master's degree requirement.

4. The CSE master's degree program requires students to complete **"kernel" course requirements**, mandated electives, and free electives, for the total of 30 credit hours. The purpose of the kernel is to give the student broad training in the major areas of computer science and engineering. Students who enter without an undergraduate engineering degree receive an M.S. degree. Students who enter with an undergraduate engineering degree have a choice of either the M.S. or M.S.E. degrees.

    One course must be taken from each of the following lists of master's kernel courses:

a. *Hardware*: Swtiching and Sequential Systems (EECS 478) or Computer Architecture (EECS 470)

b. *Intelligent Systems*: Introduction to Artificial Intelligence (EECS 492)

c. *Software*: One of the following: Introduction to Operating Systems (EECS 482) or Compiler Construction (EECS 483) or Database Management Systems (EECS 484) or Computer Networks (EECS 489) or Software Engineering Tools (EECS 581) or Advanced Operating Systems (EECS 582) or Programming Languages (EECS 583) or Advanced Database Systems (EECS 584) or Object-Oriented Databases (EECS 585)

d. *Theory*: Theoretical Computer Science I (EECS 574) or Design and Analysis of Algorithms (EECS 586).

    Courses taken at another university that are equivalent in level and content may fulfill one or more of these requirements. In general, equivalency does not fulfill any other degree requirements, in particular, credit-hour requirements. Equivalency request forms are available from the CSE Student Assistant.

5. Students may satisfy the cognate requirement—a minimum of 4 hours of graduate-level course work—

by taking course(s) associated with an EECS program not his/her own or by taking course(s) outside the department, or by a mixture thereof.

6. The option of writing a master's thesis is available to master's students in good academic standing.

M.S.E. in Construction Engineering and Management

Advisor.   Professor Robert I. Carr
Program Office, 2340 G. G. Brown Building

A student interested in a master's degree in construction engineering and management (C.E.M.) may elect to pursue a Master of Engineering in C.E.M. or a M.S.E. degree in either civil engineering or C.E.M. The M.S.E. (C.E.M.) is described below.

The M.S.E. (C.E.M.) is a graduate professional degree for students interested in research, as well as construction practice. It is particularly recommended for students who wish to enter a Ph.D. program in C.E.M following their master's degree. Regular admission to the M.S.E. (C.E.M.) is open to applicants who hold a bachelor's degree from any recognized program of engineering (e.g., civil, industrial, electrical, mechanical, naval, chemical). Data considered in admission decisions include the applicant's academic record, GRE scores (required), references, objectives, and experience.

The basic requirements to receive the M.S.E. (C.E.M.) are 30 (or 33) credit hours of graduate courses, which include 9 hours of C.E.M. core courses; 6 hours of C.E.M. electives; 3 (or 6) hours of independent study; 3 hours of mathematics, probability, statistics, or a mathematical programming elective; 3 hours of management elective; and 6 hours of program electives. At least 18 hours must be 500 level or above. The math elective and the management elective must be from outside the department. Independent study for M.S.E. students is a significant research course in which the student works independently under the supervision of a C.E.M. professor. The student selects either 3 credit hours of independent study, which results in a formal report, or 6 credit hours, which results in a thesis.

M.S. and M.S.E. in Electrical Engineering

Program Chair.   Professor Ward D. Getty

The Graduate Program in Electrical Engineering covers topics such as circuits, electronics, VLSI circuits, electromagnetics, optics, solid state materials, devices, and integrated circuits. The program is administered by the Electrical Science and Engineering division of the Department of Electrical Engineering and Computer Science (EECS).

The M.S.E. and M.S. degree programs are identical except for admission requirements. Students desiring admission to the M.S.E. program must have an earned bachelor's degree in electrical engineering or the equivalent of the undergraduate electrical engineering program at the University of Michigan. Students desiring admission to the M.S. program should have an earned bachelor's degree in engineering, physical sciences, or mathematics. Application procedures are described in a departmental brochure containing information for prospective students. The principal requirements for the M.S.E. and M.S. degrees are listed below. (A more complete statement on master's degree requirements is available from the EECS department.)

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 course work 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 and minor area and satisfy a requirement in each. The major area must be circuits and electronics, VLSI circuits, electromagnetics, optics, or solid state. The minor area must be different from the major (except in VLSI circuits) and must be chosen from either the previous list or biosystems, communications, computers, control systems, or signal processing. For each designated major and minor area there is a set of courses called the "kernel." As specified below, the major and minor requirements are to be satisfied by taking courses from the respective kernels. Specifically, at least 9 credit hours must be earned from the kernel of the major area, with at least 6 of these at the 500 level or higher. At least 6 credit hours must be earned from the kernel of the minor area, with at least 3 of these at the 500 level or higher. A grade point average of "B" or higher is required overall and also in EECS course work. Course grades must be "B-" or higher to earn credit toward the master's degree. A maximum of 4 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 6 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 requirement.

M.S. and M.S.E. in Electrical Engineering (Systems)

Program Chair. Professor Gregory H. Wakefield, EE 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, estimation and detection, robotics, networks, 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. The program is administered by the Systems Science and Engineering division of the Department of Electrical Engineering and Computer Science (EECS).

The M.S.E. and M.S. degree programs are identical except for admission requirements. Students desiring admission to the M.S.E. program must have an earned bachelor's degree in electrical engineering or the equivalent of the undergraduate electrical engineering program at the University of Michigan. Students desiring admission to the M.S. program should have an earned bachelor's degree in engineering, physical sciences, or mathematics.

Application procedures are described in a departmental brochure containing information for prospective students. The principal requirements for the M.S.E. and M.S. degrees are listed below. (A more complete statement on master's degree requirements is available from the EECS department.) 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 course work at the 500 level or higher (excluding credit hours earned in individual study, research or seminar courses). The student must also choose a major and minor area, and complete a "kernel" of courses in each. The major area must be communication, control systems, or signal processing. The minor area must be different from the major and must be chosen from either the previous list or bioelectrical sciences, circuits and electronics, computers, electromagnetics, optics, or solid state. At least 9 credit hours must be earned from the kernel of the major area, with at least 6 of these at the 500 level or higher. At least 6 credit hours must be earned from the kernel of the minor area, with at least 3 of these at the 500 level or higher. Course grades must be "B-" or better in order to be counted towards any requirements. A master's thesis is optional. Up to 6 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.

M.S.E. in Environmental Engineering

Advisor.   Professor Steven J. Wright
Environmental and Water Resources Engineering

Students interested in Environmental and Water Resources Engineering may elect to pursue an M.S.E. degree in either civil engineering or environmental engineering. The M.S.E. in environmental engineering is described below.

The program leading to the M.S.E. degree in environmental engineering is open to qualified candidates with a Bachelor of Science degree in any of the generally recognized fields of engineering or science. Program emphasis is placed on development of both technological and socio-economic concepts required for solution of a variety of environmental and water resources problems. Candidates for the M.S.E. degree must complete a minimum of 30 hours of graduate work, planned in consultation with the program advisor, constituting an integrated program. A typical program normally includes courses in surface and ground water hydrology; water quality and water pollution control; water, wastewater, and hazardous waste treatment; water chemistry and limnology; air pollution and solid wastes control; systems analysis, operations research techniques, and computer applications; political and institutional factors in environmental and water resource systems.

M.S. and M.S.E. in Industrial and Operations Engineering

Advisor.   Professor W. Monroe Keyserling
Graduate Program Office, 1603 IOE Building

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 provided.

The basic requirements include 30 credit hours of approved graduate level courses, of which: at least 18 hours must be in IOE courses; at least four courses must be at a 500 or higher level, of which at least three must be from IOE (IOE 590, independent study, does not count towards this requirement); no more than 4 credit hours of independent study.

At least two courses (4 credit hours) must be from outside the IOE department. Students are required to make up deficiencies in their preparation in probability, statistics, computer programming, 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 Manufacturing Systems Engineering, Occupational Health and Safety Engineering, and Public Systems Analysis. Material describing these options and other details of the graduate programs are available from the graduate program assistant, 1603 IOE Building.

M.S.E. and B.S.E in Industrial and Operations Engineering Engineering Global Leadership Honors Program

> http://mjmi.engin.umich.edu:8500/EGL.html
> *Advisor.*   Professor James C. Bean
> 127 IOE Building

The Engineering Global Leadership (EGL) Honors Program is a five-year, 158 hour program leading to B.S.E. I.O.E. and M.S.E. I.O.E. degrees. It seeks to educate leaders of engineering practice for the global economy of the next century. EGL combines the traditional industrial engineering core with a minor in some technology area, a core in the School of Business Administration, and a cultural core in the College of Literature, Science, and the Arts. A listing of program requirements is available in 1603 IOE Building.

Joint M.S./M.B.A. in Industrial and Operations Engineering

> *Advisor.*   Professor Jeffrey K. Liker
> 210 IOE Building

The School of Business Administration and the College of Engineering Department of Industrial and Operations Engineering offer a joint degree program enabling a student to pursue concurrent work in Business Administration and Industrial and Operations Engineering leading to the M.B.A./M.S. (I.O.E.) degree. The program is arranged so that all requirements for the degree 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.) joint 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 joint 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 30 credit hour M.B.A. core
2. 15 elective hours in business administration (12 of the 15 hours must be approved by IOE)
3. 18 credit hours in graduate level IOE courses (at least 9 of which must be in courses numbered 500 or above)
4. 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 joint 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 and Operations Engineering should consult a counselor in the Business School to work out an appropriate plan of study.

Master's in Hospital Administration and Industrial Engineering

Advisor.   Professor James B. Martin, School of Public Health

This 60 credit hour interdepartmental master's degree program is administered jointly by the Industrial and Operations Engineering department in the College of Engineering and the Health Services Management and Policy department in the School of Public Health. This program prepares graduates for engineering and administrative positions in hospitals and other health organizations. The degree provides a comprehensive program in health administration and engineering.

Areas of study include hospital administration, hospital systems engineering, management information systems, computer aided systems, and operations analysis.

Master's in Macromolecular Science and Engineering

Advisor.   Professor Richard E. Robertson
Program Office, 2541 Chemistry

Students select an option of study in this interdisciplinary program from the departments of Mechanical Engineering and Applied Mechanics, Chemistry, Chemical Engineering, Materials

Science and Engineering, Nuclear Engineering and Radiological Sciences, or Physics. Course requirements will depend on the option of study both for courses in that field and in macromolecular science. The course distribution should be a minimum of three courses in macromolecular science, a minimum of three courses from those required in the option, plus additional approved courses to complete the minimum credit hour requirement (30) for the M.S. degree. These course requirements consist of a minimum of 30 credits of graduate work with not more than 6 credits and not less than 4 allowed for a research project. There is to be a written report describing the results of such a research project. All courses must be approved by the graduate advisor.

M.S.E. in Materials Science and Engineering

Advisor: Professor I-Wei Chen
2086 H. H. Dow Building

A total of 30 graduate level credit hours of departmental and cognate subjects must be completed for this degree. At least 21 hours of the 30 hours must be formal course work which includes MSE 590 (1 credit hour) and a minimum of two cognate courses. At least 15 of the required 30 credit hours must be chosen from Materials Science and Engineering department course offerings or their equivalents recommended by the graduate advisor. Each cognate course must be in a technical discipline and at least 2 credit hours. Students receiving financial aid from the department must take 9 credit hours of MSE 690 and submit a master's thesis for approval by the department.

A booklet describing the graduate program in more detail is available from the secretary in the Materials Science and Engineering Graduate Program Office, 3062D H. H. Dow Building.

M.S.E. in Mechanical Engineering

Graduate Chair: Professor Christophe Pierre
2206 G. G. Brown Building, (313) 936-0406

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, with at least two cognate subjects. Up to 6 credit hours of research or 9 credit hours of thesis can be taken as part of a 30 credit hour requirement. Details of course requirements and fields of specialization will be furnished by the department upon request.

M.S. and M.S.E. in Naval Architecture and Marine Engineering

Advisor: Professor Robert F. Beck
209 Naval Architecture and Marine Engineering Building

Assistant: Colleen L. Vogler
219 Naval Architecture and Marine Engineering Building

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 taken in naval architecture and marine engineering. Half of the program must consist of 500 level (or higher) courses. Five or more hours must be in graduate-level mathematics courses. Two courses of at least 2 credit hours each must be taken outside the department.

The two primary areas of graduate study and research are marine hydrodynamics and marine environmental engineering, and concurrent marine design. In each of these broad areas of focus there are a number of sub-areas of specialization possible through the choice of electives such as marine hydrodynamics, marine environmental engineering, computer aided marine design, marine engineering, marine production, marine structures, marine systems management and offshore engineering. Within each of these areas of specialization students are required to take several core courses, with the remainder chosen to meet individuals' goals and objectives.

Refer to the booklet titled, "Engineering for the Marine Environment: Graduate Programs in the Department of Naval Architecture and Marine Engineering," available from the departmental office, for a more detailed description of the graduate program in naval architecture and marine engineering.

Joint M.S.E./M.B.A. in Naval Architecture and Marine Engineering

Advisor: Professor Anastassios N. Perakis
210 Naval Architecture and Marine Engineering Building

Assistant: Colleen L. Vogler
219 Naval Architecture and Marine Engineering Building

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:

1. 31.5 credit hours M.B.A. core
2. 13.5 elective hours in business administration
3. 18 hours of graduate level NAME courses, including NA 510, NA 520, NA 540, and either NA 522 or NA 562 depending on the area of study.
4. Math 450
5. 8 hours acceptable to program advisor, some of which could be part of (2).

Interested students must file separate applications and be admitted to both schools. The application fee can be paid to either of the two schools.

M.S. in Nuclear Science and M.S.E. in Nuclear Engineering

Advisor: Professor Ronald M. Gilgenbach
Program Office, 1906 M. E. Cooley Building

Students entering the program in Nuclear Engineering 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 on nuclear energy development.

Students planning to enter the M.S. degree program who do not have an undergraduate degree in Nuclear Engineering 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 EECS 315, Physics 455 or equivalent), a course in fluid mechanics (CEE 325 or equivalent), a course in electromagnetic

fields (Physics 405 or equivalent), and a course in digital computer programming (Eng 103, 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 two courses 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, with the NERS 599 credits not to exceed 3 credit hours per full term. 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. Where the entering student presents evidence of satisfactory completion of work equivalent to any of the nuclear engineering and radiological sciences courses, substitution of other courses will be arranged by the program advisor.

M.S. in Scientific Computing

The M.S. degree in Scientific Computing has been developed to meet the needs of industrial engineers who wish to return to school to upgrade their skills in numerical computation. The second target group is students, with or without industrial experience, who wish to intensively study scientific computing as a supplement to a previous or concurrent master's or doctoral degree program.

Please contact the Atmospheric, Oceanic and Space Sciences department for more complete program information.

Master's Degrees (College of Engineering)

Master of Engineering—M.Eng.

The College of Engineering offers the Master of Engineering degree for the student who has met the requirements for the degree of Bachelor of Science in Engineering at the University in the student's field of specialization, or has had essentially equivalent experience. The programs leading to the M.Eng. degree are designed with preparation for a career in the practice of engineering in industry as the primary goal. These are 12 month programs organized around a team project experience which is undertaken in close association with industry.

The M.Eng. degrees offered are designated in the titles of the graduate program descriptions that follow.

M.Eng. in Aerospace Engineering

Advisory Committee: Consult Aerospace Engineering departmental office.

The main goals of the M.Eng. in Aerospace Engineering degree are to enhance the technical competence and depth of understanding in applied areas of gas dynamics, dynamics and control, structural mechanics, and engineering design; broaden this experience to include a wider range of application areas; develop a wider understanding of industrial and business practices and/or to enhance advanced language and cultural studies; and to provide practical experience in team organization and project development and management.

The M.Eng. in Aerospace Engineering degree requires 30 credits of course work of which 18 must be at the 500 level or higher and 24 must be graded (not pass/fail). A minimum grade point average of 5.0/9.0 is required for completion of the degree. Specific course requirements may be obtained through the department.

Prospective students can apply through the College of Engineering and be evaluated by the Master of Engineering Committee of the Department of Aerospace Engineering. Admission requirements and standards are similar to those for the M.S.E. degree in Aerospace Engineering; however, relevant work experience will be given added weight for those with substantial work experience. A baccalaureate degree in engineering or related science is required for admission. In some cases, prerequisite courses may be required in addition to the courses taken for the degree.

M.Eng. in Air Quality

Advisor: Professor John R. Barker
Department of Atmospheric, Oceanic and Space Sciences

The degree of Master of Engineering in Air Quality is designed to provide both the broad knowledge base and specific training needed by air quality engineers. The degree has two concentrations: air quality monitoring and air pollution modeling. Both concentrations offer hands-on experience with the latest techniques and experience in team efforts which combine both modeling and monitoring.

The Master of Engineering in Air Quality requires 30 credits of course work, of which 18 credits must be at the 500 level or higher, 24 credits must be graded (e.g., minimum "B" average is required for completion of the degree). In addition, a minimum "B" average is required on each of the core courses offered. In addition to the core courses, students will select electives from courses offered by other Engineering departments (Engineering Electives) and from courses on environmental policy, government regulations, and environmental quality (Policy Electives).

Prospective students can apply through the Department of Atmospheric, Oceanic and Space Sciences and will be evaluated by the AOSS Graduate Admissions Committee. Admission requirements and standards are similar to those for the M.S.E. and M.S. degrees, but relevant work experience will be given added weight. A baccalaureate degree in engineering or physical science is required for admission. In some cases, prerequisite courses may be required in addition to courses taken for the degree. The AOSS Graduate Committee will counsel students, monitor their progress, and certify their completion of the degree requirements.

M.Eng. in Automotive Engineering

Director: Professor Dennis Assanis
321 W. E. Lay Automotive Laboratory, (313) 763-1134

The Master of Engineering in Automotive Engineering is a new 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 away from work.

The M.Eng. degree in Automotive Engineering requires a total of 30 credit hours of course work, of which at least 24 credit hours must be graded, and at least 18 credit hours must be in courses at the 500 level and above. A minimum grade point average of 5.0/9.0 (i.e., a "B" average) is also required. The credits will be distributed in categories arranged to meet the degree's objectives:

1) Engineering Core (9 credits, graded)
   One course should be selected per area from three of the following four core areas: power and propulsion; dynamics and controls; aerodynamics and structural mechanics; and electronics.

2) Systems Engineering (6 credits, graded)
   The student must take two courses in other engineering disciplines of their choice.

3) Management and Human Factors (9 credits, graded)
   Three courses must be taken in the Management and Human Factors core. Those courses should emphasize business and management, ergonomics and human factors, law and professional ethics, operations research, etc.

4) Automotive Engineering Seminar and Project (6 credits, S/U)
   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.

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. Students with outstanding qualifications who do not have two years of industrial experience will be considered for admission if they have relevant summer internship or co-op experience. The Graduate Record Examination (General Test) is recommended but not required. A full time student can complete the degree program in one calendar year.

M.Eng. in Concurrent Marine Design

Advisor: Professor Robert F. Beck
209 Naval Architecture and Marine Engineering Building

Assistant: Colleen L. Vogler
219 Naval Architecture and Marine Engineering Building

The M.Eng. in Concurrent Marine Design is a professionally oriented graduate degree designed to meet the needs of the marine industry. It focuses on providing entry- to mid-level marine professionals with knowledge and practical experience dealing with the design of 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 a new and simultaneous approach where performance and production are considered concurrently with the goal of an associated reduction in the design/build time. This approach requires 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 one year is required; two years is preferred. Significant accumulated experience through multiple internships or co-op assignments will be considered as a substitute. Prerequisite courses are Ship Design (NA 470), and Introduction to Probability and Statistics (Stat 412), or their equivalents.

The degree requires 30 credits of graduate courses beyond the prerequisites, of which 24 credits must be graded (not pass/fail), 15 credits must be at the 500 level and above, and 15 graded credits must be in engineering courses. The minimum grade point average for graduation is 5.0/9.0 (a "B" average).

In addition to the prerequisite courses, each student is required to meet the following course distribution requirements:

- Marine Structures II (NA 410); Ship Production Planning and Control (NA 460); Concurrent Marine Design (NA 562); and one other naval architecture and marine engineering course (such as Computer-Aided Hull Design and Production (NA 574))

- At least 6 credits from a list of advanced engineering courses in related fields
- Shipbuilding and Shipping Markets and Forecasting (NA 586) and at least 3 credits of relevant non-engineering subjects
- Two (2) credits of Concurrent Marine Design Seminar (NA 577/NA 578) and 4 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 manufacturing agility and life-cycle costs. The program helps prepare the student for participation and leadership in cross-function design teams involved in concurrent marine design.

M.Eng. in Construction Engineering and Management

Advisor: Professor Robert I. Carr
2340 G. G. Brown Building

The Master of Engineering (M.Eng.) degree in construction engineering and management (C.E.M.) is a graduate professional degree in engineering. Regular admission to the M.Eng. (C.E.M.) program is open to applicants who hold a bachelor's degree from a recognized program in any field of engineering (e.g., civil, industrial, electrical, mechanical, naval, chemical). Applicants with bachelor's degrees in architecture or other non-engineering programs (but not engineering technology programs or their equivalent) may be granted admission if they have taken a year of calculus and a year of physics. Admission requirements are similar to other master's degree programs in the College of Engineering. Data considered in admission decisions include the applicant's academic record, GRE scores (recommended but not required), references, objectives, and construction related experience.

The basic requirements to receive the M.Eng. (C.E.M.) are 30 credit hours of graduate courses (at least 18 credit hours at 500 level and above), of which at least 24 credit hours must be graded (not pass/fail), and 15 graded credit hours must be in engineering courses. The student must satisfy the course distribution requirement as follows:

1. Construction core (9 credit hours)
2. CEM electives (6 credit hours)
3. Construction Professional Practice Seminar (3 credit hours)

4. Minor area electives (6 credit hours)
5. Program electives (6 credit hours)

Construction core courses and the Construction Professional Practice Seminar contain significant team projects, and each student's program must include five courses with projects. In addition to the normal M.Eng. requirements, students without a degree in engineering must complete Theory of Structures (CEE 312), Design of Structures (CEE 315), Civil Engineering Materials (CEE 351), Construction Contracting (CEE 431), Construction Engineering (CEE 432), and Engineering Properties of Soil (CEE 445), or approved equivalents at another university. Students with architecture degrees will normally have the equivalent of structural analysis and structural design.

Dual M.Eng./M.Arch. in Construction Engineering and Management

Advisor: Professor Robert I. Carr
Program Office, 2340 G. G. Brown Building

The College of Architecture and Urban Planning and the Department of Civil and Environmental Engineering have established a dual degree program in architecture and construction engineering management. The program combines the two-year, 60 credit hour M.Arch. degree with the one-year, 30 credit hour M.Eng. degree, resulting in a two and one-half year, 75 semester hour program.

To be eligible for admission, a student must have a B.S. degree from the College of Architecture and Urban Planning, or an equivalent earned at another institution, with at least one year of calculus, one year of physics, and a minimum "B" average in science and mathematics courses. In addition to the normal M.Eng. (C.E.M.) requirements, students must complete Civil Engineering Materials (CEE 351), Construction Contracting (CEE 431), Construction Engineering (CEE 432), and Engineering Properties of Soil (CEE 445), or approved equivalents at another university. With proper planning, these courses can be included in B.Arch. and M.Arch. programs.

Two separate and complete applications are required, one to the College of Architecture and Urban Planning for Year 5/M.Arch. and one to the College of Engineering for the M.Eng. (C.E.M.) program; however, individual reference letters can be shared. Admission to the M.Arch. program is normally limited to the fall term, but winter term admission may be considered in special cases. The recommended procedure is to apply to each program for the same term, but students may apply to either program while enrolled in the other. The application fee is required only once if an application is made to each unit for the same term.

Students admitted to this dual-degree program must satisfy the following degree requirements:

1. Construction core (9 credit hours).
2. C.E.M. electives (6 credit hours).
3. Construction Professional Practice Seminar (3 credit hours).
4. Architecture courses at 500/600 level (36 credit hours).
5. Any additional cognate/elective courses needed to fulfill the 75 hours and general requirements of each degree.

Dual degree students take CEE courses to satisfy all C.E.M. course requirements of the M.Eng. (C.E.M.). Minor area electives and program electives requirements of the M.Eng. (C.E.M.) are normally fulfilled by architecture courses. For additional information on this program, see the description of the M.Arch. and dual degree program in the College of Architecture and Urban Planning *Bulletin.*

Joint M.Eng./M.B.A. in Construction Engineering and Management

Advisor. Professor Robert I. Carr
Program Office, 2340 G. G. Brown Building

The School of Business Administration and the Department of Civil and Environmental Engineering offer a joint degree program enabling a student to pursue concurrent work in business administration and construction engineering and management leading to the M.B.A. and the M.Eng. (C.E.M.). The typical student will hold a B.S. degree in engineering. The program is arranged so that all requirements for both degrees can be completed in two and one-half years of enrollment.

Students interested in this joint program must file separate applications to both schools, indicating that they are applying to the joint program, and they must be admitted by both schools. Only one application fee is necessary. Students must take the GMAT for Business School admission and the GRE for admission into the C.E.M program. This combined degree program is not open to students who have earned either the M.B.A. or M.Eng. (C.E.M.) degrees. Students registered in the first year of either program may apply.

Students admitted to this joint degree program must satisfy the following degree requirements:

1. The 30 credit hour M.B.A. core.
2. 15 elective hours in business administration.
3. 9 hours of construction engineering core courses.

4. 6 hours of graduate-level construction engineering courses.
5. 3 hours of Construction Professional Practice Seminar.
6. A 3 credit independent study course under CEE 630 to integrate the management skills learned in the Business School with the technical construction engineering skills learned in civil engineering.
7. CEE 431 if students have not previously taken it or its equivalent.

The total credit hours for the joint degree program will be 66 or 69, depending upon whether the student is required to take CEE 431. No course completed prior to admission may be counted toward the M.B.A. requirements of the joint program.

The joint program may begin with studies in either school. However, because of the sequenced nature of core courses in the M.B.A. program, most students will find it advantageous to start with year one in the Business School. Students who wish to begin in C.E.M. should see a counselor in the Business School to arrange an appropriate plan of study.

M.Eng. in Display Technology and Manufacturing

The M.Eng. in Display Technology and Manufacturing is a practiced-oriented professional degree. In comparison to the conventional pre-doctoral M.S.E. and M.S. research-oriented degrees. This program will further the education and training of individuals who plan to practice in an applied, industrial, technical-managment-based environment. It is available to recent baccalaureate recipients with no industrial experience and practicing engineers and scientists.

Please contact the Electrical Engineering and Computer Science department for more complete program information.

M.Eng. in Geoscience and Remote Sensing

Advisor: Professor John Vesecky
            Department of Atmospheric, Oceanic and Space Sciences

The mission of the Master of Engineering degree in Geoscience and Remote Sensing is to provide graduates with a sound basis in sensors, interpretation and data system fundamentals, a "kit of tools" to apply remote sensing to the student's areas of interest and relevant team project and design experience in specific applications tailored to local, national, and global needs.

A total of 30 credit hours of course work is required, of which at least 24 credit hours must be graded (i.e., are not pass/fail) and at least 18 credit hours must be at the 500 level and above.

Entrance requirements are similar to other masters level programs within the College of Engineering; however, work experience and professional achievement of mature students will be taken into account.

M.Eng. in Manufacturing

Program Advisor.   Professor A. Galip Ulsoy
                     2219 G. G. Brown Building

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, industrial, naval, chemical, material science), and who have relevant industrial experience. A total of 30 credit hours is required, of which at least 24 graded credit hours must be letter graded (i.e., not pass/fail), and at least 18 graded credit hours must be in courses at the 500 level and above. Entrance requirements are similar to other master 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: a) at least two years of college engineering mathematics (including probability and statistics); and b) a course in manufacturing processes.

Admitted students in the M.Eng. in Manufacturing program must take the course sequence Mfg 501, Manufacturing Seminar I; Mfg 502, Manufacturing Seminar II; and Mfg 503, Manufacturing Project. Lists of acceptable courses in each distribution area are available; substitutions require the approvalof the program advisor.

Dual M.Eng./M.B.A. in Manufacturing

Program Advisor.   Professor A. Galip Ulsoy
                     2219 G. G. Brown Building

The School of Business Administration (SBA) and the Program in Manufacturing (PIM) within the College of Engineering Graduate Studies offer a joint degree program that enables qualified persons 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.

The combined 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.

M.Eng. in Occupational Ergonomics

Advisor: Professor W. Monroe Keyserling
158 IOE Building, (313) 764-6480

This Master of Engineering degree focuses on applying engineering principals and the life sciences to facilitate effective integration of humans into manufacturing and service systems. This is a 30 credit hour professional degree program that is offered in the Industrial and Operations Engineering department.

M.Eng. in Optical Engineering and Ultrafast Technology

Advisor: Professor Theodore Norris
1014 IST Building, (313)764-9269

The Master of Engineering (M.Eng.) degree in Optical Engineering and Ultrafast Technology is designed to train students in the rapidly developing field of ultrafast (femtosecond) lasers and their application to a wide range of fields including high-speed electronics and optoelectronics, nonlinear optics, imaging, optical metrology, xuv and x-ray generation and applications, materials processing, medical science, and manufacturing technology. This program is offered through the Electrical Engineering and Computer Science department and the Center for Ultrafast Optical Science (CUOS).

The M.Eng. in Optical Engineering and Ultrafast Technology is a practice-oriented, professional degree — in contrast to the conventional pre-doctoral Master of Science research degree — and is designed to further the education and training of engineers who plan to practice in an applied, industrial, or technical-management-based environment. This program recognizes the growing need faced by all competitive industries to continue with the definition and practical development of new products as part of their corporate presence in the marketplace. To this end, the M.Eng. in O.E. & U.T. degree is tightly integrated with the industrial affiliates program in the CUOS. Students pursuing this degree are jointly supervised by one or more faculty members and an industrial associate who is participating in the CUOS corporate-based Ultrafast Develoment Laboratory (UDL).

The degree requires a total of 30 credit hours. At least 18 must be at the 500-level or above. Of the 30 credits, 24 must be graded. A minimum 18 of these graded credit hours must

be in engineering courses. The remaining 6 are to be in non-engineering, but appropriately related, subjects. A grade point average of 5.0 (B) out of 9.0 (A+) is required for graduation.

12 credits	Optics (e.g., EECS 434, 435, 537, 538, 539, 546, 735)
6 credits	Graded core project (598)
6 credits	Engineering breadth: EECS 422, 429, 530. Other 400- or 500-level courses in the Systems or EE areas, excluding optics, are acceptable
3 credits	Non-engineering breadth (e.g., management, finance, information systems, strategic planning, marketing, foreign language, workplace psychology, ergonomics)
3 credits	Math (e.g., 419, 454, 471)

The entrance requirements for students entering the program with a bachelor's degree, and no industrial or other work experience, shall be the same as those for admission to the Rackham School of Graduate Studies.

M.Eng. in Radiological Health Engineering

Advisor.   Professor Kim Kearfott
Program Office, 1906 M. E. Cooley Building

Radiological Health Engineering is a growing field concerned with the application of engineering and scientific principles to the solution of problems concerned with radiation protection (health physics), involving individuals, populations, or the environment. Radiological health engineers may apply their skills to the problems associated with diagnosis and treatment of disease, safe operations of nuclear utilities and industries, risk assessment, regulation, nuclear weapons non-proliferation, environmental remediation and restoration, low-level and high-level radioactive waste disposal, and public communications.

The Master of Engineering (M.Eng.) in Radiological Health Engineering, a 30 credit hour program, is designed for students with undergraduate degrees in engineering or physics, with other students being considered on a case-by-case basis. Calculus (including differential equations) and undergraduate courses in modern or nuclear physics are required. Each student's program of study, which requires approval of the program advisor, will be tailored to individual interests and strengths, with students generally satisfying the following course distribution:

1) Radiological Health Engineering Core (9 credits)
2) Engineering Specialization (6 credits), such as environmental engineering, industrial engineering, occupational safety, or bioengineering

3) Radiological Health Science (9 credits), typically taken from the School of Public Health: Up to 3 credit hours of any nuclear engineering and radiolgoical sciences course (400 level or above) can be substituted for (up to) 3 credit hours of EIH (School of Public Health) courses.

4) Practicum or project (6 credits)

Students completing the above should develop their skills at identifying optimal solutions to radiation protection problems using quantitative analysis, engineering design, and the analytical approach. A broad knowledge of radiation biology, radiation protection practices, radiation dose estimation, and radiation measurement techniques should be emphasized.

M.Eng. in Space Systems — Joint Program AeroE/AOSS

Advisor: Professor Tamas I. Gombosi
Department of Atmospheric, Oceanic and Space Sciences

This interdisciplinary Master of Engineering in Space Systems degree provides a broad interdisciplinary education in the scientific, engineering, and management aspects of complex space systems. The program is designed to enhance disciplinary skills as well as provide insight and education in systems engineering and management.

The Master of Engineering in Space Systems degree requires 30 credits of course work of which 18 must be at the 500 level or higher and 24 must be graded (not pass/fail). A minimum grade point average of 5.0/9.0 is required for completion of the degree.

The Master of Engineering in Space Systems Program (MESSP) is administered by the Joint MESSP Committee of the departments of Aerospace Engineering (Aero) and Atmospheric, Oceanic and Space Sciences (AOSS).

Prospective students may apply through either the Aero or AOSS department and will be evaluated by the MESSP committee. Admission requirements and standards are similar to those for the M.S.E. and M.S. degrees in the two departments; however, relevant work experience will be given added weight for those with substantial work experience. A baccalaureate degree in engineering or physical sciences is required for admission. In some cases, prerequisite courses may be required in addition to the courses taken for the degree.

MESSP students will be automatically enrolled in both the Department of Aerospace Engineering and the Department of Atmospheric, Oceanic and Space Sciences.

The MESSP Committee will counsel students, monitor their progress, and certify their completion of the degree requirements.

M.S. in Technical Information Design and Management

Advisory Committee: Consult program office
306 Engineering Programs Building, (313) 764-1426

The University of Michigan M.S. program in Technical Information Design and Management is a 30 credit hour program intended to produce graduates with both technical skills and strong communication skills. The graduates of the program will design, write, produce, and manage the sophisticated documentation and other forms of technical communication needed by high-technology companies. This technically based program is designed for engineers and scientists who wish to emphasize the communication side of their professional lives.

Admission Requirements: Applicants must have completed a B.S. or B.S.E. degree which includes at least the following communication and computing requirements: two advanced communications courses; one programming course in Pascal, LISP, C, FORTRAN, or COBOL; a second advanced computing course; and advanced coursework in one specific technical, scientific, social scientific, or professional discipline.

Applicants must submit a completed application form, transcripts of all previous college or university study, three letters of recommendation, two writing samples, and Graduate Record Examination (GRE) results. Foreign applicants must submit TOEFL or MELAB results. Applicants lacking sufficient preparation may be required to supplement their regular work in the program with additional courses and will be allowed to take such courses after admission.

Degree Requirements: The program requires 30 credit hours of graduate work including a thesis or internship. The program addresses the content areas relevant to technical communication and the modes in which modern technical communication occurs. The content areas include communication theory, communication contexts (corporate, technological, and multinational), communication practice, communication

management, and the technical content which is being communicated. The relevant modes for delivering modern technical communication include print, voice, still visuals, motion visuals, on-line communication, multi-media, and integrated media.

Post-Master's Degrees (Rackham)

Professional Engineer Degrees

The following programs lead to Professional Engineer degrees:

Aerospace Engineer - Aerospace E.	Industrial and Operations Engineer - I.O.E.
Applied Mechanics Engineer - App. M.E.	Marine Engineer - Mar. E.
Chemical Engineer - Ch. E.	Mechanical Engineer - M.E.
Civil Engineer - C.E.	Naval Architect - Nav. Arch.
Electrical Engineer - E. E.	Nuclear Engineer - Nuc. E.

The professional 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 average of "B" or better. Successful completion of a qualifying examination for admission to candidacy is required.

The total graduate program shall include:

1. At least 24 hours in the area of the department or program cited in the degree. The department or program advisors may specify these hours in greater detail.
2. At least 6 hours devoted to a research, design, or development problem, including a written report covering the work. A committee of faculty members will supervise the work, approve the report, and conduct a final oral examination on this work.
3. At least three courses in cognate fields other than mathematics.
4. At least 9 hours in mathematics beyond the Bachelor of Science in Engineering mathematics requirements of the department cited in the degree.

Doctoral Degrees (Rackham)

Doctor of Philosophy—Ph.D.

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 announced 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. No assurance is given that the student may become a candidate for the doctorate until evidence of superior scholarship and ability as an original investigator has been shown.

There is no general course or credit requirement 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.

A pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School office, 1004 Rackham Building, upon request.

Applied Physics—Ph.D.

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 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. A broad range of research opportunities is available through the multidisciplinary spread of faculty participating in the program.

For further information about the program, research facilities, research specialties of the faculty, fellowships, assistantships, and sources of financial assistance, write directly to the Applied Physics Program Administrative Assistant, Rohn Federbush, 2071 Randall Laboratory, The University of Michigan, Ann Arbor, MI 48109-1120 or telephone (313) 936-0653.

Admission: 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. 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 (GRE) general scores are required and the GRE Subject Test in Physics is recommended. Three letters of recommendation must be submitted, of which at least two must be from an academic institution. Students from non-English-speaking countries are required to demonstrate a proficiency in English via the TOEFL examination. Minimum score for admission is 560. Applications will be processed for fall term admission. The deadline for applications for financial aid consideration is February.

Range of Enrollment: The program is normally four to five years with an emphasis on coursework during the first two years, thereafter on research. 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 to be recommended for admission to candidacy for the Ph.D. The recommendation is made by the Applied Physics Program Executive Committee. Candidacy is normally achieved after four or five semesters of graduate work.

Specific Course Requirements: To achieve candidacy and form a dissertation committee, eight prescribed 500 level courses — AP 514, AP 518, AP 540, AP 541, AP 560, AP 561, Physics 510 and Physics 520 — must be passed with a grade "B" average. In addition, two 600 level courses and two distribution courses (chosen in consultation with the program advisor according to the student's research needs) must be completed satisfactorily. Satisfactory completion of one 4 credit hour course on non-thesis research is also required, under the supervision of a faculty member. All first-, second-, and third-year students are required to enroll in a weekly seminar course (AP 514). There is no foreign language requirement.

Qualification: The decision to qualify a student for Ph.D. study is based on the student's academic record, performance in

a 4 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 test on undergraduate level physics. Students who have taken the GRE Subject Test in Physics within the last five years with a score of 70% or more do not need to take this test. 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 qualifying examination (both parts) can be retaken once, and only once, after beginning graduate studies. The student should qualify within two years of entering the graduate program.

Preliminary Examination: A preliminary examination of the student's preparation 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.

Candidate Status: 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.

The typical structure of course work is as follows:

First Year:

Fall	*Winter*
CME I (AP 560)	QM II (AP 541)
QM I (AP 540)	CME II (AP 561)
Stat Mech (Phys 510)	Supv Res (AP 715)
Graduate Seminar (AP 514)	

Second Year:

Computational/Math Methods+	Elective Course*
Solid State (Phys 520)	Elective Course*
Elective Course*	Elective Course*

*At least two electives must be at the 600-level
+One of the following must be elected:
   Microcomputers in Experimental Res (AP 518)
   or Methods of Applied Math I (Math 556)
   or Numerical Methods for Scientific Computing I
   (Math 571) or other approved computer/math
   methods options

Third Year:

Graduate Seminar (AP 514)	
990 Precandidate	995 Candidacy

Macromolecular Science and Engineering — Ph.D.

The goal of the interdisciplinary program in Macromolecular Science and Engineering is to provide 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 as well as the biological areas. The program at the University of Michigan is one of the very few where the 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 Doctor of Philosophy degree is offered in Macromolecular Science and Engineering with concentrations in the areas of chemistry (organic or physical), chemical engineering, materials science and engineering, or physics. The faculty members are drawn from the departments listed above in addition to Mechanical Engineering and Applied Mechanics and Nuclear Engineering and Radiological Sciences, thus making the program a fully cooperative and interdisciplinary endeavor. The faculty believe that this approach permits students to eventually make a more significant contribution to macromolecular science. It also allows students to develop the self-confidence needed to adapt to the changes inherent in modern research and development.

Admission: The Macromolecular Science and Engineering program requires either a B.S. or B.A. in science or engineering with at least a "B" grade point average. Students with bachelor's degrees in chemical or materials engineering, chemistry, or physics will find it possible to continue easily with their major field within the program; others may have to make up deficiencies early in their studies. Three letters of recommendation must be submitted. Graduate Record Examination (GRE) general scores are required; GRE subject scores are recommended. International students must have a minimum TOEFL score of 600. The general admission requirements for the Rackham School of Graduate Studies must also be met.

Examinations and Candidacy: Students entering the Macromolecular Science and Engineering program in the Chemistry Option (organic or physical) are required to take the Chemistry department qualifying examinations prior to their first enrollment. It is required that these examinations be passed by the end of the second term of enrollment.

The progress to a Ph.D. is normally four to five years with coursework being emphasized during the first two years. To continue in the program, students must pass a two-part comprehensive written examination in macromolecular science before the end of the second year. Students are approved for candidacy after they have: (1) completed the basic prescribed courses satisfactorily (see below); (2) passed the comprehensive exam; (3) formed a dissertation committee; and (4) passed a preliminary oral examination by that committee. Candidacy is usually achieved after four terms.

Research: An early start in research is encouraged as soon as the student has demonstrated satisfactory progress in courses and has selected a research supervisor. The interdisciplinary nature of the program allows for a wide range of research possibilities.

Representative 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:

Chemistry Option (Organic 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 an Organic option, these courses must include: MacroSE 535, MacroSE 536, MacroSE 538, MacroSE 790, Chem 540, Chem 541, Chem 542.

For a Physical option, these courses must include: MacroSE 535, MacroSE 536, MacroSE 790, Chem 571, Chem 576, Chem 580, Chem 672.

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 ChemE and 12 hours from MacroSE. These courses must include: MacroSE 536, MacroSE 790, ChemE 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 536, MacroSE 790, an advanced course in metals, and an advanced 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 536, MacroSE 790, Physics 418, Physics 505, Physics 506, Physics 507, Physics 510, and an advanced course in physical properties of polymers.

Additional Options:

Additional options in mechanical engineering and applied mechanics and in nuclear engineering and radiological sciences are available. An individualized option may be proposed by students with a Master's Degree or extensive industrial experience. Such students must submit a detailed program in writing for approval by the Executive Committee.

For further information on the program, write directly to the University of Michigan, Macromolecular Science and Engineering Center, 930 N. University, 2541 Chemistry Building, Ann Arbor, MI 48109-1055, or telephone (313) 763-2316.

Doctoral Degree (College of Engineering)

Doctor of Engineering — D. Eng.

Manufacturing — D. Eng.

Director.   Professor A. Galip Ulsoy
2219 G. G. Brown Building

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, mechnical and applied mechanics, 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. Qualifying exams will be offered in January and May of each academic year. 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.

Military Officer

Education Programs

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 requirements. This opportunity is available through enrollment in the Military Officer Education Program (MOEP), which is nationally known 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 of $150 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, full payment for required books, and a $150 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

Program Office:
Room 154, North Hall
764-2403
Chair: Colonel Allen
Majors Lopez and Wieck; Captain Laughman

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
March 1 of the year in which students desire to enter the POC.
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. In addition to the Aerospace Studies courses, students
must satisfy certain supplemental course requirements.
Distribution is indicated below:

Basic course sequence (first and second year): Aerospace
Studies 101, 102, 201, 202 (4 hours), and an approved course
in English Composition (scholarship students only).

Advanced course sequence (third and fourth years):
Aerospace Studies 310, 311, 410, 411 (12 hours), and an
approved course in mathematical reasoning.

This sequence of courses attempts to develop an under-
standing 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 physically and mentally qualified to become
Air Force pilots receive dual and solo flight instruction under
the supervision of an Air Force instructor pilot. Flight orientation
training will be scheduled for a date after graduation and com-
missioning.

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, six years for navigators after
completion of navigator training, and eight years for pilots
after completion of flight training.

Air Force Officer Education Courses

(Aerospace Studies)

101.
The Air Force Today
Prerequisite: none. I (1 credit)
Examines the growth and development of the United States Air Force; covers Presidential, Secretary of Defense and JSC roles in the defense posture, and the national and U.S. military strategic concepts; studies the Air Force supporting forces. Compares the dynamics and interaction of all U.S. military forces in the General Purpose role and their cooperative efforts in the national security posture.

102.
The Air Force Today
Prerequisite: none. II (1 credit)
Continuation of AS 101.

201.
U. S. Aviation History and Its Development into Air Power
Prerequisite: none. I (1 credit)
Examines the development of aviation from the 18th century, from balloons and dirigibles, to the present, and how technology has affected growth and development of air power; traces use and development of air power through WW's I and II, the Korean and Vietnamese conflicts, employment in relief missions and civic action programs in the late 1960s, and employment in military actions concluding with Desert Shield/Desert Storm.

202.
U.S. Aviation History and Its Development into Air Power
Prerequisite: none. II (1 credit)
Continuation of AS 201.

310.
Air Force Leadership and Management
Prerequisite: none. I (3 credits)
The concepts, principles, and techniques of leadership and human relations presented within the framework of behavioral theories. Emphasis on the leader, group, and situation; their interaction as dynamic factors in an organizational environment with methodological implications for military and other professions. Practicum and laboratory centered on operational simulations and cadet corps activities.

311.
Air Force Leadership and Management II
Prerequisite: none. II (3 credits)
Historical overview of management theory development with particular consideration of behavioral science's impact on primary management function. Problem-solving will be incorporated into discussion of management functions, and management principles will be analyzed as they apply to various combinations of political and power relations in the organizational setting. Exercises will simulate operational situations requiring the decision-making approach.

410.
National Security Forces in Contemporary American Society

Prerequisite: none. II (3 credits)

Focuses on the Armed Forces as an integral element of society. Provides examination of a broad range of American civil-military relations, and the environmental context in which defense policy is formulated. Special themes include: social attitudes toward the military; the role of the professional military leader-manager in a democratic society; the fundamental values and so-cialization processes associated with the Armed Services; the requisites for maintaining adequate national security forces; political, economic, and social constraints on the national defense structure; the impact of technological and international developments on strategic preparedness; the manifold variables involved in the formulation and implementation of national security policy.

411.
National Security Forces in Contemporary American Society

Prerequisite: none. II (3 credits)

Continuation of AS 410.

Note: A Leadership Laboratory (0 credit), meeting for one and one-half hour each week, accompanies each of the above listed AS courses.

Army Officer Education Program

Program Office: Room 131, North Hall
764-2400, 764-2401; *Scholarships*: 764-6479
Chair: Lieutenant Colonel Buchan
Assistant Chairs: Major Blanton, Captain Smith, and Captain White

Upon graduation and completion of program requirements, students receive a commission as second lieutenant in the United States Army Reserve or in the Regular 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. Others may apply for a Regular Army

commission (same as West Point commission) and enter active duty for worldwide assignment. Service in the Army's 97 career specialties provides an opportunity to practice skills gained during university life.

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 six-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 six-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 partial-to-full tuition and partial book fees. All advanced course students receive a $150/month stipend to help cover room and board. Engineering students may request an additional year of scholarship benefits if they are enrolled in a five-year program.

Army Fellowship Program

Each year the top five percent (based on GRE scores) of all students chosen for Regular Army commissions are awarded Army ROTC Fellowships. This award permits the recipient to pursue a course of study leading to a master's degree at the Army's expense while receiving full pay and allowances as a commissioned officer.

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 $1,100 per year in addition to the $150/month stipend previously mentioned.

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, Ordinance 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 land navigation, professional ethics, military writing and speaking, 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, and physical training. In addition, courses in human behavior, effective writing, mathematics, computer science, and military history are required for completion of the program.

Military Obligation

Students may request non-active duty assignments in the Army Reserve or National Guard in order to pursue graduate schooling or civilian careers; or they may request a limited period of active duty. All Advanced Course students are obligated to eight years of service which may be served in an active or reserve status depending on individual preference and Army needs.

Army Officer Education Courses

(*Military Science*)

101.
Army Officership and Their Critical Military Skills

Prerequisite: none. (1 credit)

The course explores the basic concepts of leadership, foundations of Army leadership doctrine, and leadership in action. These fundamental elements are tied to what the United States Army officer must be, know, and do to succeed in the profession of arms. The student will then turn to investigate several critical military skills to include basic tactics, rifle marksmanship, drill and ceremony, and the customs and traditions of the Army. Student evaluation is based on quizzes, written work, oral presentation, examination, and practical demonstration.

102.
Land Navigation

Prerequisite: none. (1 credit)

The objective of the course is to develop proficiency in a critical military skill. The student will learn to use a military map and lensatic compass to navigate over unfamiliar terrain. The course will emphasize map reading skills and terrain association techniques and will include two outdoor practical exercises. Specific topics include terrain features, the military grid reference system, determining and plotting azimuths, measuring route and straight line distances, methods of intersection and resection, aerial photographs, and the use of polar coordinates. Student evaluation is based on quizzes, practical exercises, and examinations.

103.
Leadership Laboratory

Prerequisite: none. (1 credit)

The 90 minute laboratory is required for all Advanced Course cadets and scholarship students. Advanced Course and scholarship cadets attend leadership laboratory every week. MS IV cadets occupy positions of responsibility in the Cadet Battalion and plan, coordinate, and conduct cadet training and activities under faculty guidance. MS III laboratories focus on developing basic military tactical skills in preparation for summer Advanced Camp.

201.
Military Leadership

Prerequisite: none. (1 credit)

The purpose of this course is to develop a basic understanding of military leadership. The course focuses on current military leadership theory and its organizational application. It will include discussions of leadership styles, principles of leadership, human behavior, principles of motivation, ethics, counseling, communication, and the military problem solving process. It also incorporates leadership assessment training and discussions of how leadership influences the achievement of organizational goals. Student evaluation is based on quizzes, exams, and oral presentations.

202.
History of the Military Art

Prerequisite: none. (1 credit)

History of the Military Art traces the evolution of the art of warfare by examining the development of generalship, strategy, tactics, theory, doctrine, professionalism, and logistics. The course will explore the fundamental principles of war that comprise the permanent elements of military science and strategy. Though there is no simple agreed list of principles, the course will attempt to cull from the record of historic campaigns and battles enduring elements of the art of war. Students will be expected to contribute to the classroom discussions and to master the significant details of major campaigns and battles. Student performance will be evaluated through a short paper and campaign briefing.

301.
Introduction to Small Unit Tactics

Prerequisite: none. (2 credits)

This course is a part of the Advanced Course for Army ROTC cadets. It is designed to provide the MS III cadet with three essential categories of officer skills: small unit tactical planning, map reading, and communications. Students receive instruction in leadership assessment, map reading, terrain analysis and squad and platoon level operations in offensive and defensive operations. Cadets are instructed on how to give a military briefing and are required to present an information briefing to the class. The course also includes an examination of historical examples of combat leadership. Evaluation of student performance will be done through the use of quizzes, exams, oral presentations, and a military history essay.

302.
Small Unit Tactics and Patrolling Operations

Prerequisite: none. (2 credits)

This course provides the cadet with a basic understanding of the tactical employment of the combined arms team and completes the cadet's preparation for the Army ROTC Advanced Camp. Instruction is based on current U.S. Army doctrine. The course emphasizes the missions, organization, and capabilities of the elements of Light Infantry Squad and Platoon. Instruction includes practical exercises involving offensive, defensive and partrolling participation operations. Students will be evaluated through quizzes, examinations, oral presentations, and one writing assignment.

401.
Military Law

Prerequisite: none. (2 credits)

This course is a part of the Advanced Course for Army ROTC cadets. The course is a seminar on the military justice system, military administrative law, and international law of war. After a brief survey of the evolution of the Uniform Code of Military Justice and its Constitutional basis, the course focuses on the officer's role in the military justice system. Topics include criminal and military offenses, rules of evidence, the conduct of searches and seizures, non-judicial punishment, investigations and preparation of charges, court-martial procedures, and international treaties and conventions dealing with the law of war. Students are expected to become familiar with the Manual for Courts-Martial and to make recommendations on charges and specifications consistent with the facts of a case, the rules of evidence, and the required elements of proof.

The student's knowledge is evaluated through quizzes, exams, and an essay.

402.
Military Professionalism and Professional Ethics
Prerequisite: none. (2 credits)
This course explores concepts of military professionalism and relates these concepts to issues in military ethics, the conduct of military operations, and national security. Contemporary military leadership issues will be explored. Selected professional development topics will also be addressed to facilitate the transition from cadet to lieutenant. Standards of conduct governing Army personnel will be presented to inform cadets of expected and proper behavior while in the service of the military. Students will be evaluated through the use of quizzes and examinations.

Navy Officer Education Program

Program Office: Room 103, North Hall, 764-1498
Chair: Captain Michael E. Riordan, USN
CDR Ringle; Lieutenants Ellis, Godsil, Gunderson, and Noordyk;
   Major Ammerman, USMC

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 appropriate sections in the general introduction to the Military Officer Education Programs. 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 Courses

101.
Introduction to Naval Science
Prerequisite: none. I (2 credits)
An introduction to the structure and principles of naval organization and management. Practices and the concepts behind naval organization and management are examined within the context of American social and industrial organization and practice.

102.
Seapower in American History
Prerequisite: none. II (3 credits)
This course focuses on the role of sea-power in American history, with emphasis on the U.S. Navy. The course includes discussions of: the development of U.S. naval power and its application as an instrument of foreign policy; the historical relationship of the Navy and the domestic political and economic environment; and the rise of the United States as a maritime power.

201. (NA 102)
Naval Ship Systems
Prerequisite: none. II (3 credits)
A study of the various propulsion plant designs found on naval ships. Steam engineering plants, diesel engineering plants, and gas turbine engineering plants are discussed along with ship design, ship stability, and auxiliary engineering equipment.

202. (EECS 250)
Electronic Sensing Systems
Prerequisite: preceded or accompanied by 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.

301. (Astron 261)
Navigation
Prerequisite: none. I (3 credits)
Theory, principles, and procedures of ship navigation including piloting, dead reckoning, celestial methods, and modern electronic navigation; practical sextant work, plotting on charts, and use of navigational publications.

302.
Naval Operations
Prerequisite: none. II (3 credits)
Principles of ship handling and fleet operations from the point of view of Officer of the Deck, including study of relative motion, communications, tracking, and rules of the road.

310.
Evolution of Warfare
Prerequisite: none. (3 credits)

**(History 389.)
Warfare Since the Eighteenth
Century**

Prerequisite: none. (4 credits) (taught in LS&A)

Basic study of the art of war, concepts of warfare, and evolution of warfare from beginning of recorded history to present. Special emphasis is placed on technological, tactical, and organizational innovations. Conceptual base is developed in the student by study of selective battles that have had major political, military, and social significance.

**401.
Leadership and Management I**

Prerequisite: none. I (2 credits)

Study of leadership and management theory, structure of organizations, decision theory, communications, authority, chain of command, behavioral science, the manager, and ethics.

**402.
Leadership and Management II**

Prerequisite: none. II (2 credits)

Study of naval organizational administration, human goals, race relations, equal opportunity, drug awareness. Uniform Code of Military Justice, and Junior Officer responsibility with emphasis on U.S. Navy application.

**410.
Amphibious Warfare**

Prerequisite: none. (3 credits)

History, development, and techniques of amphibious tactics. Course examines in detail significant amphibious operations of the twentieth century from Gallipoli to present.

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 with prior permission of the course instructor.

Course

Descriptions

The courses offered by the College of Engineering, and by certain closely associated departments of other units of the University, are listed. *Time Schedules* 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.

A Roman numeral may appear at the end of the title that indicates the position of the course in a sequence of courses on the same subject.

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:

I	fall	*See under "Term" for definitions*
II	winter	*relating to the several terms*
III	spring-summer	
IIIa	spring half	
IIIb	summer half	

The *italics* in parentheses indicates the hours of credit for the course; for example, *(3 credits)* denotes three credit hours, or, *(to be arranged)* denotes credit to be arranged.

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.

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

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 expected to have been mastered before electing the course (or, in some cases, concurrent with).

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.

Aerospace Engineering

Department Office
3054 François-Xavier
Bagnoud Building
(313) 764-3310

(Division 235)

David C. Hyland, Ph.D., *Professor and Chair*

Professor

William J. Anderson, Ph.D.
James F. Driscoll, Ph.D.
Joe G. Eisley, Ph.D.
Gerard M. Faeth, Ph.D,
*Arthur B. Modine
Professor of Aerospace
Engineering*
Paul B. Hays, Ph.D.,
*Dwight F. Benton
Professor of Advanced
Technology; also
Atmospheric, Oceanic
and Space Sciences*
Pierre T. Kabamba, Ph.D.;
*also Electrical Engineer-
ing and Computer
Science*
C. William Kauffman, Ph.D.
Arthur F. Messiter, Jr., Ph.D.
Philip L. Roe, B.A.
Martin Sichel, Ph.D.
John E. Taylor, Ph.D.; *also
Mechanical Engineering
and Applied Mechanics*
Bram van Leer, Ph.D.
Nguyen X. Vinh, Ph.D., Sc.D.

Professor Emeritus

Thomas C. Adamson, Jr.,
Ph.D.
Frederick L. Bartman, Ph.D.;
*also Atmospheric,
Oceanic and Space
Sciences*
Frederick J. Beutler, Ph.D.;
*also Electrical Engineer-
ing and Computer
Science*
Harm Buning, M.S.E.
Elmer G. Gilbert, Ph.D.
Donald T. Greenwood, Ph.D.
Robert M. Howe, Ph.D.
Arnold M. Kuethe, Ph.D.
Edgar J. Lesher, M.S.E.
Vi-Cheng Liu, Ph.D.
James A. Nicholls, Ph.D.
Richard L. Phillips, Ph.D.
Lawrence L. Rauch, Ph.D.
William L. Root, Ph.D.
Pauline M. Sherman, M.S.
William W. Willmarth, Ph.D.

Associate Professor

Luis P. Bernal, Ph.D.
Dennis S. Bernstein, Ph.D.
Werner J.A. Dahm, Ph.D.
Kenneth G. Powell, Sc.D.
Nicolas Triantafyllidis, Ph.D.
Anthony M. Waas, Ph.D.
Peter D. Washabaugh, Ph.D.

Assistant Professor

Vincent T. Coppola, Ph.D.
Alec D. Gallimore, Ph.D.

Adjunct Professor

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

Lecturer

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

200. Introduction to Aerospace Engineering

Prerequisites: Physics 140, Math 116, Eng 103. I, II (3 credits)

Historical background. The aerospace environment: the atmosphere and deep space.
Basic aerodynamics: incompressible and compressible flow. Air-speed measurement.
Aerodynamic forces: lift, drag, and pitching moment. Elements of airplane performance
and stability. Elementary principles of space flight. Propulsion.

301. Laboratory I

Prerequisite: preceded or accompanied by EECS 314. I, II (3 credits)

Comprehensive series of lectures and experiments designed to introduce the student to basic principles of instrumentation, experimentation, measurement, and data analysis. Topics include electronics, electromechanical transducers, optics, and their implementation in modern laboratory instrumentation.

302. Laboratory II

Prerequisites: Aero 301, preceded or accompanied by Aero 330. I, II (3 credits)

Advanced lectures and experiments on the underlying principles of instrumentation, experimentation, and measurement in aerospace engineering. Experiments involve synthesis of elementary concepts in instrumentation and measurement, and culminate in a student-designed experimental project.

314. Structural Mechanics I

Prerequisites: ME 210, preceded or accompanied by Aero 350. I, II (3 credits)

Review of plane states of stress and strain; basic equations of plane elasticity and selected problems; failure criteria and applications; energy principles of structural theory; thin-walled beam theory.

320. Introduction to Gas Dynamics I

Prerequisites: ME 235, preceded or accompanied by Aero 350. I, II (3 credits)

Physical properties of gases; conservation laws for mass, momentum and energy. One-dimensional isentropic flow; stagnation and critical conditions; nozzles and diffusers. Normal shock waves; oblique shocks; expansions. One-dimensional flow with friction and heat addition.

330. Introduction to Gas Dynamics II

Prerequisite: Aero 320 or introductory course in fluid mechanics. I, II (3 credits)

Viscous stresses; elementary viscous flows. The boundary-layer approximation; laminar boundary layers; pressure gradient and compressibility; heat transfer. Instability and transition to turbulence. General description of turbulent flows; turbulent boundary-layer structure and modeling.

340. Mechanics of Flight

Prerequisites: Aero 200, ME 240. I, II (3 credits)

Mechanics of an aircraft as a rigid body; translational and rotational equations of motion. Trim conditions for steady level flight; conditions for static stability. Development of linearized differential equations which describe aircraft perturbed motions. Use of linear systems concepts to analyze aircraft motions. Longitudinal stability and control. Lateral stability and control.

350(Math 350). Aerospace Engineering Analysis

Prerequisite: Math 216 or Math 316 or the equivalent. I, II (3 credits)

Formulation and solution of some of the elementary initial- and boundary-value problems relevant to aerospace engineering. Application of Fourier series, separation of variables, and vector analysis to problems of forced oscillations, wave motion, diffusion, elasticity, and perfect-fluid theory.

351. Computational Methods in Aerospace Vehicle Analysis and Design

Prerequisites: Aero 200, 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.

380. Undergraduate Seminar

Prerequisite: junior standing. (1 credit)

A series of seminars by noted outside speakers designed to acquaint undergraduates with both current problems and state of the art aerospace industry. Will involve a short term project or paper pertinent to one of the seminar topics.

390. Directed Study

(to be arranged)

Individual study of specialized aspects of aerospace engineering.

411(CEE 411)(NA 411). Finite Element Applications

Prerequisites: Eng 103, ME 211. I, II, IIIa (3 credits)

The application of user-oriented finite element computer programs for solving practical structural mechanics problems of frames, 2-D and 3-D solids, plates, shells, etc., and displaying the solutions graphically. Students learn to prepare input data and interpret results. A short introduction to the underlying theory is also presented.

414. Structural Mechanics II

Prerequisite: Aero 314. I, II (3 credits)

Introduction to plate theory. Stability of structural elements; columns and beam columns; plate in compression and shear; secondary instability of columns. Introduction to matrix methods of deformation analysis; structural dynamics.

416(CEE 514). Theory of Plates and Shells

Prerequisites: ME 210, Math 450 or Aero 350. (3 credits)

Linear elastic plates. Membrane and bending theory of axisymmetric and non-axisymmetric shells. Approximate treatment of edge effects. Finite element techniques for plate and shell problems.

420. Aerodynamics I

Prerequisites: Aero 320, preceded or accompanied by Aero 330. I, II (3 credits)

Kinematics and dynamics of incompressible irrotational flow; velocity potential; stream function; Euler and Bernouli equations. Thin-foil theory; lift and moment for cambered airfoils. Finite-wing theory; induced drag. Compressible flow; small-disturbance theory; thin wings at subsonic and supersonic speeds.

430. Aerospace Propulsion

Prerequisite: Aero 320. I, II (3 credits)

Fundamentals of propulsion: performance parameters, thermodynamic cycles, introduction to combustion. Performance analysis of various flight propulsion systems: turbo-jets, turbo-fans, ramjets, rockets, propellers.

440. Aerospace Vehicle Systems Performance

Prerequisites: Aero 340, preceded or accompanied by Aero 420. II (3 credits)

Performance of aerospace vehicles in atmospheric flight. Vehicle modeling and performance indices. Parametric optimization with constraints. The aircraft performance problems: aerodynamic and propulsive forces; flight envelope; glide, cruise, climb, turning, takeoff and landing performance. Performance of hypervelocity re-entry vehicles.

443. Spaceflight Dynamics

Prerequisite: Aero 340. I (3 credits)

Introduction to orbital mechanics and the two body problem for spacecraft: orbit equations, Kepler's equation, orbital changes, orbit perturbations. Spacecraft attitude dynamics: Euler's equations, equations for spacecraft orientation, attitude control, gravity gradient stabilization, gyroscopes, dual spin spacecraft.

447. Flight Testing

Prerequisites: Aero 302 and Aero 340. 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.

452(EECS 401). Probabilistic Methods in Engineering

Prerequisite: junior standing. I, II, III (3 credits)

Basic concepts of probability theory. Random variables: discrete, continuous, and conditional probability distributions, averages, independence. Introduction to discrete and continuous random processes: wide sense stationarity, correlation, spectral density.

464(AOSS 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.

471. Automatic Control Systems

Prerequisite: Aero 340. I, II, IIIa (3 credits)

Automatic control problems; solution approach using feedback. Transfer function and state space description of linear control systems. Control design criteria; stability, sensitivity, time response. Use of Routh-Hurwitz, root-locus, Nyquist, Bode methods for control design. Application to design of automatic control systems for flight vehicles.

481. Aircraft Design

Prerequisites: Aero 340, senior standing. I, II (4 credits)

Integration of the disciplines of aircraft aerodynamics, performance, stability and control, structures, and propulsion in a single-system approach to create the configuration of an aircraft to perform a specific mission. Determination of takeoff weight, choice of aero-dynamic configuration, selection and integration of power plant, landing gear selection and design, control surface sizing and cost analysis, among other topics.

483. Aerospace System Design

Prerequisite: senior standing. II (4 credits)

Aerospace system design, analysis and integration. Consideration of launch facilities, booster systems, spacecraft systems, communications, data processing, and project management. Lectures and laboratory.

484. Computer Aided Design

Prerequisites: Aero 414, senior standing. I (4 credits)

Computer generation of geometric models; preprocessing, analysis, and post process-ing of finite element models; mechanism design. System design, analysis, and integration. Student teams will each complete a system design project emphasizing the use of industry standard applications software.

490. Directed Study

(to be arranged)

Individual study of specialized aspects of aerospace engineering. Primarily for undergraduates.

495. Special Topics in Aerospace Engineering

Prerequisite: permission of instructor. Term offered depends on special topic.
    Credit for course is to be arranged.

510. Finite Elements in Mechanical and Structural Analysis I

Prerequisite: Aero 414. I (3 credits)

Introductory level. Development of the linear finite element displacement method. Virtual work. Application to trusses, beams, plates, shells, and solids. Stress, displacement,

strain energy. Computer laboratory based on a general purpose finite element code. Term project.

511. Finite Elements in Mechanical and Structural Analysis II

Prerequisite: Aero 510 or AM 505(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.

512. Experimental Solid Mechanics

Prerequisites: Aero 302, Aero 414 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, optics, particle scattering, and tomography.

514. Foundations of Solid Mechanics

Prerequisite: Aero 414 or equivalent. I (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.

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.

516. Mechanics of Fibrous Composites

Prerequisite: Aero 414 or AM 412(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.

518(AM 518). Theory of Elastic Stability I

Prerequisite: AM 407. I (3 credits)

Elastic and inelastic buckling of bars and frameworks; variational principles and numerical solutions; lateral buckling of beams. Instability of rings.

520. Compressible Flow I

Prerequisite: Aero 420. 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.

521. Experimental Methods in Fluid Mechanics

Prerequisite: senior standing. II (3 credits)

Fundamental principles of modern flow facilities and advanced instrumentation: mechanics, analog and digital electronics, optics. Digital data acquisition and analysis; turbulent flow measurement; power spectrum estimation; conditional sampling techiques. Flow visualization, two- and three-dimensional velocity field measurement. Digital image analysis, contrast enhancement, pattern recognition. Lecture and laboratory.

522. Viscous Flow

Prerequisites: Aero 330, Aero 420. II (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.

523(AM 523)(ME 523). Computational Fluid Dynamics I

Prerequisite: preceded or accompanied by Aero 520 or AM 520(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.

524. Aerodynamics II

Prerequisite: Aero 420. 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.

525. Introduction to Turbulent Flows

Prerequisite: Aero 522. I (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 luctuating structure of free and wall-bounded turbulent flows.

529. Heat Transfer in Aerospace Systems
Prerequisite: Aero 330. II (3 credits)

Introduction to heat transfer processes including unsteady conduction, convection in non-reactive and reactive flows, and radiation. Aerospace applications including re-entry heat transfer, ablation, rocket nozzle cooling, convection in dissociated flows, and radiation transfer in spacecraft.

530. Turbojet Propulsion
Prerequisite: Aero 430. 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.

531. Experimental High-Temperature Gas Dynamics
Prerequisite: senior standing. II (3 credits)

Lectures and experiments to give students experience in measuring properties of high temperature reactive gases and in visualizing flow patterns using modern laser diagnostics. Laser velocimetry, Schlieren and laser light sheet flow visualization, spectroscopy and fluorescent diagnostics used in flames and supersonic flows. Lab reports required.

532(AOSS 596). Gaskinetic Theory
Prerequisite: graduate standing. I (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, Chapman-Enskog transport theory. Aerodynamics of free-molecular flow. Shock waves.

533. Combustion Processes
Prerequisite: Aero 320. (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.

535. Rocket Propulsion
Prerequisite: Aero 430. 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.

540. Intermediate Dynamics
Prerequisite: ME 240. I (4 credits)

Kinematics of motion, particle dynamics, Lagrange's equations. Rigid body dynamics including Euler's equations, the Poinsot construction, spin stabilization, the rotation matrix. Vibrations of coupled systems, orthogonality relationships, generalized coordinates and generalized system parameters.

541. Computational Dynamics
Prerequisite: Aero 540. I (3 credits)

Formulation of dynamics problems for computer solution. Kinematic preliminaries. Matrix and dyadic notation. Constraints, generalized coordinates, and quasi-coordinates. Generalized speeds. Rigid and flexible multi-body dynamics. Computational efficiency.

543. Structural Dynamics
Prerequisite: Aero 414 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.

544. Aeroelasticity
Prerequisite: Aero 414 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.

545. Principles of Helicopter and V/STOL Flight
Prerequisite: preceded or accompanied by Aero 420. I (3 credits)

Introduction to helicopter performance, aerodynamics, stability and control, vibration and flutter. Other V/STOL concepts of current interest.

546. Advanced Dynamics
Prerequisite: Aero 540 or AM 443(ME 443). II (3 credits)

Hamilton's equations, canonical transformations, and Hamilton-Jacobi theory. Applications to orbital problems. General perturbation theory. Introduction to special relativity.

548. Astrodynamics
Prerequisite: Aero 443. II (3 credits)

Motion of aerospace vehicles in space. Orbit determination. Orbit transfer. The restricted three-body problem. Canonical equations of motion. Perturbation theory with application to the motion of artificial satellites.

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.

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.

552(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-square estimation, and convergence of random sequences.

553(EECS 502). Stochastic Processes
Prerequisite: EECS 501. II (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, auto-regression). Renewal and regenerative processes, Markov chains, random walk and run, branching processes, Markov jump processes, uniformization, reversibility, and queueing applications.

564(Mfg 564). Computer Aided Design and Manufacturing
Prerequisite: Aero 484 or ME 454 or permission of instructor based on familiarity with industrial standard CAE software. II (3 credits)

Computer generation of geometric models, optimal design for manufacturing, manufacturing methods based on geometric models such as numerical control tool path generation, plastic mold design and rapid prototyping using stereolithography. Testing and redesign.

565(AM 565). Optimal Structural Design
Prerequisites: Aero 414, Aero 350. I (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.

570. Guidance and Navigation of Aerospace Vehicles

Prerequisite: Aero 550. II (3 credits)

Principles of guidance and navigation in two and three dimensions. Explicit, linear perturbation, and velocity-to-be gained guidance modes. Mechanization by inertial and other means, including strapped-down and stable-platform inertial systems. Celestial navigation procedures with redundant measurements. Application of Kalman filtering to recursive navigation theory.

571(EECS 561)(ME 561). Design of Digital Control Systems

Prerequisite: EECS 460 or Aero 471 or ME 461. I, II (4 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. Computer simulations and laboratory implementation of real-time control systems.

574. Control of Aircraft and Space Vehicles

Prerequisites: Aero 471, Aero 550. II (3 credits)

Feedback control techniques for aircraft, rockets, and space vehicles. Analysis and synthesis of autopilots for aircraft. Attitude control systems for space vehicles; use of gas jets and momentum wheels.

575. Optimization of Space Trajectories

Prerequisite: permission of instructor. I (3 credits)

Introduction to optimal control. Switching theory. Applications to aerospace trajectories: orbital transfer and rendezvous, atmospheric reentry, aero-assisted transfer.

576(EECS 563). Optimal Control

Prerequisites: Aero 550 (EECS 560). II (3 credits)

Definition of optimal control problems. Formulation of discrete time optimal control problems as constrained mathematical programming problems. Formulation of continuous time optimal control problems as variational problems. The Pontryagin necessary condition. Application to a variety of specific optimal control problems from diverse disciplines. Introduction to computational methods in optimal control.

577(EECS 505)(IOE 511)(Math 562). Continuous Optimization Methods

Prerequisites: Math 217, Math 417 or Math 419. I, II (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.

578(EECS 564). Estimation, Filtering, and Detection

Prerequisites: 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.

579. Control of Aerospace Structures

Prerequisites: Aero 471, Aero 414, Aero 550. II (3 credits)

Equations of motion of controlled elastic structures; modal and finite element formulations; shape control; active damping using feedback; application to control of flexible aircraft and flexible space structures.

580(EECS 565). Linear Feedback Control Systems

Prerequisites: EECS 460 or Aero 471 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.

Mike Hess (BSE Aero '91 and BSE ME '91) and Tricia Mack (BSE Aero '94) are also graduates at the Extravehicular Activities (EVA) Section at the NASA/Johnson Space Center. Hess is shown preparing for a training event in the Weightless Environment Training Facility (WETF) where he will wear an Extravehicular Mobility Unit (space suit) under water to simulate the weightlessness of space.

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.

582(AOSS 582). Spacecraft Technology
Prerequisite: graduate standing. I (3 credits)
A systematic and comprehensive review of spacecraft and space mission technology, including trajectory and orbital mechanics, propulsion systems, power and thermal systems, structures, control, and communications.

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.

590. Directed Study
(to be arranged)
Individual study of specialized aspects of aerospace engineering. Primarily for graduates.

592. Space Systems Projects
Prerequisite: senior or graduate standing. Term to be arranged. (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.

595. Seminar
Prerequisite: senior or graduate standing. Term to be arranged. (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.

596. Projects
Prerequisite: graduate standing in Master of Engineering program. Term to be arranged. (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.

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.

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.

614(CEE 614). Advanced Theory of Plates and Shells

Prerequisites: Aero 416, CEE 514. II (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.

615(AM 649)(CEE 615)(ME 649). Random Vibrations

Prerequisite: CEE 513 or ME 541(AM 541) or Aero 543. II (3 credits)

Accelerated coverage of elements of probability theory. Characterization of random processes and fields. Correlation and spectral density functions. Response of linear discrete and continuous systems to random excitation. Introduction to problems involving random systems. Maxima and minima of random processes. Applications to problems of engineering interest.

618(AM 618). Theory of Elastic Stability II

Prerequisites: 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.

620. Dynamics of Turbulent Shear Flows

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.

621. Compressible Flow II

Prerequisite: Aero 520. II (3 credits)

Characteristics theory and flows with shock waves, including various examples of unsteady flows and steady supersonic flows. Linear and nonlinear small-disturbance approximations, with applications to acoustics, three-dimensional steady supersonic flows, transonic and hypersonic flows.

623. Computational Fluid Dynamics II

Prerequisites: 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.

627. Topics in Advanced Fluid Mechanics

Prerequisites: 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.

632. Gas Flows with Chemical Reactions

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.

651(EECS 600)(IOE 600). Function Space Methods in System Theory

Prerequisite: EECS 400 or Math 419. I, 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.

672(EECS 662)(MEAM 662). Advanced Nonlinear Control

Prerequisite: EECS 562 or MEAM 548 or permission of instructor. 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.

714. Special Topics in Structural Mechanics

Prerequisite: permission of instructor. Term offered depends on special topic. Credit for course is to be arranged.

729. Special Topics in Gas Dynamics
Prerequisite: permission of instructor. (to be arranged)
Advanced topics of current interest.

740. Special Topics in Flight Dynamics and Control Systems
(to be arranged)

800. Seminar
(to be arranged)

810. Seminar in Structures
(to be arranged)

820. Seminar in Aerodynamics
(to be arranged)

830. Seminar in Propulsion
(to be arranged)

840. Dynamics and Control Systems
(to be arranged)

850. Space Systems Seminar
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.

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

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

Applied Mechanics

(Division 239)

Academic Services Office
2206 G.G. Brown Building
(313) 763-4277

*Administered by the Department of Mechanical
Engineering and Applied Mechanics.
See page 410 for faculty list.*

401(ME 401)(Mfg 402). 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.

402(ME 402). Experimental Stress Analysis

Prerequisites: ME 211, Math 216. I (3 credits)

Review of plane stress-strain relationships; fundamentals of photoelastic method
of stress determination using transmission polariscope and methods of separating
principal stresses; theory and application of brittle coatings; fundamentals of Moiré
fringe method of strain analysis; techniques of mechanical, optical, and electrical
resistance strain gages and related circuitry. Lectures and laboratory experiments.

404(ME 404). Coherent Optical Measurement Techniques

Prerequisite: senior or graduate standing. II (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.

412(ME 412). Advanced Strength of Materials

Prerequisite: ME 311. II (3 credits)

Review of energy methods, Betti's reciprocal theorem; elastic, thermo-elastic and
elasto-plastic 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.

419(ME 419). Mechanics of Composite Materials

Prerequisites: ME 211, ME 240. II (3 credits)

Classification and characterization of composite materials. Behavior in the elastic range.
Stress-strain relations for anisotropic media. Orthotropic laminae. Plane problems.
Theory of anisotropic plates. Bending, buckling and vibrations of laminated plates.

441(ME 441). Intermediate Vibrations

Prerequisite: ME 240. I, II, IIIa (3 credits)

Transient and forced single-degree-of-freedom linear vibrations; support motion, rotating unbalance, vibration isolation. Linear multiple-degree-of-freedom systems, analysis by matrix and approximate methods. Lagrange formulation. Continuous systems, modal summation.

442(ME 442). Analysis and Synthesis of Motion

Prerequisite: ME 240. II (3 credits)

Particle and rigid body kinematics in 3-D rotating reference frames. Algebraic and graphical analysis and synthesis of planar mechanisms. Coordinate translations and rotations, homogeneous displacement matrices. Solution of direct kinematics problem. Euler and Rodrigues parameters. Solution of indirect kinematics problem. Computer projects. Applications to robotics.

443(ME 443). Intermediate Dynamics

Prerequisite: ME 240. I, II (3 credits)

Vector Kinematics in 3-D, rotating coordinate systems. Systems of particles. Rigid body inertial properties. Rigid body dynamics: Euler equations, direct and inverse dynamic problems, bearing reactions, tops and gyroscopes.

456(BiomedE 456)(ME 456). Biomechanics

Prerequisites: ME 211, ME 240. II (3 credits)

Definition of biological tissue behaviors, including elastic, viscoelastic, and plastic properties, with emphasis on bone; dynamics of gait; impact and tolerance criteria in vehicle design for human safety; prosthetic and orthotic mechanics and design.

495(BiomedE 495). Introduction to Bioengineering

Prerequisite: permission of instructor. I (1 credit)

Definition of scope, challenge, and requirements of bioengineering field; faculty members review engineering-life sciences interdisciplinary activities as currently pursued in the College of Engineering and Medical School.

501(ME 501). Analytical Methods in Mechanics I

Prerequisites: ME 211, ME 240, Math 216. I (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.

502(ME 502). Methods of Differential Equations in Mechanics

Prerequisite: Math 454. II (3 credits)

Applications of differential equation methods of particular use in mechanics. Boundary value and eigenvalue problems are particularly stressed for linear and non-linear

elasticity, analytical dynamics, vibration of structures, wave propagation, fluid mechanics, and other applied mechanic topics.

503(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.

504(ME 504). Principles and Applications of Variational Methods

Prerequisite: AM 443(ME 443). 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.

505(ME 505). Finite Element Methods in Mechanical Engineering and Applied Mechanics

Prerequisites: AM 501(ME 501), ME 311, ME 320, or ME 370. 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.

511(ME 511). Theory of Solid Continua

Prerequisite: ME 211 and 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.

512(ME 512). Theory of Elasticity

Prerequisite: AM 511(ME 511) or AM 412(ME 412). I (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. Asymmetric contact and crack problem. Asymmetric torsion.

514(ME 514). Nonlinear Fracture Mechanics

Prerequisite: AM 412(ME 412). II (3 credits)

Elements of solid mechanics, historical development of fracture mechanics, energy release rate of cracked solids, linear elastic fracture mechanics, elastic-plastic fracture mechanics.

515(ME 515). Contact Mechanics

Prerequisites: ME 311 or ME 350. I (alternate and even years) (3 credits)

Hertzian elastic contact; elastic-plastic behavior under repeat loading; shake-down. 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.

517(ME 517)(MacroSE 517). Theory of Linear Viscoelasticity I

Prerequisite: AM 511(ME 511) or permission of instructor. II (3 credits)

Constitutive equation for linear isothermal viscoelastic response; constant stress or strain rate response; sinusoidal oscillations and the complex modulus, bending and torsion; three-dimensional response; correspondence theorem and boundary value problems for elastic and viscoelastic response; Laplace transform and numerical solution methods.

518(Aero 518). Theory of Elastic Stability I

Prerequisite: AM 511(ME 511). I (3 credits)

Elastic and inelastic buckling of bars and frameworks; variational principles and numerical solutions; lateral buckling of beams. Instability of rings.

519(ME 519). Theory of Plasticity I

Prerequisite: AM 511(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. Applications to problems of bending, torsion, plane strain and plane stress; technological problems.

520(ME 520). Advanced Fluid Mechanics I

Prerequisite: ME 320. I, II (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.

521(ME 521). Advanced Fluid Mechanics II

Prerequisite: AM 520(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.

523(Aero 523)(ME 523). Computational Fluid Dynamics I

Prerequisite: preceded or accompanied by Aero 520 or AM 520(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.

527(ME 527). Multiphase Flow

Prerequisite: AM 520(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.

541(ME 541). Mechanical Vibrations

Prerequisite: AM 441(ME 441). I (3 credits)

Time and frequency domain mathematical techniques for linear system vibrations. Equations of motion of discrete nonconservative 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.

543(ME 543). Analytical and Computational Dynamics I

Prerequisite: AM 443(ME 443). 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 proper-ties, generalized forces, Gibb's function, Routhian, Kanes's equations, Hamilton's principle, LaGrange's equations, holonomic and nonholonomic constraints, constraint processing, computational simulation.

565(Aero 565). Optimal Structural Design

Prerequisite: Aero 414 or Aero 435. 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.

590. Engineering Practice and Problem Solving in Applied Mechanics

Prerequisite: graduate standing. I, II, IIIa, IIIb (3 credits)

An individual study course designed for the master's degree candidate. Student and individual faculty members will select a problem of mutual interest and appropriate depth and complexity. The course is designed to develop the ability to do background research, to select analytical and computational models, and to utilize experimental evidence.

605(ME 605). Advanced Finite Element Methods in Mechanics

Prerequisite: AM 505(ME 505) or CEE 510(NA 512). II (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.

618(Aero 618). Theory of Elastic Stability II

Prerequisites: Aero 518 or equivalent, 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.

619(ME 619). Theory of Plasticity II

Prerequisite: AM 519(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.

622(ME 622). Inviscid Fluid

Prerequisite: AM 520(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.

623(ME 623). Hydrodynamic Stability

Prerequisite: AM 520(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.

624(ME 624). Turbulent Flow

Prerequisite: AM 520(ME 520). I (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.

625(ME 625). Nonhomogenous Fluids

Prerequisite: AM 520(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 nonhomogenous fluids in porous media. Analogy with rotating fluids.

626(ME 626). Perturbation Methods for Fluids

Prerequisite: AM 520(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.
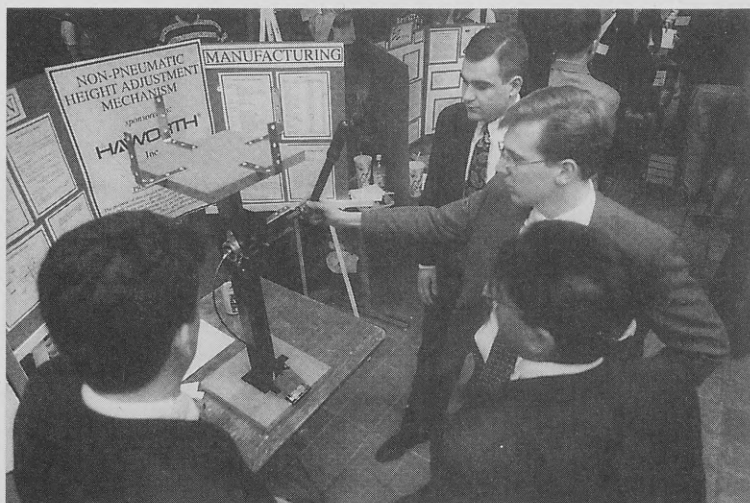
627(ME 627)(NA 627). Wave Motion in Fluids

Prerequisite: AM 520(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.

641(ME 641). Advanced Vibrations of Structures

Prerequisite: AM 541(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.

643(ME 643). Analytical and Computational Dynamics II

Prerequisite: AM 543(ME 543). II (alternate years) (3 credits)

Kinematic 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.

645(ME 645). Wave Propagation in Elastic Solids

Prerequisite: ME 541(AM 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.

648(ME 648). Nonlinear Oscillations and Stability of Mechanical Systems

Prerequisite: AM 541(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.

649(Aero 615)(CEE 615)(ME 649). Random Vibration

Prerequisite: CEE 513 or AM 541(ME 541) or Aero 543. II (3 credits)

Accelerated coverage of elements of probability theory. Characterization of random processes and fields. Correlation and spectral density functions. Response of linear discrete and continuous systems to random excitation. Introduction to problems

involving random systems. Maxima and minima of random processes. Applications to problems of engineering interest.

662(Aero 672)(EECS 662). Advanced Nonlinear Control
Prerequisite: EECS 562 or MEAM 548 or permission of instructor. 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.

699. Advanced Special Topics in Applied Mechanics
Prerequisite: permission of instructor. I, II, IIIa, IIIb, III (to be arranged)
Advanced selected topics pertinent to applied mechanics.

790(ME 790). Mechanical Sciences Seminar
Prerequisites: candidate status in MEAM. I (1 credit)
Every Ph.D. student in the field of mechanical sciences is requested 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.

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.

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

Applied Physics * ** (Division 320)

Department Office
2071 Randall Laboratory
(313) 936-0653

College of Literature, Science and the Arts
**College of Engineering*

Professor Roy Clarke, *Director*

Professors Allen, Atzmon, Bhattacharya, Bilello, Dierker, Gilgenbach, Gland, Haddad, Kapteyn, Kopelman, Lau, Merlin, Mourou, Murnane, Orr, Pang, Pavlidis, Rand, Ross, Sander, Singh, Srolovitz, Steel, Uher, Winful, Yalisove, Zorn.

See page 225 for statement on Course Equivalence.

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.

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.

530(EECS 530). Electromagnetic Theory I
Prerequisite: EECS 332 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.

540(EECS 540). Applied Quantum Mechanics I
Prerequisite: EECS 300 or Math 404, Physics 242. I (3 credits)
Introduction to nonrelativistic quantum mechanics. Summary of classical mechanics; one dimensional quantum problems including quantum wells, WKB approximation, tunneling and the harmonic oscillator; introduction to angular momentum; the

hydrogen atom; molecular orbitals; the rigid rotator and diatomic molecules; spin and identical particles; and time independent perturbation theory.

541(EECS 541). Applied Quantum Mechanics II

Prerequisite: AP 540 or EECS 540. I (3 credits)

Advanced theory of angular momentum, time dependent perturbation theory, quantization of fields, second quantization for bosons and fermions, scattering theory, the density matrix, reservoir theory.

550(EECS 538)(Physics 650). Lasers and Electro-Optics I

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.

551(EECS 539)(Physics 651). Lasers and Electro-Optics II

Prerequisite: AP 550(EECS 538)(Physics 650). II (3 credits)

Laser resonators, eigenmodes, and stability analysis; rate equation analysis; homogeneous and inhomogeneous broadening mechanism; laser gain and gain saturation; Q-switching and mode locking. Special topics: laser pulse compression; Raman and Brillouin scattering; phase conjugation.

560. Classical Mechanics and Electromagnetism I

Prerequisite: EECS 331 or Physics 405. I (3 credits)

Mechanics (Discrete Systems): linear systems: small oscillations, linear response, dissipation; variational methods (analytic and numerical), Lagrange's equations, action; Hamilton's equations, phase space, Liouville's theorem, symmetries and conservation laws; nonlinear systems; local stability, period-doubling, chaos, noise; two body problem, scattering, planetary motion, perturbative methods; (Continuous Systems): elasticity and tensors, soap films and Laplace's equation, variational and perturbative methods; waves in homogeneous and inhomogeneous media, mechanical impedance, scattering, nonlinear phenomena and solitons. Electromagnetism: electrostatics; magnetostatics; multipole expansions, conservation laws.

561. Classical Mechanics and Electromagnetism II

Prerequisite: AP 560. II (3 credits)

Electromagnetism: energy and momentum in electromagnetic fields; special relativity, tensor formalism; propagation of electromagnetic waves in vacuum; Doppler effect; interaction of light with matter: linear and nonlinear response, Kramers-Kronig relations, harmonic generation, plasma oscillations, optical traps; waves in confined geometries: waveguides, cavities, optical fibers; scattering: Rayleigh, Brillouin, Raman; radiation from moving charges: multipole expansions, antennas, synchrotron radiation; motion of charges in magnetic fields: plasmas, guiding-center approximation; adiabatic invariants.

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.

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.

611(EECS 634)(Physics 611). Nonlinear Optics

Prerequisite: EECS 530, EECS 537, or EECS 538 or permission of instructor. (3 credits)

Variety of nonlinear optical phenomena, formalism of nonlinear optics — the non-linear susceptibility, wave propagation in nonlinear media, the slowly-varying envelope approximation, effects due to the second-order nonlinear susceptibility — second harmonic generation, sum frequency generation, parametric amplification and oscillation, phase-matching considerations; effects due to the third-order nonlinear susceptibility — self-focusing, self-phase modulation, four-photon interactions, third harmonic generation, optical bistability, phase conjugation; Stimulated scattering processes — Raman, Brillouin, Rayleigh; Nonlinear phenomena in optical fibers–soliton propation, pulse compression, polarization instabilities; nonlinear dynamics in optics–chaos, bifurcations, arrays of coupled nonlinear devices, spatio–temporal dynamics.

619(Physics 619). Advanced Solid State

Prerequisites: Physics 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.

633(Physics 633). Fluid Dynamics

(3 credits)

The course begins with a derivation of the hydrodynamical equations as proto-typical 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.

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.

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.

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.

674(NERS 674). High-Intensity Laser Plasma Interactions

Prerequisites: 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.

Atmospheric, Oceanic and Space Sciences

(Division 241)

Department Office
2243 Space Research
Building
(313) 764-3335
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Lennard A. Fisk, Ph.D., *Professor of Atmospheric Science and Chair*
S. Roland Drayson, Ph.D., *Professor of Atmospheric Science and Associate Chair for Academic Affairs*

Professor

Sushil K. Atreya, Ph.D.
Atmospheric Science
Peter M. Banks, Ph.D.,
Atmospheric, Oceanic and Space Sciences; also Electrical Engineering and Computer Science
John R. Barker, Ph.D.,
Atmospheric Science; also Chemistry
John P. Boyd, Ph.D.,
Atmospheric and Oceanic Science, also Director, Ph.D. Program in Scientific Computing
Anthony W. England, Ph.D.,
Atmospheric, Oceanic and Space Sciences; also Electrical Engineering and Computer Science
Tamas I. Gombosi, Ph.D.,
Atmospheric Science; also Aerospace
Paul B. Hays, Ph.D.,
Dwight F. Benton Professor of Advanced Technology; also Aerospace Engineering
Stanley J. Jacobs, Ph.D.,
Oceanic Science
Timothy L. Killeen, Ph.D.,
Atmospheric Science

William R. Kuhn, Ph.D.,
Atmospheric Science
Andrew F. Nagy, Ph.D.,
Atmospheric Science; also Electrical Engineering and Computer Science
Joyce Penner, Ph.D.,
Atmospheric Science
Perry J. Samson, Ph.D.,
Arthur F. Thurnau Professor of Atmospheric Science; also Environmental and Industrial Health, School of Public Health
John Vesecky, Ph.D.,
Atmospheric Science
James C. G. Walker, Ph.D.,
Arthur F. Thurnau Professor of Atmospheric Science; also Geological Sciences

Professor Emeritus

Frederick L. Bartman, Ph.D.,
Atmospheric Science; also Aerospace Engineering
Albert Nelson Dingle, Sc.D.,
Atmospheric Science

Thomas M. Donahue, Ph.D.,
Edward H. White II Distinguished University Professor Emeritus of Planetary Science; also Physics
Ernest G. Fontheim, Ph.D.
Donald J. Portman, Ph.D.,
Atmospheric Science

Adjunct Professor

George R. Carignan
Atmospheric Science; also Associate Dean for Graduate Education and Research of the College of Engineering
George Gloeckler, Ph.D.

Visiting Professor

Paul Drake, Ph.D.; *also Plasma Physics*

Associate Professor

Dennis G. Baker, Ph.D.,
Atmospheric Science
Mary Anne Carroll, Ph.D.,
Atmospheric Science; also Chemistry

Gerald Keeler, Ph.D.;
*also School of Public
Health*
Guy A. Meadows, Ph.D.,
Oceanic Science; also
Naval Architecture and
Marine Engineering

Adjunct Associate Professor
Hal Marshall, Ph.D.,
Atmospheric Science

Assistant Professor
Brian E. Gilchrist,
Ph.D.; *also
Electrical
Engineering and
Computer Science*
Peter J. Sousounis,
Ph.D., *Atmospheric Science*

Lecturer
Lee H. Somers, Ph.D.,
*Oceanic Science;
also Kinesiology*

See page 225 for statement on Course Equivalence.

105(Chem 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.

111. Diving Science and Technology
Prerequisite: none. I, II (3 credits)
Principles and practices of conducting engineering and research operations underwater: human performance; use of diving equipment; underwater safety; underwater engineering and research techniques. Lecture only.

123(Geol Sci 123)(SNRE 123). Life and the Global Environment
Prerequisite: none. II (2 credits)
Life has affected the global environment throughout Earth's history, but the changes brought about by human beings are much more rapid than any the planet has experienced before. This course views the global change of the present from the perspective of planetary history, emphasizing environmental constraints on biological evolution and possible constraints on human activity in the future.

171(Biol 110)(Univ Course 110)(SNRE 110). 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.

172(Univ Course 111)(SNRE 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.

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.

203. The Oceans

Prerequisite: none. I, II (3 credits)

Elementary descriptions of the oceans: characteristics and behaviors; the sea as a world resource, and as an influence on civilizations.

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.

280. Environmental Impact of Technological Change

Prerequisite: sophomore standing in engineering or natural science. I (2 credits)

An exploration of the unexpected environmental side effects of technological innovation, with a comparison of benefits and costs. How science and engineering have remade the world with good intentions that sometimes have had bad results. Methods that can be used to estimate environmental consequences, distinguishing between serious problems and false alarms.

304. The Atmospheric and Oceanic Environment

Prerequisites: Physics 140, Math 116, Chem 130. I (3 credits)

An introduction to the physical and chemical processes that control the atmosphere and oceans. Emphasis is placed on the present state and future evolution of these terrestrial systems. The influence of man on his surroundings is considered.

305. Introduction to Atmospheric and Oceanic Dynamics

Prerequisites: AOSS 304, Math 215. II (3 credits)

A continuation of AOSS 304 with emphasis on the fluids mechanics of the oceans and atmosphere. Topics include geophysical fluid wave motions, steady circulations, and physical processes of interest in climatology.

310. Synoptic Laboratory I
Prerequisite: AOSS 202 or preceded or accompanied by AOSS 304. I (1 credit)
An introduction to weather observations, analyses, displays and forecasting.

311. Synoptic Laboratory II
Prerequisites: AOSS 310, preceded or accompanied by AOSS 305. II (2 credits)
Analysis of meteorological data in space and time; vertical distribution of different elements in the atmosphere; weather forecasting.

335. Space Science and Spacecraft Applications
Prerequisite: junior standing in engineering. I, II (3 credits)
The sun, solar radiation and the solar wind. The terrestrial atmosphere and ionosphere: general structure and controlling processes. Aurora and radiation belts. Useful spacecraft orbits, lifetime and causes of decay. Remote sensing principles and the performance of sensors. Representative examples of remote sensing satellites.

401. Geophysical Fluid Dynamics
*Prerequisites: Physics 240, preceded or accompanied by Aero 350 or Math 450. I
    (3 credits)*
Dynamics of the oceans and atmosphere. Equations of motion in spherical coordinates, beta-plane approximation, wave properties in the oceans and atmosphere.

407. Mathematical Methods in Geophysics
Prerequisite: Math 216. I (3 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.

408. Environmental Problem Solving with Computers
Prerequisites: Eng 103, Math 216. I (3 credits)
Solution of meteorological, oceanographic, and general environmental problems using computers. Applications of numerical analysis, statistics, and data handling to geophysics and environmental numerical output in terms of observed phenomena.

411. Cloud and Precipitation Processes
Prerequisite: AOSS 430. 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.

412. Dynamics of Climate
Prerequisite: none. I (3 credits)
Climatic fluctuations and change; paleo and historical climates; construction of climatic models; and the climatic implications of human activity.

414. Weather Systems

Prerequisite: AOSS 305 or AOSS 401. I (3 credits)

Identification and description of significant weather systems from satellite imagery and from data sources. These systems are examined further through application of theoretically derived dynamical concepts to datasets from actual events. A range of phenomena including mid-latitude cyclones, hurricanes, lake-effect storms, and tornadoes will be addressed.

422. Micrometeorology I

Prerequisite: Physics 240 or Math 215. I (3 credits)

Physical processes responsible for the thermal and moisture conditions in the air layer near the ground. Components of net radiation exchange, heat transfer in soil, wind structure and turbulence near the ground, turbulent transfer of sensible heat and water vapor, evapotranspiration; forest climatology, transitional microclimates.

424. Mesometeorology

Prerequisite: AOSS 305 or AOSS 401. I (3 credits)

An introduction to mesometeorological phenomena including organized convection, thunderstorms, tornadoes, foehns, lee waves, orographic blocking, sea breezes, urban heat islands, and effects from the Great Lakes.

425(NAME 425). Environmental Ocean Dynamics

Prerequisite: NA 321 or CEE 325 or AOSS 305 or permission of instructor. I (4 credits)

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

430. Thermodynamics of the Atmosphere

Prerequisite: preceded or accompanied by Math 216. II (3 credits)

Physical principles of thermodynamics with emphasis on atmospheric applications. Topics include atmospheric statics; first and second principles of thermodynamics; adiabatic processes; thermodynamics of moist air; equilibrium with droplets and crystals; fundamentals of cloud and precipitation processes.

432. Environmental Radiative Processes

Prerequisites: Math 216, Physics 240. II (3 credits)

The nature of electromagnetic radiation. Solar and terrestrial radiation. The transfer of radiation including absorption, emission and scattering. Radiation and climate. Satellite observations and remote sounding.

434. Mid-Latitude Cyclones

Prerequisite: AOSS 414 or AOSS 451. II (3 credits)

A dynamical approach is used to describe the development of mid-latitude cyclones. Various aspects of these cyclones are examined through application of theoretically derived dynamical concepts to datasets from actual storms. Topics including the Norwegian cyclone model, explosive coastal cyclogenesis, lee cyclo-genesis, and recent cyclone models will be discussed.

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.

451. Atmospheric Dynamics I

Prerequisite: AOSS 401. II (3 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.

454. Weather Analysis and Forecasting Laboratory

Prerequisites: AOSS 311, preceded or accompanied by AOSS 414. II (3 credits)

Principles of meteorological analysis. Structure of wave cyclones and fronts; vorticity, divergence, and vertical velocity; quasi-geostrophic theory and diagnostics; cyclogenesis and fronto-genesis. Description of operational numerical forecast models and facsimile products. Daily weather discussion and forecasting.

458. Principles and Applications of Visible and Infrared Remote Sensing

Prerequisites: Math 216, Physics 140 or equivalent. I (3 credits)

Principles of visible and infrared remote sensing are discussed, beginning with electromagnetic wave propagation, emission, absorption and scattering, followed by air and spacecraft instruments. These principles are applied to case studies in environmental science and protection, global change, urban metabolism, surveillance and treaty monitoring as well as law enforcement.

459. Principles and Applications of Radio and Active Remote Sensing

Prerequisites: Math 216, Physics 140. II (3 credits)

Principles of radio and lidar remote sensing are discussed, beginning with electromagnetic wave propagation, emission, absorption and scattering, followed by air and spacecraft instruments. These principles are applied to case studies in environmental science and protection, global change, urban metabolism, military surveillance and treaty monitoring as well as law enforcement.

460. Satellite Meteorology

Prerequisite: none. I (3 credits)

Topics selected from characteristics of meteorological satellite orbits and of instruments used for the measurement of meteorological parameters using visible, infrared, and microwave radiation. Application of satellite measurements to Earth's radiation balance and albedo, surface temperature, atmospheric temperature structure, cloud heights and types, minor atmospheric constituents, aerosols and precipitation, winds, and circulation.

461. Meteorological Instrumentation for Air Pollution Studies

Prerequisite: none. II (2 credits)

Analysis of meteorological factors that affect dispersion directly and indirectly. Guidelines in selecting wind speed, wind direction, turbulence, temperature, and humidity measuring instruments. Significance of rate of response of sensors. Methods of measuring these parameters above the heights of towers. Methods of measuring diffusion by tracer experiments, both visible and invisible. Wind tunnel modeling of urban problems.

462. Instrumentation for Atmospheric and Space Sciences

Prerequisite: AOSS 305. II (3 credits)

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

463. Air Pollution Meteorology

Prerequisite: none. II (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.

464(Aero 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.

465. Space System Design for Environmental Observations

Prerequisite: senior standing. I (3-4 credits) Credit hours to be arranged with instructor.

A space system is designed to address a defined problem in environmental observations, e.g. remote sensing from spacecraft for public health applications. Information is gathered from speakers, literature, and university and industrial contacts. Team members complete a design, and report formally to interested parties on a national scale.

466(Geol Sci 466). Computational Models of Geochemical Processes

Prerequisite: ability to program in BASIC. I (3 credits)

Computational models of the processes that govern the composition of ocean and atmosphere. Geochemical reservoirs, mechanisms of transfer, chemical interactions, and feedback processes. The impact of organisms on the global environments geological history of atmospheric and oceanic composition.

467(Chem 467)(Geol Sci 465). Biogeochemical Cycles

Prerequisites: Math 116, Chem 210, Physics 240. I (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.

469(NA 469). Underwater Operations

Prerequisite: none. II (3 credits)

Survey of manned undersea activities in oceanography and ocean engineering. The tools of underwater operations: decompression chambers, habitats, submarines, diving apparatus; pertinent design criteria and applications as based on human hyperbaric physiology and performance. Topics in research diving for engineering and oceanographic studies.

475. Earth-Ocean-Atmosphere Interactions

Prerequisite: senior standing. II (3 credits)

To develop students' abilities to integrate processes important to global change; surface characteristics, hydrology, vegetation, biogeochemical cycles, human dimensions, analysis of large data sets. Students are expected to define and analyze a global change problem utilizing one of the state-of-the-art models.

479. Atmospheric Chemistry

Prerequisites: Chem 130, Math 216. I (3 credits)

Thermochemistry, photochemistry, and chemical kinetics of the atmosphere; geochemical cycles, generation of atmospheric layers and effects of pollutants are discussed.

480(Geol Sci 480). The Planets: Composition, Structure, and Evolution

Prerequisites: Math 216, Physics 240, Chem 130. II (3 credits)

Origin of the solar system, composition and radial distribution of material in planets and satellites; relationship of gravity fields to shape and density distribution; magnetism; origin and significance of topography; structure of planetary atmospheres; energetics and dynamics of interiors and atmospheres, thermal histories and evolution of interiors, devolatization, origin, and evolution of atmospheres.

495. Thermosphere and Ionosphere

Prerequisite: senior standing in engineering or physical science. II (3 or 4 credits)

Basic physical processes significant to the structure and characteristics of the upper atmosphere; photo-chemistry, diffusion, ionization, distribution of neutral and charged particles; thermal structure of the upper atmosphere; atmospheric motions, geomagnetic storms.

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.

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.

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.

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.

528(NA 528). 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.

532. Radiative Transfer

Prerequisite: none. 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.

550(NA 550). Offshore Engineering Analysis II

Prerequisites: NA 420, NA 450. 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 TLP's.

551. Advanced Geophysical Fluid Dynamics

Prerequisite: AOSS 451. I (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.

555. Spectral Methods

Prerequisites: Math 216, Eng 103 or 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.

556. Space System Design for Space Sciences

Prerequisite: graduate standing. II (4 credits)

Team leadership in high level project design of a space system, including launch facilities, booster systems, spacecraft subsystems and their integration,
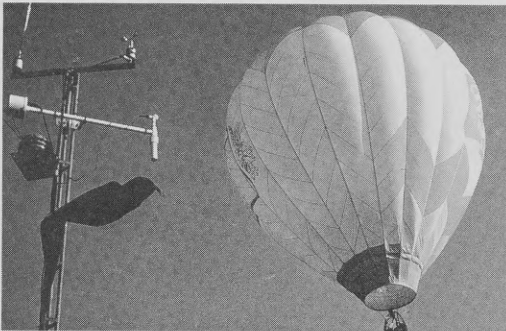
communications, ground control, data processing, project management, safety, environmental impact, economic, and political factors. One hour is spent on topics such as concurrent engineering, manufacturing, marketing and finance, etc.

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.

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.

565. Planetary Atmospheres

Prerequisite: graduate standing. I (3 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.

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.

575. Air Pollution Monitoring

Prerequisites: 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.

576. Air Quality Field Project

Prerequisites: 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 experimentalists.

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.

580. Remote Sensing and Geographic Information System Project Laboratory
Prerequisites: Math 216, Physics 140. II (2 hours)
Lectures and hands-one 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.

581(Aero 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.

582(Aero 582). Spacecraft Technology
Prerequisite: graduate standing. I (3 credits)
A systematic and comprehensive review of spacecraft and space mission technology, including trajectory and orbital mechanics, propulsion systems, power and thermal systems, structures, control, and communications.

585. Introduction to Remote Sensing and Inversion Theory
Prerequisite: graduate standing. II (3 credits)
An introduction to the techniques of remote sensing in the optical spectral region. Atmospheric sounding and spectroscopic study of the atmosphere. Methods of inversion of measurements to yield model parameters. Optimal estimation, non-linear inversion, and sequential estimation.

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.

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.

596(Aero 532). Gaskinetic Theory

Prerequisite: graduate standing. I (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.

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.

605. 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.

606. Computer Applications to Geo-Fluid Problems

Prerequisites: AOSS 442 or AOSS 451, Eng 103, 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.

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.

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.

731(EECS 731). Space Terahertz Technology and Applications

Prerequisite: none. I (1 credit)

Study and discussion of various topics related to high frequency applications in space exploration. Topics will be chosen from the following areas: planetary atmospheres and remote sensing, antennas, active and passive circuits, space instrumentation.

747. Atmospheric Science and Environment Seminar

Prerequisite: none. I, II (1 credit)

Student and faculty presentations about current research results, research papers, and new ideas related to our atmospheric environment. Each enrolled student will give a presentation.

749. Space Science Seminar

Prerequisite: none. May be repeated every term. I, II (1 credit)

Student and faculty presentations about current research results, "classic" research papers and new ideas.

990. Dissertation/Pre-Candidate

I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)

Election for dissertation work by doctoral student not yet admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

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 doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Biomedical Engineering

(Division 242)

Department Office
3304 G.G. Brown Building
(313) 764-9588

Charles A. Cain, Ph.D., P.E., *Professor of Electrical Engineering and Computer Science; and Chair, Biomedical Engineering*

The Department of Biomedical Engineering at the University of Michigan is an interdisciplinary graduate program in the Rackham School of Graduate Studies granting the M.S. and Ph.D. degrees in Biomedical Engineering. The Department and the Center for Biomedical Engineering Research are jointly supported by the College of Engineering and the Medical School. **See page 173 for program information.**

See page 225 for statement on Course Equivalence.

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.

410(MSE 410). Biomedical Materials Considerations
Prerequisite: MSE 250 or permission. (2 credits)
Interactions of materials implanted in the body. Histological and hematological considerations including general foreign body reactions, inflammation and reparation, carcinogenicity, thrombosis, hemolysis, protein and cellular issues, immunogenic and toxic properties. Basic discussion of implants versus transplants and relevant biological components. Tours of relevant university facilities.

417(EECS 417). Electrical Biophysics
Prerequisites: EECS 211 or EECS 314, preceded or accompanied by EECS 316. I (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.

432(EECS 432). Fundamentals of Ultrasonics with Medical Applications
Prerequisite: EECS 331. II (3 credits)
Basic principles; waves, propagation, impedance, reflection, transmission, attenuation, power levels. Generation of ultrasonic waves; transducers, focusing, Fraunhofer and Fresnel zones. Instrumentation; display methods, Doppler techniques, signal processing. Medical applications will be emphasized.

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434. Microbiology for Engineers

Prerequisite: Chem 225. I, II (4 credits)

Principles and techniques of microbiology with an introduction to their application in the several fields of engineering. Lectures and laboratory.

456(AM 456)(ME 456). Biomechanics

Prerequisites: ME 211, ME 240. II (3 credits)

Definition of biological tissue behaviors, including elastic, viscoelastic, and plastic properties, with emphasis on bone; dynamics of gait, impact and tolerance criteria in vehicle design for human safety; prosthetic and orthotic mechanics and design.

458(EECS 458). Biomedical Instrumentation and Design

Prerequisite: none. 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. Lectures and laboratory.

476(ME 476). Thermal-Fluid Science in Bioengineering

Prerequisite: none. Credit restrictions. Not open to ME students. I (3 credits)

Fluid dynamics, thermodynamics, and heat transfer at micro- and macro-level. Systematic circulation, microcirculation, simulation of flow regulation, artificial flow-regulating devices. First and second laws of thermodynamics. Conduction, metabolic heat generation, convection, radiation, regulation of body temperature, clothing, micro heat transfer, hyperthermia, hypothermia and cryogenic applications.

480(NERS 480). Computational Projects for Engineering Aspects of Radiology and Nuclear Medicine

Prerequisite: preceded or accompanied by NERS 481. II (1 credits)

Computational projects illustrate the principles of radiation imaging from NERS/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. Projects will be 3 to 4 weeks in duration.

481(NERS 481). Engineering Aspects of Radiology and Nuclear Medicine

II (2 credits)

Radiation sources, image formation, and visual performance of radiation imaging is covered with an emphasis on statistical processes. Film/screen radiography, digital radiography, computed tomography, Anger camera, and positron emission tomography systems are considered. While emphasis is placed on medical imaging, the imaging concepts covered apply to industrial inspection.

484(NERS 484). Radiological Health Engineering Fundamentals

Prerequisite: NERS 312 or equivalent or permission of instructor. I (3 credits)

This course presents quantitative radiation protection design through lectures, problem solving, and group projects. Topics covered include radiation quantities, regulations, external and internal dose estimation, and health effects. Special topics such as non-ionizing radiation, radioactive waste, radon gas, and emergencies will be included dependent upon class interests.

495(AM 495). Introduction to Bioengineering

Prerequisite: permission of instructor. 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.

500. Bioengineering Seminar

I (1 credit)

This seminar will feature various bioengineering related speakers.

517(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 ultra-sound.

518(ChE 518). Engineering Fundamentals in Biological Systems

Prerequisite: ChemE 417 or Biol 311 or permission of instructor. II (alternate years) (3 credits)

Application of fundamental chemical engineering principles (mass, heat and momentum transport, kinetics) to the study of biological systems. Focus will be on current bioengineering research in the department.

519(Physiol 519). Bioengineering Physiology

Prerequisites: Biol 105 or Biol 112 or equivalent, permission of instructor. (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.

525(Microb 525). Systems Analysis of the Microbial Cell

Prerequisites: 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.

534(IOE 534)(Mfg 534). Occupational Biomechanics

Prerequisites: 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.

548(EECS 548). Advanced Bioinstrumentation and Computation

Prerequisites: EECS 458, EECS 451. I (3 credits)

Application of computer hardware and software to acquisition, pattern recognition, analysis, and diagnosis of physiological signals. These include, but are not restricted to, the electrocardiogram, the electroencephalogram, the electromyogram, and blood pressure measurement. This course will teach skills required for computer-based analysis of clinical signals, and computer modelling of physiological systems. Lecture and laboratory.

569(EECS 569). Signal Analysis in Biosystems

Prerequisites: 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.

582(NERS 582). Medical Radiological Health Engineering

Prerequisite: NERS 484(BiomedE 484) or permission of instructor. 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.

583(ChemE 583)(MSE 583). Biocompatibility of Materials

Prerequisites: 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.

590. Directed Research

(credit to be arranged)

Provides opportunity for bioengineering students to participate in the work of laboratories devoted to living systems studies.

591. M.S. Thesis

Prerequisite: 2 hrs of BiomedE 590. 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.*

616(ChemE 616). Analysis of Chemical Signalling

Prerequisites: 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.

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.

690(Anat 690)(Neurol 690)(Pharmacol 690)(Physiol 690)(Psych 690) (Zool 691). Neuroscience

Prerequisites: graduate standing, permission of instructor. I (3 credits)

Study of nervous system including comparative aspects, structure, function, chemistry, behavior, and pathology.

691(Anat 691)(Neurol 691)(Physiol 691)(Zool 691). Neuroscience Laboratory

Prerequisites: Physiol 690, permission of instructor. I (3 credits)

Laboratory exercises and demonstrations in neurobiology.

990. Dissertation/Pre-Candidate

I, II, III (1-8 credits); IIIa, IIIb (1-4 credits)

Election for dissertation work by doctoral students not yet admitted to status as candidates. Defense of dissertations, that is, final oral examinations, must be held under full-term candidacy enrollments.

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 doctoral students who have been admitted to status as candidates. The defense of dissertations, that is, final oral examinations, must be held under full-term candidacy enrollments.

Business Administration

Department Office
2260 Business Administration
Building
(313) 763-5796

Engineering undergraduate students interested in complementing their course work with business electives can consult with counselors in the Office of Admissions and Student Services, Room 2260 Business Administration. Business electives give students a deeper understanding of corporate and manufacturing issues. Engineering students interested in consulting, information systems development, and in industrial and operations management are especially encouraged to consider electives in business.

For those interested in graduate work, excellent career opportunities exist for engineers who earn the MBA degree. In general, however, students interested in pursuing an MBA are expected to have two or more years of full-time work experience.

The business courses below are of special interest to students enrolled in the undergraduate engineering curriculum. In the election of such courses, attention is called to the administrative rules of the School of Business Administration, which affect elections as follows:

No student shall elect courses in the School of Business Administration who does not have at least third-year standing (55 credit hours). This does not apply to Accounting 271 and 272, which are listed as sophomore-level courses in the accounting area of the School of Business Administration.

Juniors may elect courses numbered 300 to 399 inclusive, and seniors may elect courses numbered 300 to 499 inclusive, provided they have satisfied particular course prerequisites. Please note that some courses are restricted to BBA students only in specific terms. The course listing below gives the term(s) in which non-business students can elect a particular course.

Courses numbered 500 or above may be elected only by properly qualified graduate students and are not open to undergraduate students.

For descriptions of the following and other courses in Business Administration, see the undergraduate *Bulletin* of the School of Business Administration.

Accounting and Information Analysis

A 271. Principles of Accounting
I, II, IIIa (3 credits)

A 272. Principles of Accounting
I, II, IIIa (3 credits)

Computer and Information Systems

CIS 315. Expert Systems
I (3 credits)

CIS 340. Technical Foundations of Computer Information Systems
I (3 credits)

CIS 341. Analysis and Design of Business Systems
I (3 credits)

CIS 350. Simulation and Systems Analysis
(3 credits)

Finance

F 300. Financial Management
II (3 credits)

Law, History, and Communication

LHC 305. Business Law
I, II or IIIa (3 credits)

LHC 306. Business Law
I, II or IIIa (3 credits)

Marketing

M 300. Marketing Management
II, IIIa (3 credits)

Organizational Behavior and Industrial Relations

OB 300. Behavioral Theory in Management
II (3 credits)

OB 315. Management of Personnel
I, II (3 credits)

OB 322. Management-Union Relations
II (3 credits)
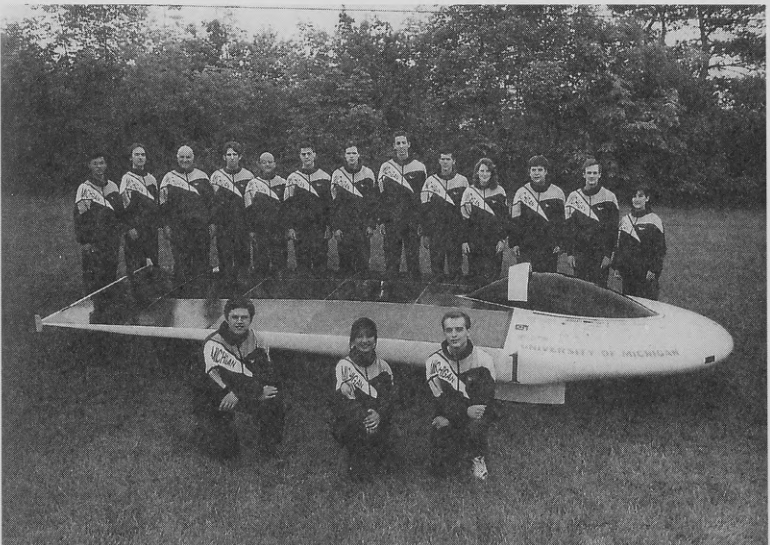
U-M Solar Car Team '95 with *Solar Vision*.

Chemical Engineering

(Division 245)

Department Office
3074 H.H. Dow Building
(313) 764-2383

Ralph T. Yang, Ph.D., *Professor and Chair*

Professor

Dale E. Briggs, Ph.D., P.E.
Brice Carnahan, Ph.D., P.E.
Rane L. Curl, Sc.D.
Francis M. Donahue, Ph.D.
H. Scott Fogler, Ph.D., P.E.,
   Vennema Professor of
   Chemical Engineering
John L. Gland, Ph.D.
Erdogan Gulari, Ph.D.; *also*
   Macromolecular Science
   and Engineering
Costas Kravaris, Ph.D.
Johannes W. Schwank, Ph.D.
Henry Y. Wang, M.S., Ph.D.
James Oscroft Wilkes, Ph.D.
Gregory S. Y. Yeh, Ph.D.

Professor Emeritus

Robert H. Kadlec, Ph.D., P.E.
John E. Powers, Ph.D.
Maurice J. Sinnott, Sc.D.;
   also Metallurgical
   Engineering
Mehmet Rasin Tek, Ph.D., P.E.
George Brymer Williams,
   Ph.D., P.E.
Edwin Harold Young, M.S.E.,
   P.E.; *also Metallurgical*
   Engineering

Associate Professor

Stacy G. Bike, Ph.D.; *also*
   Macromolecular Science
   and Engineering

Mark Burns, Ph.D.
Jennifer J. Linderman,
   Ph.D.
Phillip E. Savage, Ph.D.
Levi T. Thompson, Jr., Ph.D.
Robert Ziff, Ph.D.; *also*
   Macromolecular
   Science and
   Engineering

Assistant Professor

Susan M. Montgomery,
   Ph.D.
David J. Mooney, Ph.D.

Assistant Visiting Professor

Christian Lastoskie, Ph.D.

> **Note:** Laboratory fees are required to be paid in advance for each course involving laboratory work.

See page 225 for statement on Course Equivalence.

230. Thermodynamics I
Prerequisites: Eng 103, Chem 130, and Math 116. I (4 credits)
An introduction to applications of the first law of thermodynamics. Steady and unsteady state material and energy balances, the equilibrium concept. Properties of fluids. Engineering systems.

330. Thermodynamics II
Prerequisite: ChemE 230. II (4 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.

341. Fluid Mechanics

Prerequisite: preceded or accompanied by ChemE 230. II (3 credits)

A study of fluid mechanics for chemical engineering. Mass, energy, and momentum balances on finite and differential systems. Laminar and turbulent flow in pipes, porous media, and equipment. Boundary layer and potential flow.

342. Heat and Mass Transfer

Prerequisites: ChemE 230, ChemE 341, and Math 216. I (3 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.

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.

344. Reaction Engineering and Design

Prerequisites: ChemE 330, preceded or accompanied by ChemE 342. II (3 credits)

Fundamentals of chemical reaction engineering. Rate laws, kinetics, and mechanisms of homogeneous and heterogeneous reactions. Analysis of rate data. Diffusion limitations. Design of industrial reactors.

360. Chemical Engineering Laboratory I

Prerequisite: ChemE 342. I, II (3 credits)

Experimentation in thermodynamics and heat, mass, and momentum transport on a bench scale. Measurement error estimation and analysis. Lecture laboratory, conferences, and reports.

412(MacroSE 412)(MSE 412). Polymeric Materials

Prerequisite: MSE 350. II (3 credits)

The synthesis, characterization, morphology, structure and rheology of polymers. Polymers in solution and in the bulk liquid and glassy states. Engineering and design properties including viscoelasticity, creep, stress relaxation, yielding, crazing and fracture. Forming and processing methods.

414(MacroSE 414)(MSE 414). Applied Polymer Processing

Prerequisite: MSE 350. II (3 credits)

Theory and practice of polymer melt processing. Non-Newtonian flow. Extrusion, injection and molding operations. Fiber, film, and rubber processing. Kinetics of solidification. Mechanical Orientations. Product characterization. Structure-property relationships. Lecture and laboratory.

417(Mfg 417). Biochemical Technology

Prerequisite: organic chemistry. I (3 credits)

Concepts necessary in the adaptation of biological and biochemical principles to industrial processes and technology of the biochemical engineering industries. Lectures, problems, and library study will be used to develop the ideas presented.

447(Mfg 448). Waste Management in Chemical Engineering

Prerequisites: 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.

460. Chemical Engineering Laboratory II

Prerequisite: ChemE 343. I, II (3 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.

466. Process Dynamics and Control

Prerequisites: ChemE 343, ChemE 344. I (3 credits)

Introduction and process control in chemical engineering. Application of Laplace transforms and frequency domain theory 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.

470. Colloids and Interfaces

Prerequisites: 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.

486. Chemical Process Simulation and Design I

Prerequisites: preceded or accompanied by ChemE 342, ChemE 343. I (3 credits)

Economic evaluation of chemical processes. Strategies for decision-making, trouble-shooting faults, potential problem analysis, plant safety and failure analysis. The selection and specification of engineering materials for use in the chemical, petro-chemical, and petroleum industries.

487. Chemical Process Simulation and Design II

Prerequisites: ChemE 344, ChemE 486, preceded or accompanied by ChemE 466. I, II (4 credits)

Process synthesis and design. Process simulation with computer assistance. Process and corporate economics. Design project with technical report.

490. Directed Study, Research and Special Problems

(to be arranged)

Laboratory and/or conferences. Provides an opportunity for undergraduate students to work in research or areas of special interest such as design problems and economic studies. Not open to graduate students.

507. Mathematical Modeling in Chemical Engineering

Prerequisites: ChemE 344, Eng 303. I (3 credits)

Formulation of deterministic models from conservation laws, population balances; transport and reaction rates. Formulation of boundary and initial conditions. Dimensional analysis, analytical and numerical methods.

508. Applied Numerical Methods I

Prerequisite: Eng 103. (3 credits)

Numerical approximation, integration, and differentiation. Single and simultaneous linear and nonlinear equations. Initial-value methods for ordinary differential equations. Finite-difference methods for parabolic and elliptic partial differential equations. Implementation of numerical methods on the digital computer, with applications to fluid flow, heat transfer, reactor engineering, and related areas.

509. Statistical Analysis of Engineering Experiments

(3 credits)

The use of statistical methods in analyzing and interpreting experimental data and in planning experimental programs. Probability, distributions, parameter estimation, test of hypotheses, control charts, regression and an introduction to analysis of variance.

510. Mathematical Methods in Chemical Engineering

Prerequisites: 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.

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 the rheological behavior. The course will make frequent reference to synthesis, processing, characterization, and use of polymers for high technology applications.

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.

518(BiomedE 518). Engineering Fundamentals in Biological Systems

Prerequisite: ChE 417 or Bio 311 or permission of instructor. II (alternate years) (3 credits)

Application of fundamental chemical engineering principles (mass, heat and momentum transport, kinetics) to the study of biological systems. Focus will be on current bioengineering research in the department.

525. Catalysis, Kinetics, and Research Reactors

Prerequisites: two physical chemistry courses. (3 credits)

The course covers topics in heterogeneous catalytic reactions and research reactor kinetics. It emphasizes basic principles of heterogeneous catalysis, surface effects, reaction kinetics, and design of research reactors.

526. Heat Transfer

Prerequisite: ChemE 342. (3 credits)

Principles of conduction, convection, and radiation. Application to processes in the chemical and petroleum industries. Selected topics such as heat transfer effects in two-phase flow, condensation of multicomponent vapors, extended surfaces, and radiation from gases and flames.

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.

528. Chemical Reactor Engineering

Prerequisite: ChemE 344. (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.

529. Mass Transfer

Prerequisite: ChemE 342. (3 credits)

Formulation of diffusional mass balances; diffusion in solids, liquids, and gases; Fick's first and second laws; convective mass transfer, modeling of mass transfer systems.

537. Thermodynamic Relations and Applications

Prerequisite: ChemE 330. (3 credits)

The fundamental property relation and its application to physical and chemical equilibria in homogeneous and heterogeneous systems. Magnetic, electric, surface, and stress

effects. Fugacities and activities of the constituents of multicomponent mixtures are determined through analyses of experimental PVT, concentration, and electrochemical potential data.

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.

541. Fluid Mechanics and Heat Transfer
Prerequisite: ChemE 342. (3 credits)

An integrated study of fluid mechanics and heat transfer. Differential mass, momentum, and energy balances. Inviscid, viscous, and turbulent flow; dimensional analysis. Motion of bubbles; two-phase flow and fluidization. Conduction, convection; radiation from surfaces and gases. Application to problems in the chemical and petroleum industries.

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.

547. Separations Processes II
Prerequisite: ChemE 343. (3 credits)

A general approach to the design of separation processes based on mathematical modeling. Fundamental bases for separation and possible arrangements to improve performance. Thermal diffusion, distillation, adsorption; ideal cascades and batch processes.

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.

552. Fundamentals of Polymer Processing
Prerequisites: ChemE 341, Math 216. I (alternate years) (3 credits)

Introduction to rheology of non-Newtonian fluids; analysis of viscometric flows; mathematical modeling of common polymer melt processing operations such as extrusion, spinning, film blowing and injection molding; heat and mass transfer in polymer systems.

566(Mfg 566). Process Control in the Chemical Industries

Prerequisites: ChemE 343, ChemE 460. II (3 credits)

Techniques of regulation applied to equipment and processes in the chemical and petrochemical industries. Linear and nonlinear control theory, largely in the spectral domain. Controller types, transducers, final control elements, interacting systems, and applications.

573(MSE 573). Corrosion Engineering

Prerequisite: course in materials engineering. (3 credits)

Fundamentals involved in choosing materials in corroding media, corrosion control methods, and corrosion-failure analysis.

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.

583(BiomedE 583)(MSE 583). Biocompatibility of Materials

Prerequisites: 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.

585. Production and Processing of Petrochemicals

Prerequisite: ChemE 343. (3 credits)

Production, pipelining, conservation, processing and storage of crude oil and natural gas. Chemical Engineering calculations, economics, and design applied to reservoir engineering, petroleum processing, refining, and other related areas of the petrochemicals industry.

587. Chemical Process Design

II (2 or 4 credits)

First half-term: Selection and design of chemical, biochemical, or petrochemical processes, equipment and control systems; economic studies; comparison and optimization. Equipment evaluation and estimating procedures; computer methods. Second half-term: Engineering design and economic analysis of a process. Original and individual work, and excellence of reporting are emphasized. Oral examination on final written report.

588. Optimization and Control of Chemical Systems

Prerequisite: ChemE 407 or ChemE 508. (3 credits)

Techniques for finding extrema of functions and functionals relating to chemical process problems. Solution methods, including digital computation, alternative, and approximate procedures. Geometric, dynamic, and linear programming. Constrained variables and systems. Variational methods, the maximum principle, search methods. Sensitivity and errors.

595. Chemical Engineering Research Survey

(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.

607. Mathematical Methods in Chemical Engineering

Prerequisite: Chem 507. (3 credits)

Matrices and their application to reaction and separation processes. Linear operator theory and application to transport phenomena. Non-linear systems, stability, bifurcation. Perturbation methods and chaotic systems.

608. Applied Numerical Methods II

Prerequisite: ChemE 508 or EECS 404. (2 or 3 credits)

The finite-element method for solving partial differential equations, with applications to incompressible fluid flow and heat transfer, occupies at least one-third of the course. Banded equation-solving techniques. Stiff systems of ordinary differential equations. Boundary-value problems. Hyperbolic equations. Matrix eigenvalues. Computer applications. Credit depends on topics selected.

616(BiomedE 616). Analysis of Chemical Signalling

Prerequisites: 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.

617(Mfg 617). Advanced Biochemical Technology

Prerequisite: ChemE 417 or permission of instructor. II (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.

625. Coupled Rate Processes

Prerequisites: ChemE 526 and ChemE 528 or ChemE 527 or ChemE 529. (3 credits)

Theoretical and experimental phenomena associated with the coupling of two or more rate processes. Material selected from contemporary chemical engineering involving reaction kinetics in two-phase flow, thermal effects in chemical reactors, coupled diffusional processes, coupled chemical reactions, flames, and electrolytes.

627. Computational Fluid Mechanics and Rheology

Prerequisite: ChemE 527 or ChemE 508 or equivalent. II (3 credits)

Conservation equations and boundary conditions. Constitutive equations. Finite element and time-integration. Confined free surface and multilayer flow. Viscoelastic liquids and polymer processing. Processing of composites and semiconductors. Heat and mass transfer. Chemical reaction and phase change. Stability and bifurcation analysis.

628. Industrial Catalysis

Prerequisite: ChemE 528. (3 credits)

Theoretical and experimental aspects of heterogeneous catalysis and surface science. Design, preparation, and characterization of catalysts. Kinetics of heterogeneous catalytic reactions, thermal and diffusional effects in catalytic reactors. Case studies of important industrial catalytic processes.

687. Chemical Process Design II

Prerequisite: ChemE 587. (3 credits)

The application of machine computation to process and equipment design and simulation. Process-oriented languages, data banks, decompositional methods related to process system arrangement. Heuristic synthesis of equipment sequences. Applications in chemical, petrochemical, and petroleum industrial processes. Recycle, chemical reactors, heat transfer, and separations are emphasized.

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.

696. Selected Topics in Chemical Engineering

(to be arranged)

697. Problems in Chemical Engineering

(to be arranged)

698. Directed Study in Chemical Engineering

(to be arranged)

707. Special Topics in Mathematical Modeling

Prerequisite: graduate standing or permission of instructor. I (3 credits)

Selected topics on modeling chemical engineering processes at both the macroscopic and microscopic levels.

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.

807. Seminar in Mathematical Modeling

Prerequisite: candidacy in chemical engineering. II (3 credits)

Current literature on mathematical modeling of chemical engineering processes will be reviewed and studied.

895. Seminar in Chemical Engineering

(to be arranged)

990. Dissertation/Pre-Candidate

I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)

Election for dissertation work by doctoral student who has not yet been 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.

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 doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Chemistry * (Division 334)

Department Office
1500 Chemistry Building
(313) 747-2858

*College of Literature, Science, and the Arts
Professor Kuczkowski, *Chair*

Professors Ashe, Barker, Cordes, Coucouvanis, Coward, Curtis, Dunn, Ege, B.J. Evans, Francis, Gland, Gordus, Griffin, Kopelman, Koreeda, Lawton, Lohr, Lubman, Marino, Meyerhoff, Morris, Pearson, Pecoraro, Penner-Hahn; Rasmussen, Sacks, Sharp, Townsend, Wiseman, Yocum; **Associate Professors** Carroll, Glick, Laine, Lee, Zellers; **Assistant Professors** Banaszak Holl, C.E. Evans, Goldstein, Marsh, Pugh, Sension, Toogood; **Adjunct Professors** Czarnik; **Lecturers** Coppola, Hallada, Kerner, Weathers; **Professors Emeritus** Bartell, Blinder, Longone, Nordman, Oncley, Overberger, Rulfs, Smith, Tamres, Taylor, Westrum

Note: Safety regulations forbid the wearing of contact lenses in the laboratory.

For further details with respect to these courses and for additional courses in chemistry consult the Literature, Science, and the Arts Bulletin *and the Horace H. Rackham School of Graduate Studies* Bulletin.

105(AOSS 105). Our Changing Atmospheres
Prerequisite: none. I (3 credits)

106. Environmental Issues
Prerequisite: none. II (3 credits)

125. General and Inorganic Chemistry Laboratory
Prerequisite: to be elected by students who are eligible for, or enrolled in, Chem 130. I, II, IIIa (2 credits)

130. General Chemistry: Macroscopic Investigations and Reaction Principles
Prerequisites: three years of high school math or Math 105; one year of high school chemistry recommended. Placement by testing, or permission of Chemistry Department. Intended for students without AP credit in chemistry. I, II, IIIa (3 credits)

210. Structure and Reactivity I
Prerequisites: high school chemistry. Placement by examination during orientation or AP credit. To be taken with Chem 211. I, II, IIIa (4 credits)

211. Investigations in Chemistry
Prerequisite: to be taken with Chem 210. I, II, IIIa (1 credit)

215. Structure and Reactivity II

*Prerequisites: Chem 210, Chem 211, concurrent enrollment in Chem 216. I, II, IIIa
(3 credits)*

216. Synthesis and Characterization of Organic Compounds

Prerequisites: Chem 210, Chem 211. Must be taken with Chem 215. I, II, IIIa (2 credits)

230. Physical Chemical Principles and Applications

*Prerequisite: Chem 215 or permission of instructor. No credit for students who have
completed or are enrolled in Chem 260. No credit granted to those who have
completed Chem 340. I, II, IIIa (3 credits)*

241. Introduction to Chemical Analysis

*Prerequisites: prior or concurrent enrollment in Chem 260. No credit granted to those
who have completed Chem 340. Note: This course is linked to Chemistry 242.
Students must elect both Chemistry 241 (for 2 credits) and Chemistry 242 (for 2
credits). I, II (2 credits)*

242. Introduction to Chemical Analysis Laboratory

*Prerequisites: prior or concurrent enrollment in Chem 260. No credit granted to those
who have completed Chem 340. Note: This course is linked to Chemistry 241.
Students must elect both Chemistry 241 (for 2 credits) and Chemistry 242 (for 2
credits). I, II (2 credits)*

260. Chemical Principles

*Prerequisites: Chem 215/216, Math 115, and prior or concurrent enrollment in
Physics 140. No credit granted to those who have completed Chem 340. I, II, IIIa
(3 credits)*

302. Inorganic Chemistry: Principles of Structure, Reactivity, and Function

Prerequisites: Chem 260 (or 340). I, II (3 credits)

312. Synthesis and Characterization

*Prerequisites: Chem 215, Chem 216. Prior or concurrent enrollment in Chem 302.
I, II (2 credits)*

365. Principles of Physical Chemistry

*Prerequisites: two terms of Chemistry, Physics 140-141 or Physics 190, preceded or
accompanied by Math 215 or Math 285. II (4 credits)*

402. Intermediate Inorganic Chemistry

Prerequisites: Chem 302, and 461/462 (or 469). I, II (3 credits)

420. Intermediate Organic Chemistry

Prerequisites: Chem 215, Chem 216, or equivalents. II (3 credits)

436. Polymer Synthesis and Characterization
Prerequisite: Chem 241/242 or equivalent or permission of instructor. (3 credits) Lab

447. Physical Methods of Analysis
Prerequisites: Chem 260 and 241/242 (or 340). I, II (3 credits)

451. Introduction to Biochemistry I
Prerequisites: Chem 215, Biol 152 or 195 and Math 115. No credit granted to those who have completed or are enrolled in Biology 311 or Biological Chemistry 415. I (4 credits)

452. Introduction to Biochemistry II
Prerequisite: Chem 451. II (4 credits)

461. Physical Chemistry I
Prerequisites: Chem 260 (or 340), Physics 240, and Math 215. No credit granted to those who have completed Chem 397 or 469. I, II, IIIa (3 credits)

462. Computational Chemistry Laboratory
Prerequisites: Math 215 and prior or concurrent enrollment in Chem 461. I, II, IIIa (1 credit)

463. Physical Chemistry II
Prerequisites: Chem 461/462. No credit granted to those who have completed Chem 396 or 468. I, II, IIIa (3 credits)

467(AOSS 467)(Geol Sci 465). Biogeochemical Cycles
Prerequisites: Math 116, Chem 210, and Phys 240. I (3 credits)

480. Physical and Instrumental Chemistry
Prerequisites: Chem 447, Chem 461/462; and concurrent enrollment in Chem 463 or permission of instructor. I, II (3 credits)

485. Projects Laboratory
Prerequisite: Chem 480 or the equivalent. (2 credits)

530. Introduction to Bioorganic Mechanisms
Prerequisites: Chem 215, Chem 216, Chem 241/242, Chem 260. I (3 credits)

535(MacroSE 535). Physical Chemistry of Macromolecules
Prerequisite: Chem 463 or Chem 468. I (3 credits)

536. Laboratory in Macromolecular Chemistry
Prerequisite: Chem 535 or Physics 418 or permission of instructor. I (alternate years)
(2 credits)

538(MacroSE 538). Organic Chemistry of Macromolecules
Prerequisites: Chem 215, Chem 216, and Chem 230 or Chem 241/242, 260. I
(3 credits)

565. Nuclear Chemistry
Prerequisite: permission of instructor. Intended for graduate students and seniors.
(3 credits)

567(AOSS 567). Chemical Kinetics
Prerequisite: Chem 461 or AOSS 479. I (3 credits)
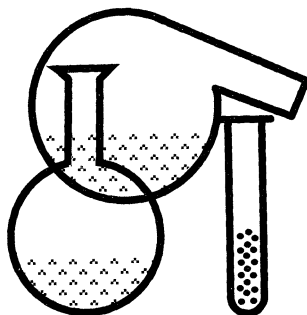
Civil and Environmental Engineering (Division 248)

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Professor

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Eugene Andrus Glysson,
 Ph.D., P.E.
Robert Blynn Harris,
 M.S.C.E., P.E.
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Wadi Saliba Rumman, Ph.D.
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Photios G. Ioannou, Ph.D.

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Adjunct Associate Professor

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Assistant Professor

Peter Adriaens, Ph.D.
Kevin R. Collins, Ph.D.
John G. Everett, Ph.D., P.E.
Jeremy D. Semrau, Ph.D.
Bozidar Stojadinovic, Ph.D.

Adjunct Lecturer

Rajendra K. Aggarwala, M.S.

280. Introduction to Environmental Engineering

Prerequisites: Chem 125, Math 116. I, II (3 credits)

An introduction to environmental engineering; discussion of the physical, chemical, and biological processes which influence the extent of air, water, and land pollution; methods for monitoring, controlling and preventing pollution; environmental impact assessment and pollution control philosophy; current critical pollution issues.

303(Eng 303). Computational Methods for Engineers and Scientists

Prerequisites: Eng 103, preceded or accompanied by Math 216. I, II (3 credits)

Applications of numerical methods to problems in various areas of engineering and science; personal computer case studies; development and comparison of techniques for roots of nonlinear equations, simultaneous linear algebraic equations, curve fitting, numerical integration, and ordinary differential equations.

312. Theory of Structures I

Prerequisite: preceded or accompanied by ME 211. I, II (4 credits)

Calculations of reactions, shears, bending moments/axial forces, and deflections in structures. Influence lines for beams and trusses. Moment distribution and computer structural analysis methods developed. Physical and analytical behavior of structures compared through experiments and computer solutions. Lectures and laboratory.

315. Design of Structures

Prerequisite: CEE 312. I, II (3 credits)

Fundamentals of design of structural elements in reinforced concrete, steel, and timber. Allowable stress and ultimate strength design procedures. Lectures, problems.

325. Fluid Mechanics

Prerequisites: ME 240, preceded or accompanied by ME 235. I, II, IIIa (3 credits)

Principles of mechanics applied to real and ideal fluids. Topics include fluid properties and statics; continuity, energy and momentum equations by control volume; dimensional analysis and similitude; laminar and turbulent flow; boundary layer, drag, lift; incompressible flow in pipes; free-surface flow; adiabatic flow of ideal gases in conduits; fluid measurement and turbomachinery.

332. Engineering Surveying Measurements and Applications

Prerequisites: Math 116, Eng 103. I, IIIa (3 credits)

Engineering surveying measurements of terrain including contouring and layout of infrastructural works. Survey measurement theory and practice in engineering applications. Survey measurement errors and analysis in direct and indirect measurements. Design of measurements and field operations. Use of topographic maps. Use of computers for surveying computations design and plotting.

351. Civil Engineering Materials
Prerequisites: MSE 250, ME 211. II (3 credits)

Studies of single and multicomponent construction materials such as Portland cement and bituminous concretes, plastics, wood, steel and others. Evaluation of constituents and design of mixtures and composites, load-time-deformation characteristics, and response to typical service environments. Introduction to concepts of material variability. Lectures and laboratory.

400. Contracts and Engineering Legal Relationships
Prerequisite: senior standing. I, II (2 credits)

Principles of contracts, including formation, interpretation, performance, discharge and remedies; other engineering-related legal issues and professional ethics.

401. Professional Issues in Civil and Environmental Engineering
Prerequisite: junior or senior standing. II (1 credit)

Principles of project management (personnel and budget), ethical obligations and responsibilities of professional engineers, concept of licensing of professional engineers, including public safety related to engineering decisions and designs.

405. Civil Engineering Systems
Prerequisite: Math 216. II (3 credits)

Introduction to optimization techniques with applications to civil engineering systems. Statistical topics, stochastic processes, mathematical programming, computer applications, economic concepts, and decision-making.

411(Aero 411)(NA 411). Finite Element Applications
Prerequisites: Eng 103, ME 211. I, II (3 credits)

The application of user-oriented finite element computer programs for solving practical structural mechanics problems of frames, 2-D and 3-D solids, plates, shells, etc., and displaying the solutions graphically. Students learn to prepare input data and to interpret results. A short introduction to the underlying theory is also presented.

413. Design of Metal Structures
Prerequisites: CEE 312, CEE 315. 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.

415. Design of Reinforced Concrete Structures
Prerequisites: CEE 312, CEE 315. 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.

420. Hydrology
Prerequisite: CEE 325. II (3 credits)
The hydrologic cycle; precipitation, its causes, distribution, and frequency; snow-melting processes; evaporation; transpiration; infiltration; aquifers, well hydraulics; normal and low flows, magnitude and frequency of floods; storm sewer capacities; flood routing; storage requirements for flow augmentation; measurement of river discharge.

421. Hydraulics
Prerequisites: Eng 103, CEE 325. I, II (3 credits)
Gradually varied flow, controls, and hydraulic jump; orifices, weirs, and venturi meters; turbomachines, pumping systems, pipe flow, and pipe networks; sewer hydraulics and control devices; system optimization; unsteady flow. Lecture, laboratory and computation.

428. Introduction to Groundwater Hydrology
Prerequisite: junior standing. I (3 credits)
Importance and occurrence of ground-water; chemical and physical properties of the groundwater environment; basic principles of ground-water flow; measurement of parameters; pump test design and analysis; transport of contaminants; use of computer models for the simulation of flow and transport problems.

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.

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.

432. Construction Engineering
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. Concreting methods include mixing, delivery, and placement. Design of forms for concrete walls and supported slabs.

445. Engineering Properties of Soil

Prerequisite: ME 211. I, II (3 credits)

Soil classification and index properties; soil structure and moisture, seepage; compressibility and consolidation; stress and settlement analysis; shear strength. Lectures, problems, and laboratory.

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.

470. Transportation Engineering

Prerequisite: junior standing. II (3 credits)

Planning, location, design, and operation of transportation facilities. Introduction to engineering economics.

480. Dynamics of Environmental Systems

Prerequisites: Chem 130, CEE 280, Math 216. I (3 credits)

Dynamics of transformation processes in natural and engineered environmental systems; application of ideal and non-ideal reactor concepts to system modeling; energetics and rates of intraphase and interphase mass transport and reaction processes in surface and ground-waters, treatment operations, and other systems of concern in environmental engineering. Lectures, problems, and laboratory.

485. Water Supply and Wastewater Engineering

Prerequisite: junior or senior standing. I, IIIa (3 credits)

Design of works for the collection and purification of water for municipal use, fundamentals of design of wastewater collection systems and wastewater treatment plants. Lecture and recitation.

490. Independent Study in Civil Engineering

Prerequisite: permission of instructor. I, II, IIIa, IIIb (1-3 credits)

Individual or group experimental or theoretical research in any area of Civil 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.

501. Legal Aspects of Engineering

Prerequisite: CEE 400 or a course in contract law. I (3 credits)

Provides insight into various areas of civil litigation. Includes personal and property loss, professional liability, product liability, land use, and the role of the engineer as an expert witness.

502(Mfg 504). Artificial Intelligence Applications in Civil Engineering
Prerequisite: senior or graduate standing. I (3 credits)
Introduction to artificial intelligence for engineers; theoretical concepts of AI explored and illustrated with applications in civil engineering and construction management, such as facilities design, site layout, planning and scheduling, selection of construction equipment and operation methods, construction automation. Students acquire hands-on experience with expert systems in final project.

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.

511. Fiber-Reinforced Cement-Based Composites
Prerequisite: CEE 415 or CEE 553. (3 credits)
Fiber-reinforcement of cement-based matrices; continuous and discontinuous fibers and meshes. Fiber-reinforced concrete and Ferrocement. Behavior and mechanical properties. Mechanics of fiber reinforcement. Constitutive models. High-strength, high-performance fiber composites. Influence of additives such as superplasticizers, micro-silica and polymers. Lectures, projects and laboratory.

512. Theory of Structures II
Prerequisite: CEE 312. I (3 credits)
Energy theorems and their application. Shear deformations in beams. Matrix analysis of two-dimensional frames by the stiffness method. Temperature effects. Behavior of frames and approximate methods of analysis.

513. Structural Dynamics
Prerequisite: none. I (3 credits)
Structural vibrations. Transient and steady-state response to dynamic forces. Response beyond the elastic range. Earthquake forces. The response spectrum. Seismic building codes and their relation to structural dynamics.

514(Aero 416). Theory of Plates and Shells
Prerequisites: ME 211, Math 450 or Aero 350. I (3 credits)
Linear elastic plates. Membrane and bending theory of axisymmetric and non-axisymmetric shells. Approximate treatment of edge effects. Finite element techniques for plate and shell problems.

515. Prestressed Concrete

Prerequisite: CEE 315. 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.

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.

517. Reliability of Structures

Prerequisite: CEE 315. 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.

518. 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.

519. 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.

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.

523. Flow in Open Channels

Prerequisite: CEE 325 or ME 320. I (3 credits)

Energy and momentum concepts; flow in the laminar and transition ranges; selection of canal cross-sections; minor losses; critical depth; rapidly varied flow; controls; gradually varied flow; channels of varying width; steep chutes; translatory waves; high velocity transitions; bends.

525. Turbulent Mixing in Environmental Applications

Prerequisite: CEE 325 or ME 320. II (3 credits)

Mechanics of fluid waste discharges to the environment. Solution of the diffusion equation with applications including longitudinal dispersion. Detailed analysis of jet mixing including surface jets, effects of ambient current and density stratification, and buoyancy effects.

526. Design of Hydraulic Systems

Prerequisites: CEE 420, preceded or accompanied by CEE 421. II (3 credits)

Hydraulic aspects of the design of canals, dams, gates, spillways, sea walls, breakwaters, and other structures. Determination of the most economical design of an hydraulic engineering project. Application of the digital computer to engineering design.

527. Coastal Hydraulics

Prerequisite: CEE 325 or ME 320. I (3 credits)

Equations of oscillatory wave motion; generation of waves by wind; refraction; energy transmission, breaking waves, diffraction; energy dissipation; run-up and overlapping; wave forces; he design of sea walls and breakwaters; currents and wind tides; shore erosion processes; harbor design.

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.

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.

530. Construction Professional Practice Seminar

Prerequisite: permission of instructor. 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.

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.

532. Construction Management and Project Engineering

Prerequisite: preceded or accompanied by CEE 431. II (3 credits)

Project, company organization. Manpower planning, procurement; union, non-union 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.

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.

534. Heavy Industrial Construction

Prerequisite: senior or graduate standing. (3 credits)

Design interdependencies, procurement, construction, and start-up of heavy industrial facilities; power plants, chemical plants, oil refineries. Design interfaces, specifications, drawing preparation. Procurement contracts, fabrication, quality control. Construction: site, structural, piping and vessels, electrical, instrumentation. Job planning and organization. Facility start-up. Examples from construction settings.

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.

536(Mfg 536). Critical Path Methods

Prerequisite: senior or graduate standing. I, II, 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.

537. Construction of Buildings

Prerequisite: CEE 315. 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.

538. Concrete Construction

Prerequisites: CEE 351, CEE 315. 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 precasting and prestressing methods and field erection. Sprayed, vacuum, and preplaced aggregate concrete applications. Industrialized concrete systems. Concrete grouting, repair.

540. Biotechnical Slope Stabilization

Prerequisite: senior or graduate standing in Engineering or Natural Resources.
    I (alternate years) (3 credits)

Introduction to soil bioengineering and biotechnical methods for protecting slopes against erosion and mass wasting. Role of herbaceous and woody vegetation in slope stability. Selection, handling, establishment of live plant materials. Reinforced grass systems, using hard and soft armor. Case studies of biotechnical stabilization of cut and fill slopes, streambanks, landfill covers.

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.

542. Soil and Site Improvement

Prerequisite: CEE 445. I (3 credits)

Analysis of geotechnical problems affecting site use including weak, compressible soil; water-logged conditions; high shrink-swell potential; erodibility. Stabilization techniques including compaction, earth reinforcement, drainage and erosion control, admixture stabilization, grouting, precompression, thermal and electrokinetic stabilization. Geotechnical aspects of disposal fills, e.g., tailings, fly ash, sanitary landfills, and hazardous waste.

543. Geosynthetics

Prerequisite: CEE 445. 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.

544. Rock Mechanics

Prerequisite: ME 211. I (3 credits)

Engineering properties and classification of rocks. Strength and deformability of intact and jointed rock; insitu stresses; lab and field test methods. Stereonets and structural geology. Rock slopes; stability and reinforcement. Foundations on rock.

545. Foundation Engineering

Prerequisite: CEE 445. 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; and lateral resistance of piles and pile groups.

546. Stability of Earth Masses

Prerequisite: CEE 445. 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.

547. Soils Engineering and Pavement Systems

Prerequisite: CEE 445. II (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.

548. Foundations for Marine Structures

Prerequisite: CEE 445. I (3 credits)

Effects of seepage and dewatering on design of waterfront structures. Soil retaining structures, cellular cofferdams, anchored bulk-heads. Compaction and consolidation of soil masses. Water wave forces on offshore and harbor structures. Soil-structure interaction for offshore towers, piers, wharves, sea walls, and jetties.

549. Geotechnical Aspects of Landfill Design

Prerequisite: CEE 445. 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.

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.

551. Rehabilitation of Constructed Facilities

Prerequisite: CEE 351. I (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.

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.

553. Advanced Concrete Materials

Prerequisite: CEE 351. I (3 credits)

Concrete components, microstructure, and properties of Portland cement pastes. Early heat of hydration and thermal stress development in concrete. Strength, fatigue, failure mechanisms, creep, shrinkage, and durability of hardened concrete. Special concretes: lightweight, heavy-weight, high strength, and ultra high strength.

554(Mfg 551). Materials in Engineering Design

Prerequisite: CEE 351 or permission of instructor. II (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.

560. Digital Mapping and Geographical Information Systems

Prerequisite: Math 215. II (3 credits)

Maps as multiple representations and abstractions of reality and visualization. Digital representations. Databases/models. Principles and techniques of mapping, Geographical Information Systems analysis and modeling. Integration of multi-source data, map

updating. Errors in maps and Geographical Information Systems products. Applications in Civil/Environmental Engineering and Interdisciplinary Studies, e.g. global change studies and Intelligent Vehicle Highway Systems.

571. Traffic Engineering

Prerequisite: CEE 470. (3 credits)

Driver, pedestrian, transit rider, vehicle and way characteristics and studies. Traffic system management including planning and design of information and control device applications.

572. Transportation Evaluation Methods

Prerequisite: CEE 470. (3 credits)

Methods of evaluation in transportation systems planning, design and operation. Cost and impact analysis; transportation economics; multi-objective decision methods.

573. Geometric Design of Ways and Terminals

Prerequisite: CEE 470. (3 credits)

Land transportation geometric design controls. Alignment, cross section, and intersection design for highway and railway routes. Geometric design of bus and rail terminals, parking facilities, and airports. Lecture, problems, and design laboratory.

574. Public Transportation Systems

Prerequisite: CEE 470. (3 credits)

The planning, location, design, construction, maintenance and operation of railroad facilities, other guideway systems and public bus transportation services.

575. Airport Planning and Design

Prerequisite: CEE 470. (3 credits)

Planning, site selection, and configuration; airport capacities; air traffic control; geometric design of landing area; development of terminal area; lighting; pavement requirements; drainage.

576. Disaggregate Transportation Demand Models

Prerequisite: senior or graduate standing. (3 credits)

An introduction to the development of disaggregate travel demand methodology including multinomial logit and probit models, aggregation techniques and application to the urban transportation planning process.

577. Traffic Flow I

Prerequisite: a course in statistics. (3 credits)

Studies of determinants and characteristics of traffic flow and accidents.

578. Transportation Planning

Prerequisite: CEE 470. (3 credits)

Application of systems analysis techniques to the generation, evaluation, and selection of alternative transportation plans. Use of quantitative and qualitative analysis of multimode networks for the selection of operating policies and investment programs. Consideration of planning processes and federal guidelines.

579. Special Problems in Transportation

Prerequisite: permission of instructor. I, II, IIIa (1-3 credits)

Advanced problems selected from the broad area of transportation engineering, including railroads, airports, highways, traffic, and mass transportation.

580. Physicochemical Processes in Environmental Engineering

Prerequisite: CEE 480. 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.

581. Aquatic Chemistry

Prerequisite: Chem 125. I, 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.

582. Environmental Microbiology

Prerequisite: Chem 130. I (3 credits)

Description, biochemistry and environmental activities of bacteria, algae, and protozoa. Emphasis on role of micro-organisms in changing chemistry of environment and on role of environment in selecting for certain microbial characteristics. Degradation of pollutants by microbes is discussed. Lecture and lab.

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.

584(EIH 667). Hazardous Waste Processes

I (3 credits)

The study of thermal, chemical and other systems and processes used in the detoxification of hazardous wastes, other than radioactive wastes.

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.

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.

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.

590. Stream, Lake, and Estuary Analysis

Prerequisite: CEE 480 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 bio-chemical kinetics and mass transfer processes on oxygen resources in streams, lakes, and estuaries. Demonstration of case studies and applied problems.

592. Biological Processes in Environmental Engineering

Prerequisite: CEE 480. II (3 credits)

Analysis and modeling of the kinetics of microbial substrate utilization and bio-mass production as these relate to processes in water quality control. Topical emphasis is placed on aerobic and anaerobic biological unit processes for renovation of waters and wastewaters to illustrate these fundamental principles. Lecture and lab.

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.

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.

595. Field Methods in Hydrogeochemistry

Prerequisite: CEE 428. Students must be in residence at site for 8 weeks. Must complete field, lecture and special project requirements. 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.

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. II (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.

612. Metal Structural Members

Prerequisite: CEE 413. I (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. Behavior of steel and aluminum structural members is studied with reference to their code design procedures.

613. Reinforced Concrete Members

Prerequisite: CEE 415. II (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.

614(Aero 614). Advanced Theory of Plates and Shells

Prerequisite: CEE 514 or Aero 416. II (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.

615(Aero 615)(AM 649)(ME 649). Random Vibrations

Prerequisite: CEE 513 or ME 541(AM 541) or Aero 543. II (3 credits)

Accelerated coverage of elements of probability theory. Characterization of random processes and fields. Correlation and spectral density functions. Response of linear discrete and continuous systems to random excitation. Introduction to problems involving random systems. Maxima and minima of random processes. Applications to problems of engineering interest.

616. Structural Design for Dynamic Forces

Prerequisite: CEE 513. II (3 credits)

Determination of dynamic loads on structures caused by earthquakes, wind, impact, and vibration. Methods of design to resist these forces utilizing elastic and inelastic material and member characteristics. Lectures and independent projects.

618. Advanced Prestressed Concrete

Prerequisite: CEE 515. II (3 credits)

Prestressing in statically indeterminate structures; design of prestressed concrete slabs; analysis and design of partially prestressed concrete beams; nonlinear analysis; optimum design; analysis of members prestressed with unbonded tendons; prestressed tensile members. Special research and/or application related topics.

621. Computational Hydraulics

Prerequisites: CEE 523, ChemE 508. II (3 credits)

Development of computational techniques for two- and three-dimensional flow problems. Simulation of shallow-water flow in rivers and estuaries. Flood-waves and tidal bores. Groundwater and seepage models. Computation of contaminant transport in streams and aquifers. Comparative analysis, verification and calibration of regional models. Computer graphics for multidimensional flow problems.

622. Special Problems in Hydraulic Engineering or Hydrology

Prerequisite: 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.

624. Free Surface Flow

Prerequisite: CEE 523. II (3 credits)

Dynamics of spatially varied flow; unsteady momentum and continuity equations applied to prismatic and nonprismatic channels. Rainfall and overland flow relationships.

Different numerical solutions to flood routing in channels and flood plains. Simulation techniques using digital computer.

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.

629. Hydraulic Transients II

Prerequisite: CEE 529. II (3 credits)

Steady-oscillatory flow by impedance methods and characteristics methods; self-excited and forced resonance of piping systems; pulsatile flow through distensible tubes. Digital computer applications to reciprocating pumps, valving, resonance in complex piping systems, hydropower systems.

630. Directed Studies in Construction Engineering

Prerequisite: graduate standing. I, II, IIIa, IIIb (1-3 credits)

Selected reading in specific construction areas.

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.

632. International Construction

Prerequisite: preceded or accompanied by CEE 532. (3 credits)

Conditions and practices necessary for multinational construction operations. Financial environment, world trade, and investment. Cross-cultural influences. International construction markets. International construction contracts. Mobilization and performance of international construction projects.

633. Construction Management Information Systems

Prerequisites: CEE 531, preceded or accompanied by CEE 536. II (3 credits)

Design of computerized construction management information systems (MIS). Students perform microcomputer database and spreadsheet programming to develop estimating, planning and scheduling, financial and cost accounting, and project control subsystems having common, integrated data structures. Students implement subsystems as an integrated MIS which they apply to construction problems and case studies.

636. Project Networking Techniques

Prerequisite: CEE 536. (3 credits)

Advanced networking techniques. Unlimited and limited resource leveling. Time-cost trade-offs using precedence networks. Targeting, updating and float trend analyses. Network cost analysis using PMS criteria. Extensions to precedence networks. Survey of computerized CPM systems. CPM implementation in major projects.

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.

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.

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.

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.

650. Fracture and Micromechanics of Fibrous Composites

Prerequisite: permission of instructor. I (3 credits)

Fracture mechanics fundamentals and micromechanics of cement, ceramic- and polmer-based fibrous composites. Topics include elastic crack mechanics, energy principles, interface mechanics; shear lag models; residual stress; non-alignment problems; first crack strength, steady state cracking and reliability; multiple cracking, bridging fracture energy; and R-curve behavior. Lectures and project.

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.

676. Traffic Control I
Prerequisite: CEE 577. (3 credits)
Theory and application of traffic control techniques.

677. Traffic Flow II
Prerequisite: CEE 676. (3 credits)
Detailed studies of microscopic and macroscopic traffic flow theories.

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.

687(EIH 617). Special Problems in Solid Waste Engineering
Prerequisites: CEE 585 and permission of instructor. 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 an individual student basis.

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.

810. Structural Engineering Seminar
I, II (to be arranged)
Preparation and presentation of reports covering assigned topics.

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.

870. Transportation and Traffic Engineering Seminar
I, II (to be arranged)
Assigned reading and student reports on problems selected from the fields of transportation and traffic engineering.

875. Highway Engineering Seminar

Prerequisite: graduate standing. I, II (to be arranged)

Seminar dealing with highway design, materials and construction. Assigned reading and student reports.

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.

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.

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.

930. Construction Engineering Research

(to be arranged)

Selected work from a wide range of construction engineering areas including planning, equipment, methods, estimating and costs.

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.

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.

970. Transportation Engineering Research

Prerequisite: permission of instructor. (to be arranged)

Individual research and reports on library, laboratory, or field studies in the areas of transportation and traffic engineering.

975. Highway Engineering Research

Prerequisite: permission of instructor. (to be arranged)

Individually assigned work in the field of highway engineering.

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.

990. Dissertation/Pre-Candidate

I, II (2-8 credits); IIIa, IIIb (1-4 credits)

Election for 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.

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 doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Economics *

Introductory Courses
Students who want to take
advanced courses in
Economics must elect
Economics 101 and 102.

*For further details with
respect to these courses
and for additional courses
in the field of economics,
consult the* Bulletin *of
the College of Literature,
Science, and the Arts.*

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J. Cross, A. Deardorff, R. Gordon, E. Gramlich, E.P. Howrey,
S. Hymans, G. Johnson, J. Laitner, D. Lam, L.F. Lee,
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Professors** S. Basu, K. Charles, Y. Chen, M. Chernew,
R. Hirth, L. Kilian, M. Levenstein, D. Li, D. Roth, S. Sakata,
G. Shaffer, Tayfun Sönmez, R. Thomas; **Lecturers**
J. Gerson, F. Thompson, J. Wolfe; **Adjunct Associate
Professor** S. Kossoudji; **Adjunct Assistant Professor**
John Hussman

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101. Principles of Economics I
(4 credits)

102. Principles of Economics II
Prerequisite: Econ 101. (4 credits)

109. Laboratory Economics
(4 credits)

310. Money and Banking
*Prerequisites: Econ 101, Econ 102. No credit granted to those who have completed
    or are enrolled in Econ 411 or Econ 412. (3 credits)*

320. Survey of Labor Economics
Prerequisites: Econ 101, Econ 102. (3 credits)

330. Industrial Performance and Public Policy

Prerequisites: Econ 101, Econ 102. Credit is not granted for Econ 330 concurrently with or after Econ 431 or Econ 432. (3 credits)

340. International Economics

Prerequisites: Econ 101, Econ 102. No credit granted to those who have completed or are enrolled in Econ 441 or Econ 442. (3 credits)

350. Comparative Economic Systems

Prerequisites: Econ 101, Econ 102. No credit granted to those who have completed or are enrolled in Econ 451. (3 credits)

360. The Developing Economies

Prerequisites: Econ 101, Econ 102. No credit granted to those who have completed or are enrolled in Econ 461. (3 credits)

380. Public Finance

Prerequisites: Econ 101, Econ 102. Credit is not granted for Econ 380 concurrently with or after Econ 481 or Econ 482. (3 credits)

395. Topics in Economics and Economic Policy

Prerequisites: Econ 101, Econ 102. (3 credits)
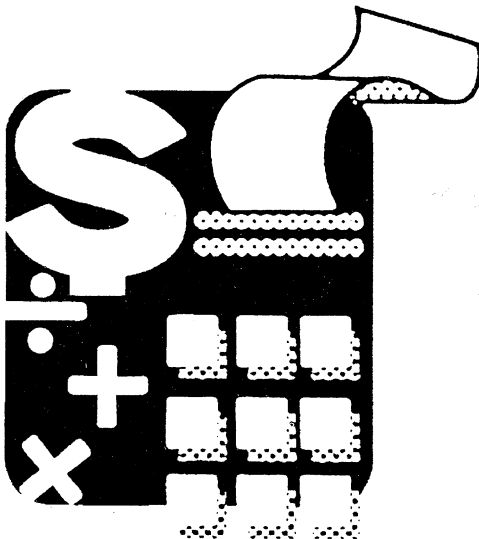
Electrical Engineering and Computer Science

Department Office
3316 EECS Building
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Toby J. Teorey, Ph.D., *Professor and Associate Chair, Computer Science and Engineering Division*

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Peter M. Banks, Ph.D.; *also Atmospheric, Oceanic and Space Sciences*
Spencer L. BeMent, Ph.D.
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Keki B. Irani, Ph.D.
Janice M. Jenkins, Ph.D.

Pierre T. Kabamba, Ph.D.; *also Aerospace Engineering*
Jerzy Kanicki, Ph.D.
Stephen Kaplan, Ph.D.
Linda B. Katehi, Ph.D.
Pramod P. Khargonekar, Ph.D.
Emmett N. Leith, Ph.D., *Schlumberger Professor of Engineering*
Ronald J. Lomax, Ph.D.
N. Harris McClamroch, Ph.D.; *also Aerospace Engineering*
Semyon M. Meerkov, Ph.D.
John F. Meyer, Ph.D.
Gerard A. Mourou, Ph.D.; *also Applied Physics; also Director of the Center for Ultrafast Optical Science*
Trevor N. Mudge, Ph.D.
Andrew F. Nagy, Ph.D.; *also Atmospheric, Oceanic and Space Sciences*
David L. Neuhoff, Ph.D.
Matthew O'Donnell, Ph.D.
Yale Patt, Ph.D.

Dimitris Pavlidis, Ph.D.; *also Applied Physics*
William B. Ribbens, Ph.D.
William C. Rounds, Ph.D.
Kang G. Shin, Ph.D.
Jasprit Singh, Ph.D.
Elliot Soloway, Ph.D.
Duncan G. Steel, Ph.D.
Quentin F. Stout, Ph.D.
Demosthenis Teneketzis, Ph.D.
Fawwaz T. Ulaby, Ph.D., *R. Jamison and Betty Williams Professor of Engineering*
John L. Volakis, Ph.D.
William J. Williams, Ph.D.
Herbert G. Winful, Ph.D.; *also Applied Physics*
Kensall D. Wise, Ph.D., *J. Reid and Polly Anderson Professor of Manufacturing Technology*

Adjunct Professor

William M. Brown, Ph.D.
Betram Herzog, Ph.D.
George J. Zissis, Ph.D.

Professor Emeritus

Ben F. Barton, Ph.D.
Frederick J. Beutler, Ph.D.;
    also Aerospace
    Engineering
Arthur W. Burks, Ph.D., Sc.D.
John J. Carey, M.S., P.E.
Kan Chen, Sc.D.
Kuei Chuang, Ph.D.
Chiao-Min Chu, Ph.D.
William G. Dow, M.S.E., P.E.
Hansford W. Farris, Ph.D.
Bernard A. Galler, Ph.D.
Ralph E. Hiatt, M.A.
Louis F. Kazda, Ph.D.
John A. M. Lyon, Ph.D.
Alan B. Macnee, Sc.D.
Charles W. McMullen, Ph.D.
Raymond F. Mosher, S.M., P.E.
Arch W. Naylor, Ph.D.
Andrejs Olte, Ph.D.
Norman R. Scott, Ph.D.
Charles B. Sharpe, Ph.D.
Chen-To Tai, Sc.D.
Herschel Weil, Ph.D.
Chai Yeh, D.Sc.

Associate Professor

William P. Birmingham, Ph.D.
Richard B. Brown, Ph.D.
Kevin J. Compton, Ph.D.
Edmund H. Durfee, Ph.D.
Larry K. Flanigan, Ph.D.
James S. Freudenberg, Ph.D.
Alfred O. Hero III, Ph.D.
Mohammed Islam, Ph.D.
Henry Kapteyn, Ph.D.
David E. Kieras, Ph.D.
Daniel Koditschek, Ph.D.
Stephane Lafortune, Ph.D.
John E. Laird, Ph.D.
Pinaki Mazumder, Ph.D.
Leo C. McAfee, Jr., Ph.D.
Margaret Murnane, Ph.D.
Khalil Najafi, Ph.D.
Clyde L. Owings, M.D., Ph.D.

Stella W. Pang, Ph.D.
Stephen C. Rand, Ph.D.
Gabriel Rebeiz, Ph.D.
Karem Sakallah, Ph.D.
Wayne E. Stark, Ph.D.
Fred Terry, Ph.D.
Gregory H. Wakefield, Ph.D.
Kim A. Winick, Ph.D.
Andrew Yagle, Ph.D.

Adjunct Associate Professor

Peter Honeyman, Ph.D.;
    also Associate
    Research Scientist, CITI
Lauren Peterson, Ph.D.
Juris Upatnieks, M.S.E.

Assistant Professor

Peter Chen, Ph.D.
John T. Coffey, Ph.D.
Emad Ebbini, Ph.D.
Jeffrey A. Fessler, Ph.D.
Brian E. Gilchrist, Ph.D.
Farnam Jahanian, Ph.D.
Sugih Jamin, Ph.D.
Sang W. Lee, Ph.D.
Carlos Mastrangelo, Ph.D.
Clark Nguyen, Ph.D.
Theodore Norris, Ph.D.
Marios Papaefthymiou, Ph.D.
Atul Prakash, Ph.D.
Steven Reinhardt, Ph.D.
Elke Rundensteiner, Ph.D.
Kamal Sarabandi, Ph.D.
Nandit Soparkar, Ph.D.
Kimblery M Wasserman,
    Ph.D.
Michael Wellman, Ph.D.

Adjunct Assistant Professor

Charles Antonelli, Ph.D.
Sandra Bartlett, Ph.D.
Peter Bird, Ph.D.

Research Scientist

Jack R. East, Ph.D.
Michael Elta, Ph.D.
Valdis Liepa, Ph.D.
Peter Pronko, Ph.D.
Marlin P. Ristenbatt,
    Ph.D., *Lecturer*

Associate Research Scientist

James L. Daws, Jr., Ph.D.,
    Lecturer
Kurt Metzger, Ph.D.
Kent Moncur, Ph.D.
Chinya Ravishankar, Ph.D.
Donald Umstadter, Ph.D.
Terry Weymouth, Ph.D.
John F. Whitaker, Ph.D.
Xiangkun Zhang, Ph.D.

Assistant Research Scientist

Selden Crary, Ph.D.
M. Craig Dobson, M.A.
Heribert Eisele, Ph.D.
Dennis Grimard, Ph.D.
Randy Jones, Ph.D.
Karl Kluge, Ph.D.
Xinbing Liu, Ph.D.
Anatoly Maksimchuk, Ph.D.
James Moyne, Ph.D.
John Nees, M.S.
Paul Nielsen, Ph.D.
Leland Pierce, Ph.D.
Jianping Sun, Ph.D.
Weiqian Sun, Ph.D.
Steve Underwood, Ph.D.
Kyounghoon Yang, Ph.D.
Babak Ziaie, Ph.D.

Adjunct Research Scientist

John H. Bryant, Ph.D.

Adjunct Associate Research Scientist
Richard Mains, Ph.D.
Patrick McCleer, Ph.D.

Adjunct Assistant Research Scientist
Spencer Thomas, Ph.D.

Lecturer
Ann Ford

Adjunct Lecturer
Randall Frank, B.S.; *also*
Executive Director of
Information Technology
and the Computer Aided
Engineering Network
(CAEN)

See page 225 for statement on Course Equivalence.

100(CS 100). Introduction to Computing Systems
Prerequisite: none. I, II (4 credits)
How a computer works, from the machine level to high level programming. Circuits, instructions, memory, data. Assembly language. Binary arithmetic, data types, data structures. Translation of high level languages. The C programming language: data structures, control, iteration, recursion. Basic algorithm analysis.

181(CS 181). Introduction to Computer Systems
Prerequisite: none. A student can receive credit for only one: EECS 181, Eng 103,
or Eng 104. I, II (4 credits)
Introduces students to computers. Focuses on software, hardware, and social impact of computers. Elementary programming concepts, software packages and applications, word processing, data communications, information management, input-output, data entry, computer hardware components and storage devices, microcomputers, and ethics in computing. Programming assignments using a personal computer. Term paper required.

183(CS 183). Elementary Programming Concepts
Prerequisite: none. Not intended for CS or Computer Engineering majors.
I, II, III (4 credits)
Introduction to a high-level programming language, top-down analysis, and structured programming. Basic searching and sorting techniques. No previous experience in computers or programming is assumed. Students will write and debug several computer programs.

210. Electrical Engineering I

Prerequisite: Math 116. I, II, III (4 credits)

Introductory electrical engineering topics: audio signals and their processing; basics of electricity; elementary circuit design and analysis. Frequency content of signals, Fourier series, filtering. Analysis of resistive circuits. Steady-state response of circuits of resistors, capacitors, inductors and operational amplifiers to sinusoidal signals (frequency response). Laboratory experience with electrical signals and circuits.

211. Electrical Engineering II

Prerequisite: EECS 210. I, II, III (4 credits)

Introductory electrical engineering topics, continued: basic circuit analysis; elementary transistor and diode circuits. Equivalent transformations of electric circuits. Transient analysis of circuits. Introduction to diode and transistor circuits. Amplifiers, limiters, filters and logic circuits. Laboratory experience with electrical signals and circuits.

250(Nav Sci 202). Electronic Sensing Systems

Prerequisite: preceded or accompanied by 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.

270(CS 270). Introduction to Logic Design

Prerequisite: EECS 100 or equivalent. I, II, III (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 hardware design and CAD experiments.

280(CS 280). Programming and Introductory Data Structures

Prerequisites: Math 115 and EECS 100 or equivalent. 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.

284(CS 284). Introduction to a Programming Language or System

Prerequisite: Some programming knowledge. Note: Credit will not be given for the C minicourse to students who have taken EECS 280. I, II (1 credit)

A course covering the fundamentals of a high level programming language or a system such as UNIX. Programming problems will be assigned. Specific languages or systems to be offered will be announced in advance.

303(CS 303). Discrete Structures

Prerequisite: Math 115. I, II (4 credits)

Fundamental concepts of algebra; partially ordered sets, lattices, Boolean algebras, semi-groups, rings, polynomial rings. Graphical representation of algebraic systems; graphs, directed graphs. Application of these concepts to various areas of computer engineering.

314. Circuit Analysis and Electronics

Prerequisites: Math 216, Physics 240. Not open to electrical engineering or engineering science students. I, II, III (3 credits)

A survey of electrical and electronic circuits for non-electrical engineering students. Formulation of circuit equations; equivalent circuits; frequency response ideas; steady-state and transient response; introduction to amplifiers; operational amplifiers; survey of electronic devices and circuits. Use of computer simulations for analysis of more advanced circuits.

315. Circuit Analysis and Electronics Laboratory

Prerequisite: preceded or accompanied by EECS 314. Not open to electrical engineering or engineering science students. I, II (1 credit)

Lecture and laboratory designed to illustrate the principles developed in EECS 314 with application to other engineering disciplines. AC and DC measurements; steady-state and transient response; amplifiers and filters. Transducers for the measurement of strain, position and velocity, temperature. Design of a simple thermostat and electric motor speed control circuit.

316. Signals and Systems

Prerequisite: EECS 211. I, II, III (4 credits)

Basic concepts in linear system theory, and their use in analyzing signals and linear systems. Topics include: superposition; convolution and impulse response; Fourier series and transforms; Laplace transforms; transfer functions; Bode plots and stability. Systems concepts. Discrete Fourier series and Fourier transform methods. Introduction to z-transforms.

317. Solid-State Devices and Digital Electronics

Prerequisites: EECS 211 and EECS 270. I, II, III (4 credits)

Circuit models for diodes, bipolar-junction and field-effect transistors; piecewise linear and nonlinear analysis; logic circuits; memory circuits (flip-flops, RAM, ROM); computer analysis of electronic circuits.

318. Analog Electronics

Prerequisites: EECS 316, EECS 317. I, II (4 credits)

Operation and small-signal models of diodes, junction and field-effect transistors; basic single-stage and multi-stage amplifiers: gain, biasing, and frequency response; feedback; op-amp circuits: amplifiers, rectifiers, oscillators, filters. Design problems. Lecture and laboratory.

320. Introduction to Semiconductor Device Theory

Prerequisites: EECS 211 or EECS 314 and Physics 240. I, II, III (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. Introduction to: PN junctions, metal-semiconductor junctions, bipolar junction transistors, junction and insulated-gate field-effect transistors.

331. Electromagnetics I

Prerequisites: Physics 240, Math 216. I, II (4 credits)

Gauss's law and the static electric field; boundary value problems in electrostatics. Dielectric and magnetic media. Magnetostatics; Faraday's law and applications. Maxwell's equations; wave equation; plane waves.

332. Electromagnetics II

Prerequisite: EECS 331. I, II (3 credits)

Theory and applications of electromagnetic waves; reflection, refraction, and attenuation in various media. Antennas and radiating systems. Introduction to radio and optical transmission including waveguides, striplines, optical fibers, and the Earth's atmosphere.

359. Measurements and Instrumentation

Prerequisite: EECS 316. I (3 credits)

Measurements of circuit parameters, electric and magnetic fields, characteristics of discrete and integrated devices. Basic concepts of modern instrumentation. Two lectures and laboratory.

360. Dynamic Systems and Modeling

Prerequisite: EECS 316. I, II (3 credits)

Introduction to the fundamentals of modeling and analysis of real world systems using mathematical techniques. Examples drawn from engineering, biology, economics, medicine, politics and sociology to illustrate linear, nonlinear, differential and/or difference equations, lumped parameter and distributed parameter models, state space and input-output systems, discrete-event systems. Basic systems concepts: superposition, time-invariance, causality, stability. Simulation on modern CAE packages. Group project.

361. Automotive Electronic Systems

Prerequisite: EECS 316 or ME 360. II (even years) (3 credits)

Theory and practice of electronic systems on automobiles. Detailed qualitative, quantitative, and performance analyses are made of automotive electronic systems including: digital engine/drivetrain control, instrumentation, vehicle multiplexing, diagnostics, suspension, steering, antilock braking/traction control, communication and safety subsystems.

370(CS 370). Introduction to Computer Organization

Prerequisites: EECS 270, EECS 280. I, II (4 credits)

Computer organization will be presented as a hierarchy of virtual machines representing the different abstractions from which computers can be viewed. These include the logic level, microprogramming level, and assembly language level. Lab experiments will explore the design of a microprogrammed computer.

373. Design of Microprocessor-Based Systems

Prerequisites: EECS 270, junior standing. I, II (3 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.

380(CS 380). Data Structures and Algorithms

Prerequisites: EECS 280, EECS 303. I, II (4 credits)

Abstract data types. Recurrence relations and recursions. Advanced data structures: sparse matrices, generalized lists, strings. Tree-searching algorithms, graph algorithms, general searching and sorting. Dynamic storage management. Analysis of algorithms O-notation. Complexity. Top-down program development: design, implementation, testing modularity. Several programming assignments.

398(CS 398). Special Topics

Prerequisite: permission of instructor. (1-4 credits)

Topics of current interest selected by the faculty. Lecture, seminar, or laboratory.

400(Math 419). Linear Spaces and Matrix Theory

Prerequisite: four semesters of college mathematics beyond Math 110. Not open to students with credit for Math 417 or Math 513. I, II (3 credits)

Finite dimensional linear spaces and matrix representations of linear transformations. Bases, subspaces, determinants, eigenvectors, and canonical forms. Structure of solutions of systems of linear equations. Applications to differential and difference equations. The course provides more depth and content than Math 417. Math 513 is the proper election for students contemplating research in mathematics.

401(Aero 452). Probabilistic Methods in Engineering

Prerequisite: junior standing. I, II, III (3 credits)

Basic concepts of probability theory. Random variables: discrete, continuous, and conditional probability distributions; averages; independence. Introduction to discrete and continuous random processes: wide sense stationarity, correlation, spectral density.

411. Microwave Circuits I

Prerequisite: EECS 332. I (3 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.

413. Monolithic Amplifier Circuits
Prerequisites: EECS 318, EECS 320. 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.

415(ME 424). Engineering Acoustics
Prerequisites: Math 216, Physics 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.

417(BiomedE 417). Electrical Biophysics
Prerequisites: EECS 211 or EECS 314, preceded or accompanied by EECS 316.
*   I (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.

421. Properties of Transistors
Prerequisites: EECS 320, EECS 331. I (3 credits)
DC, small and large signal AC, switching and power-limiting characteristics, and derivation of equivalent circuit models of: PN junctions, metal-semiconductor and metal-insulator semiconductor diodes, bipolar junction transistors, junction and insulated-gate field-effect transistors, and thyristors.

422. Electronic Properties of Semiconductor Materials
Prerequisite: EECS 320. I (3 credits)
Free electron theory for transport, crystal structure and X-ray diffraction, Bloch theorem, band structure and effective mass; donors and acceptors and carrier statistics; phonons; transport in electric field; heterostructure concepts.

423. Solid-State Device Laboratory
Prerequisite: EECS 320. 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.

424. Integrated Circuit Process Technology and Process Integration

Prerequisites: EECS 320, EECS 317. II (3 credits)

Integrated circuit processing techniques: oxidation, diffusion, ion implantation, epitaxy, deposition, etching, process integration for silicon CMOS and bipolar technologies. Relationship between processing, device design, and device performance.

425. Integrated Circuits Laboratory

Prerequisites: EECS 320, EECS 427. II (3 credits)

Integrated circuit fabrication; mask design, photographic reduction; photoresist application, exposure, development, and etching; oxidation; diffusion; metal film deposition by evaporation and sputtering; die bonding, wire bonding, and encapsulation; testing of completed integrated circuits.

426(CS 426). Fundamentals of Electronic Computer-Aided Design

Prerequisites: EECS 280, senior level standing. I (3 credits)

Course will address, in roughly equal proportion: (1) modeling, simulation, and verification at various abstraction levels; (2) behavioral and logic synthesis; and (3) placement and routing. Emphasis will be on understanding the underlying techniques and algorithms of these various CAD areas rather than on the use of specific CAD tools.

427. VLSI Design I

Prerequisite: EECS 317. 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.

429. Semiconductor Optoelectronic Devices

Prerequisite: EECS 320. 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.

430. Radiowave Propagation and Link Design

Prerequisite: EECS 332. 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, multipath interference, and scattering are studied.

431. Fields and Optics Laboratory

Prerequisite: preceded or accompanied by EECS 332. I (2 credits)

Experiments and lectures to demonstrate the behavior and practical aspects of electro-magnetic fields at microwave and optical frequencies. Microwave experiments

involving transmission lines, waveguides, antennas, sources, and detectors. Fiber optics and lasers.

432(BiomedE 432). Fundamentals of Ultrasonics with Medical Applications

Prerequisite: EECS 331. II (3 credits)

Basic principles; waves, propagation, impedance, reflection, transmission, attenuation, power levels. Generation of ultrasonic waves; transducers, focusing, Fraunhofer and Fresnel zones. Instrumentation; display methods, Doppler techniques, signal processing. Medical applications will be emphasized.

433. Principles of Optics

Prerequisites: Physics 240, Math 216. A student cannot receive credit for both Physics 402 and EECS 433. I (3 credits)

Basic principles of optics: generation and propagation of light; interaction of light and matter; geometrical optics, ray tracing and introduction to aberration theory; superposition of waves, coherence and interference; Fresnel and Fraunhofer diffraction. Special topics such as lasers and holography.

434. Principles of Photonics

Prerequisite: EECS 332. II (3 credits)

Wave propagation in crystals; propagation of Gaussian beams; optical resonators; optical wave guides; interaction of radiation and atomic systems; theory of laser operation; the modulation of optical radiation; the detection of optical radiation; noise in optical detection and generation; nonlinear optical phenomena.

435. Fourier Optics

Prerequisites: EECS 316, preceded or accompanied by EECS 433. I (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.

436. Optical Radiation and Detector Technology

Prerequisites: Physics 240, Math 216. I (odd years) (3 credits)

Theory and instrumentation for sensing and measuring visible and infrared radiation. Topics include: blackbody radiation; radiometric concepts; radiative transfer through the atmosphere; basic optics of semiconductors; photon detectors (photoconductive, photovoltaic, and photoemissive); thermal detectors; detector noise sources and figures of merit; imaging detectors (pyroelectric arrays and CCDs); LEDs and diode laser sources.

437. Coherent Optics Laboratory

Prerequisite: EECS 433. II (2 credits)

Experimental aspects and techniques of coherent optics. Lasers, alignment techniques for optical systems, characteristics of photographic recording materials, spatial filtering, coherent imaging, interferometry and coherence measurement of light sources, holography. Lecture and laboratory.

442(CS 442). Computer Vision

Prerequisites: EECS 303, EECS 380. I (3 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 and relaxation labeling, stereo, shading texture, object representation and recognition, dynamic scene analysis, and knowledge-based techniques. Hardware/software techniques.

450(NR 543). Imaging Radar as a Remote Sensor

Prerequisite: NR 541 or permission of instructor. II (3 credits)

Descriptive treatment of imaging radar systems, theoretical and operational performance and limitations, reflection from terrestrial and vegetal surfaces, interpretation of imagery; application to topics of student's interest (e.g., geology, oceanography, forestry). Special topics include holographic radar, passive microwave systems, synthetic aperture radar, and imaging sonar.

451. Digital Signal Processing and Analysis

Prerequisite: EECS 316. I, II, III (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. Laboratory experiences exercise and illustrate the concepts presented.

452. Digital Signal Processing Design Laboratory

Prerequisite: preceded or accompanied by EECS 451. I, II (3 credits)

Architectural features of single-chip DSP processors are introduced in lecture. Laboratory exercises using two different state-of-the-art fixed-point processors include sampling, A/D and D/A conversion, digital wave form generators, real-time FIR and IIR filter implementations. The central component of this course is a 12-week team project in real-time DSP Design (including software and hardware development).

453. Analog Communication Signals and Systems

Prerequisite: EECS 316. I (3 credits)

Mathematical analysis of the signals and signal processing used in analog communication systems; spectral analysis, signal transmission; amplitude, phase, frequency, and

pulse modulation; modulation and demodulation techniques; frequency and time multiplexing; analysis of signal-to-noise ratio; application to radio and television.

455. Digital Communication Signals and Systems

Prerequisites: EECS 316, EECS 401. II (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.

458(BiomedE 458). Biomedical Instrumentation and Design

Prerequisite: none. 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.

459. Advanced Electronic Instrumentation

Prerequisite: EECS 360 or EECS 359 or EECS 453 or EECS 458. II (odd years) (3 credits)

Systematic design of optimum measuring instruments which give maximum confidence in results. Analog and digital signal processing, transducer modeling. A/D and D/A conversion, survey of modern instrumentation components.

460. Fundamentals of Control Systems

Prerequisites: ME 240, EECS 316 or EECS 360, and senior standing. I, II, III (3 credits)

Concept and importance of control systems. Control system descriptions; state variable and transfer function representations. System performance and design criteria: stability, sensitivity, time response. Concept of feedback. Time response of linear control systems. Use of Hurwitz, root-locus, Nyquist, and Bode methods for analysis and synthesis of linear control systems.

463(Mfg 464)(ME 463). Modern Control Systems Design

Prerequisite: EECS 460 or ME 461 or Aero 471. I, II (4 credits)

The class is organized into teams of four to five students. Each team must select, plan and complete a design project within the general theme of automatic control systems. The project accounts for approximately 75% of the course grade. Lectures will cover state space analysis techniques, system ID basics and state space feedback design methods.

467(Mfg 467)(ME 467). Robotics: Theory, Design, and Application

Prerequisites: ME 360 or EECS 360 and senior standing. I, II (3 credits)

Basic concepts underlying the design and application of computer-controlled manipulators: Manipulator geometry, work volume, sensors, feedback control of manipulator

linkages, kinematics, trajectory planning, programming, robot system architecture, design and application. Lab experiments cover kinematics, dynamics, trajectory planning, control of manipulators and motion by fixed robots and mobile robots.

470(CS 470). Computer Architecture
Prerequisite: EECS 370. I, II (4 credits)
Basic concepts of computer architecture and organization. Computer evolution. Design methodology. Performance evaluation. Elementary queueing models. CPU architecture. Introductions sets. ALU design. Hardware and microprogrammed control. Nanoprogramming. Memory hierarchies. Virtual memory. Cache design. Input-output architectures. Interrupts and DMA. I/O processors. Parallel processing. Pipelined processors. Multiprocessors.

473(CS 473). Advanced Digital System Design
Prerequisite: EECS 373 or permission of instructor. II (3 credits)
This course introduces advanced digital system design concepts, such as timing analysis, reliability, and testability. These concepts are then applied to a semester-long design project of the student's choice. The result of this project will be a highly testable, highly reliable digital system.

476(CS 476). Foundations of Computer Science
Prerequisites: EECS 280, EECS 303 or equivalent. I, II (4 credits)
An introduction to computation theory: finite automata, regular languages, push-down automata, context-free languages, Turing machines, recursive languages and functions, and computational complexity.

477(CS 477). Introduction to Algorithms
Prerequisite: EECS 380. I (3 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.

478(CS 478). Switching and Sequential Systems
Prerequisites: EECS 303, EECS 270, and senior or graduate standing. I, II (3 credits)
An introduction to the theory of switching networks and sequential systems. Switching functions and realizations, threshold logic, fault detection, connectedness and distinguishability, equivalence and minimality, state identification, system decomposition.

481(CS 481). Software Engineering
Prerequisite: EECS 380. 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.

482(CS 482). Introduction to Operating Systems

Prerequisites: EECS 370, EECS 380. I, II (4 credits)

Operating system functions and implementations: multi-tasking; concurrency and synchronization; deadlock; scheduling; resource allocation; real and virtual memory management; input/output; file systems. Students write several substantial programs dealing with concurrency and synchronization in a multi-task environment.

483(CS 483). Compiler Construction

Prerequisites: EECS 380, EECS 476. I, II (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.

484(CS 484)(IOE 484). Database Management Systems

Prerequisite: EECS 380 or IOE 373. I, II (3 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, normalization, access methods, query optimization, transaction management and concurrency control, recovery, and integrity.

486(CS 486). Object-Based Software Development

Prerequisite: EECS 380. II (3 credits)

Object-based programming concepts such as data and program abstraction, decomposition of large systems into reusable objects, and inheritance. Programming projects will be done in an object-based language such as Ada. Comparative studies will be made of languages such as C++, Objective C, Eiffel, and Smalltalk that support object-based programming.

487(CS 487). Interactive Computer Graphics

Prerequisites: EECS 380 or IOE 373, and senior standing. I, II (3 credits)

Graphics devices and fundamentals of operation. Two dimensional and three dimensional transformations. Interactive graphical techniques and applications, three dimensional graphics, perspective transformation, hidden line elimination. Data structures and languages for graphics. Interactive graphical programming.

489(CS 489). Computer Networks

Prerequisite: EECS 482. II (3 credits)

Hardware and software architectures employed in building modern computer networks. Emphasis is placed on architectural and design considerations over actual implementation issues. Trade-offs in network architectures and in understanding what choices are available. Software problems assigned.

492(CS 492). Introduction to Artificial Intelligence

Prerequisite: EECS 380. I, II (4 credits)

Basic artificial intelligence methods using LISP. Topics covered include search, rule-based systems, logic, constraint satisfaction, and knowledge representation.

493(CS 493)(IOE 437). User Interface Design and Analysis

Prerequisite: EECS 481. I (3 credits)

Current theory and design techniques concerning how user interfaces for computer systems should be designed to be easy to learn and use. Focus on cognitive factors, such as the amount of learning required, and the information-processing load imposed on the user, rather than ergonomic factors.

497. Analysis and Design Projects

Prerequisite: successful completion of at least two-thirds of the credit hours required for the program subjects. A student may elect this course more than once ONLY with the explicit approval of the Chief Program Advisor. I, II, III (1-4 credits)

Professional problem-solving methods developed through intensive group and individual studies. Normally, two or three significant engineering analysis and design projects will be carefully chosen from devices, software tools, and systems. Use of analytic, computer, design, and experimental techniques where applicable. Lecture and laboratory sessions will be arranged.

498. Special Topics

Prerequisite: permission of instructor. (1-4 credits)

Topics of current interest selected by the faculty. Lecture, seminar or laboratory.

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.

500-1, 2, 3. Tutorial Lecture Series in System Science

Prerequisite: graduate standing. 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.

501(Aero 552). 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.

502(Aero 553). Stochastic Processes

Prerequisite: EECS 501. II (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 processing, Markov jump processes, uniformization, reversibility, and queueing applications.

503. Introduction to Numerical Electromagnetics

Prerequisite: EECS 332. 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.

505(Aero 577)(IOE 511)(Math 562). Continuous Optimization Methods

Prerequisites: 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.

506(CS 506). Computing System Evaluation

Prerequisites: EECS 183 or EECS 280, and EECS 370, EECS 501. II (odd years)
(3 credits)

Theory and application of analytic methods for evaluating the performance and reliability of computing systems. Measures of performance, reliability, and performability. Reliability evaluation: classification and representation of faults, stochastic process models, coherent systems. Performance evaluation: Markovian queueing models, networks of queues. Unified performance-reliability evaluation.

509(IOE 517). Traffic Modeling

Prerequisites: IOE 315, Stat 310, or EECS 401. II (3 credits)

Traffic Models and their analysis in the context of ITS (Intelligent Transportation Systems). Those aspects of traffic theory relevant to ITS are presented including traffic flow and signalized intersections, with particular emphasis on the optimization via route guidance and signal control of large scale traffic networks.

510. Intelligent Transportation Systems Research Topics

Prerequisites: 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).

511. Microwave Circuits II

Prerequisite: EECS 411. II (odd years) (3 credits)

General theory of waveguides; inhomogeneously filled waveguides. Surface waveguides. Circuit theory of waveguiding systems. Passive microwave devices; directional couplers, filters, isolators, circulators.

512. Amorphous and Microcrystalline Semiconductor Thin Film Devices

Prerequisites: EECS 421 or/and permission of instructor. I (3 credits)

Introduction and fundamentals of physical, optical and electrical properties of amor-phous 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.

513. Flat Panel Displays

Prerequisites: 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.

514. Intelligent Vehicle-Highway Systems Technologies

Prerequisites: graduate standing, college calculus and physics. I (3 credits)

This course covers various technologies relevant to IVHS, including systems architecture, communications, and computers. Intended for students with a variety of backgrounds appropriate for the study of IVHS. Followed by EECS 515, the laboratory portion.

515. Intelligent Vehicle-Highway Systems Technologies Laboratory

Prerequisite: EECS 514. II (1 credit)

This is the laboratory portion of IVHS Technologies. Experience applying the concepts and techniques learned in the lecture part of the course.

516(BiomedE 517). 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.

517. Physical Processes in Plasmas

Prerequisite: EECS 332. II (even years) (3 credits)

Plasma physics applied to electrical gas discharges used for materials processing. Gas kinetics; atomic collisions; modeling RF and microwave discharges; ambipolar diffusion; transport coefficients; sheaths; distribution function calculation by Boltzmann equation and Monte Carlo methods; plasmas in dc magnetic fields; analysis of plasmas tools; plasma diagnostics.

518(AOSS 595). Magnetosphere and Solar Wind

Prerequisite: graduate standing. I (even years) (3 credits)

General principles of magnetohydrodynamics; theory of the expanding atmosphere; properties of solar winds, interaction of solar wind with the magnetosphere of the Earth and other planets; bow shock and magnetotail, trapped particles, auroras.

519(NERS 575). Plasma Generation and Diagnostics Laboratory

Prerequisite: preceded or accompanied by a course covering electromagnetism. II (3 credits)

Laboratory techniques for plasma ionization and diagnosis relevant to plasma processing, propulsion, vacuum electronics, lasers, 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.

520. Theoretical Methods for Solid-State Electronics

Prerequisite: EECS 422. II (odd years) (4 credits)

Bandstructure in semiconductors; strain dependence of bandstructure; perturbation approaches to scattering; transport in semiconductors; optical properties of semiconductors.

521. High-Speed Transistors

Prerequisite: EECS 421 or EECS 422. 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.

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.

523. Digital Integrated Circuits

Prerequisites: EECS 320 and EECS 317, or EECS 424. I (4 credits)

Device technologies for LSI circuits. Approaches to logic implementation, including gate arrays, master-slices, PLAs. Non-volatile semiconductor memory structures, including ROM, PROM, EPROM, and EAROM. Static and dynamic random access memory and microcomputers. Relationship of terminal performance to the design, layout, and fabrication techniques used. Circuit layout and computer simulation.

524. Field-Effect-Transistors and Microwave Monolithic Integrated Circuits Technology

Prerequisites: graduate standing and EECS 421, and either EECS 525 or EECS 528. II (even years) (3 credits)

Physical and electrical properties of III-V materials, epitaxy and ion-implantation, GaAs and InP based devices (MESFETs, HEMTs varactors) and Microwave Monolithic Integrated Circuits (MMICs). Cleaning, Photolithography, metal and dielectric deposition, wet and dry etching. Device isolation, ohmic and Schottky contacts, dielectrics, passive component technology, interconnects, via holes, dicing and mounting. Study of the above processes by DC characterization.

525. Solid State Microwave Circuits

Prerequisites: EECS 411, EECS 421. I (3 credits)

General properties and design of nonlinear solid-state microwave networks, including: negative resistance oscillators and amplifiers, frequency convertors and resistive mixers, transistor amplifiers, power combiners, and harmonic generators.

526. High-Performance Dynamic Device Models and Circuits

Prerequisites: EECS 413, or both EECS 318 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.

527. Computer-Aided Design for VLSI System

Prerequisite: EECS 478. II (3 credits)

Theory of circuit layout partitioning and placement algorithms. Routing algorithms, parallel design automation on shared memory and distributed memory multi-processors, simulated annealing and other optimization techniques and their applications in CAD, layout transformation and compaction, fault-repair algorithms for RAMs and PLAs hardware synthesis from behavioral modeling, artificial intelligence-based CAD.

528. Principles of Microelectronics Process Technology

Prerequisites: 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, microstructure processing, and process modeling.

529. Semiconductor Lasers and LEDs

Prerequisite: EECS 429. I (alternate years) (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.

530(Appl Phys 530). Electromagnetic Theory I

Prerequisite: EECS 332 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.

531. Antenna Theory and Design

Prerequisite: EECS 332. 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.

532. Microwave Remote Sensing I: Radiometry

Prerequisites: EECS 332, 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.

533. Microwave Measurements Laboratory

Prerequisites: EECS 332, 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.

534(CS 534). Design and Characterization of Microwave Devices and Monolithic Circuits

Prerequisites: graduate standing, EECS 421 or EECS 525. I (odd years) (4 credits)

Theory and design of passive and active microwave components and monolithic integrated circuits including: microstrip, lumped inductors and capacitors, GaAs FETs,

varactor and mixer diodes, monolithic phase shifters, attenuators, amplifiers and oscillators. Experimental characterization of the above components using network analyzer, spectrum analyzer, power and noise meters. Lecture and laboratory.

535. Optical Information Processing

Prerequisites: EECS 300, EECS 433. II (odd 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.

536. Classical Statistical Optics

Prerequisites: EECS 433 or EECS 434, and EECS 401 or Math 425. II (3 credits)

Applications of random variables to optics; statistical properties of light waves. Coherence theory, spatial and temporal. Information collecting interferometers; stellar, intensity, and speckle. Phase retrieval; imaging through inhomogeneous media; noise processes in imaging and interferometric systems.

537. Integrated and Guided Wave Optics

Prerequisite: EECS 332. I (3 credits)

Theory of guided light wave propagation; planar and channel waveguides; optical fibers. Waveguide excitation and coupling; integrated devices; directional couplers, gratings, filters, and modulators. Materials issues; dispersion and attenuation; aspects of wave-guide and device fabrication. Introduction to non-optical phenomena in waveguide structures.

538(Appl Phys 550)(Physics 650). Lasers and Electro-Optics I

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.

539(Appl Phys 551)(Physics 651). Lasers and Electro-Optics II

Prerequisite: EECS 538(AP 550)(Physics 650). 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; Gaussian beams; laser dynamics, Q-switching and modelocking. Special topics such as femto-second lasers and ultra high power lasers.

540(Appl Phys 540). Applied Quantum Mechanics I

Prerequisites: EECS 300 or Math 404 and Physics 242. I (3 credits)

Introduction to nonrelativistic quantum mechanics. Summary of classical mechanics; one-dimensional quantum problems including the quantum wells, WKB approximation,

tunneling and the harmonic oscillator; introduction to angular momentum; the hydrogen atom; molecular orbitals; the rigid rotator and diatomic molecules; spin and identical particles, and time independent perturbation theory.

541(Appl Phys 541). Applied Quantum Mechanics II

Prerequisite: EECS 540. II (3 credits)

Advanced theory of angular momentum, time dependent perturbation theory, quantization of fields, the second quantization for bosons and fermions, scattering theory, the density matrix, reservoir theory.

542(CS 542). Vision Processing

Prerequisite: EECS 442. I (odd 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.

543(CS 543). Knowledge-Based Systems

Prerequisites: EECS 492, permission of instructor. II (even years) (3 credits)

Techniques and principles for developing application software based on explicit representation and manipulation of domain knowledge, as applied to computer vision, robotic control, design and manufacturing, diagnostics, autonomous systems, etc. Topics include identifying and representing knowledge, integrating knowledge-based behavior into complex systems, reasoning, and handling uncertainty and unpredictability.

545(CS 545). Machine Learning

Prerequisite: EECS 492. II (odd years) (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.

546. Ultrafast Optics

Prerequisite: EECS 434. I (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.

547(CS 547). Cognitive Architectures

Prerequisite: EECS 492. II (3 credits)

Survey of architectures of symbolic systems in artificial intelligence. Architectures such as blackboards, production systems, logic systems, reflective systems, discovery systems and learning systems. Also integrated cognitive architectures such as ACT*, SOAR, MRS, and EURISKO.

548(BiomedE 548). Advanced Bioinstrumentation and Computation

Prerequisites: EECS 458, EECS 451. I (3 credits)

Application of computer hardware and software to acquisition, pattern recognition, analysis, and diagnosis of physiological signals. These include, but are not restricted to, the electrocardiogram, the electroencephalogram, the electromyogram, and blood pressure measurement. This course will teach skills required for computer-based analysis of clinical signals, and computer modelling of physiological systems. Lecture and laboratory.

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.

551. Deterministic Signal Processing

Prerequisite: preceded or accompanied by EECS 451. I (3 credits)

Fundamentals of deterministic signal processing are introduced: Signal representation, linear vector spaces, parametric representations, time-frequency distributions, time-varying models; least-squares filtering; adaptive signal processing. Principles presented in lecture are investigated through open laboratory projects.

552. Fiber Optical Communications

Prerequisites: EECS 332, EECS 320. II (odd years) (3 credits)

Fundamentals of lightwave communication systems. Introduction to calculus of variations and geometrical optics; propagation in step-index and graded-index fibers; intra- and inter-modal dispersion; optoelectronic devices: LEDs, lasers, PIN and APD detectors; direct detection and heterodyne receiver structures; noise calculations; and basic statistical communication theory for optical channels.

554. Introduction to Digital Communication and Coding

Prerequisites: EECS 316, 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.

555. Digital Communication Theory

Prerequisites: 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.

556. Image Processing

Prerequisites: EECS 451, EECS 501. 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.

557. Communication Networks

Prerequisites: 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.

558. Stochastic Control

Prerequisites: EECS 501, EECS 560. I (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.

559. Advanced Signal Processing

Prerequisites: EECS 451, EECS 501. II (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.

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.

561(Aero 571)(ME 561). Design of Digital Control Systems

Prerequisite: EECS 460 or Aero 471 or ME 461. I, II (4 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. Computer simulations and laboratory implementation of real-time control systems.

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.

563(Aero 576). Optimal Control

Prerequisite: EECS 560 (Aero 550). II (3 credits)

Definition of optimal control problems. Formulation of discrete time optimal control problems as constrained mathematical programming problems. Formulation of continuous time optimal control problems as variational problems. The Pontryagin necessary conditions. Application to a variety of specific optimal control problems from diverse disciplines. Introduction to computational methods in optimal control.

564(Aero 578). 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.

565(Aero 580). Linear Feedback Control Systems

Prerequisites: EECS 460 or Aero 471 or ME 461 and EECS 560(Aero 550). 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.

567(Mfg 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.

568(Mfg 570). Process Control for Microelectronics Manufacturing

Prerequisite: graduate standing or permission of instructor. I (3 credits)

Selected processing steps in microelectronics manufacturing, design of experiments, process and substrate sensors, statistical process control, run-to-run control, real-time control, failure diagnostics, computer implementation of control systems.

569(BiomedE 569). Signal Analysis in Biosystems

Prerequisites: 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.

570(CS 570). Parallel Computer Architecture

Prerequisite: EECS 470. I or II (3 credits)

Pipelining and operation overlapping, SIMD and MIMD architectures, numeric and non-numeric applications, VLSI, WSI architectures for parallel computing, performance evaluation. Case studies and term projects.

571(CS 571). Principles of Real-Time Computing

Prerequisites: EECS 470, EECS 482 or permission of instructor. II (3 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.

574(CS 574). Theoretical Computer Science I

Prerequisite: EECS 476. 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.

575(CS 575). Theoretical Computer Science II

Prerequisite: EECS 574. II (4 credits)

Advanced computational complexity, intractability, classical probability and information theory, algorithmic information theory, and special topics such as computational algebra, concurrency, semantics, and verification.

577(CS 577). Reliable Computing Systems

Prerequisites: EECS 478, EECS 280. I (3 credits)

An introduction to models and methods used in the analysis and design of reliable hardware systems, software systems and computing systems. Aspects of reliability

considered include fault tolerance, fault detection and diagnosis, reconfiguration, design verification and testing, and reliability evaluation.

579(CS 579). Digital System Testing

Prerequisite: EECS 478. II (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.

580(CS 580). Formal Specification and Validation of Computer Systems

Prerequisites: EECS 303 or equivalent, and either EECS 481, 482, 483, 484; or EECS 470 or EECS 473. I (3 credits)

Learn to formally specify and validate real-life software and hardware systems of various kinds: sequential, parallel synchronous, distributed (and if time permits, real-time). A survey of major formal specification and verification approaches is presented.

581(CS 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.

582(CS 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.

583(CS 583). Programming Languages

Prerequisites: EECS 483, EECS 476. I (4 credits)

Various programming languages are compared to understand general principles. To do this systematically and ignore inessential details, a format specification method is introduced. Current programming paradigms are examined; their potentials and compatibility are assessed. For example, the question of why functional languages become imperative when the "go public" is discussed.

584(CS 584). Advanced Database Systems

Prerequisite: EECS 484. II (3 credits)

Advanced topics and research areas in information and database systems. Distributed database technology: transaction processing, reliability, data allocation, and query processing. Object-oriented, deductive, client-server, and heterogeneous databases. Emerging areas, such as main memory databases, data mining, and parallel databases. Case studies of commercial and experimental systems. Group projects.

585(CS 585). Object-Oriented Databases

Prerequisites: EECS 484 and permission of instructor. I (3 credits)

Basic principles of object-oriented data models: classes, encapsulation, object identity. Advanced research issues such as schema evolution, views, and authorization. OODB implementation technology: transaction and secondary storage management. Case study of popular OODB systems and their use for advanced scientific and engineering applications. Programming projects generally required.

586(CS 586). Design and Analysis of Algorithms

Prerequisite: EECS 380. II (3 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.

587(CS 587). Parallel Algorithms

Prerequisites: EECS 380, graduate standing. I (3 credits)

The design and analysis of efficient algorithms for parallel computers. Fundamental problem areas, such as sorting, matrix multiplication, and graph theory, are considered for a variety of parallel architectures. Simulations of one architecture by another.

588(CS 588)(IOE 578)(Mfg 588)(ME 551). Geometric Modeling

Prerequisite: EECS 487(IOE 478) or ME 454 or permission of instructor. II (3 credits)

Individual or group study of topics in geometric modeling and computer graphics. Geometric data structures for curves, surfaces, and volume parameterization, and topological data structures for vertices, edges, faces, and bodies. Algorithms for set operations. Euler operations and deformations. Design and experimentation with geometric modeling facilities.

589(CS 589). Raster Graphics — Principles and Applications

Prerequisite: EECS 487. I (3 credits)

A detailed account of modern raster-based computer graphics. Topics include solid area scan conversion, color theory and application, hidden surface elimination, shading, highlights, animation, painting, and standardized graphics software.

590. EECS Introductory Seminar

Prerequisite: senior standing. I (1 credit)

Introduction to the technical areas of graduate study and research in the EECS department. Discussion of the policies and practices of graduate study.

592(CS 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.

593(CS 593). The Human as an Information Processing System

Prerequisites: graduate standing, permission of instructor. I (odd years) (3 credits)

Basic human information handling processes such as perception, learning cognitive map information, and problem solving are analyzed in an evolutionary context. Emphasis is largely theoretical. Includes the application to the human-computer interface of the principles that emerge.

594(CS 594). Introduction to Adaptive Systems

Prerequisites: EECS 303, Math 425(Stat 425). II (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.

595(CS 595)(Ling 541). 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.

596. Master of Engineering Team Project

Prerequisite: enrollment in the M.Eng. program in EECS. I, II, 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.

598(CS 598). Special Topics in Electrical Engineering and Computer Science

Prerequisite: permission of instructor or academic advisor. I, II, 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.

599. Directed Study

Prerequisite: prior arrangement with instructor. I, II, 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.

600(Aero 651)(IOE 600). Function Space Methods in System Theory

Prerequisite: EECS 400 or Math 419. I, 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.

623. Integrated Sensors and Sensing Systems

Prerequisites: EECS 413, either EECS 423 or EECS 424, or EECS 425, or EECS 523. I (4 credits)

Fundamental principles and design of integrated solid-state sensors and sensing systems. Micromachining and wafer bonding. Microstructures for the measurement of visible and infrared radiation, pressure, acceleration, temperature, gas purity, and ion concentrations. Merged process technologies for sensors and circuits. Data acquisition circuits, micro-actuators and integrated microsystems.

627. VLSI Design II

Prerequisite: EECS 427. I (4 credits)

Advanced very large scale integrated (VLSI) circuit design: VLSI CAD tools and techniques. IC failure modes: testing. Design for testability. Self-checking circuits. Automated layout. Design verification; placement and compaction; routing. Gate arrays; silicon compilers. Advanced projects in chip design and CAD tool development. Testing of chips fabricated in EECS 427. (3 hours lecture plus design laboratory.)

631. Electromagnetic Scattering

Prerequisites: EECS 530 and graduate standing. I (even 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.

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.

633. Numerical Methods in Electromagnetics

Prerequisite: EECS 530. I (odd 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.

634(Physics 611). Nonlinear Optics

Prerequisite: EECS 537 or EECS 538 or EECS 530. II (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.

638(Appl Phys 609)(Physics 542). Quantum Theory of Light

Prerequisites: 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.

650. Channel Coding Theory

Prerequisites: EECS 501 and EECS 400. 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.

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.

658. Fast Algorithms for Signal Processing

Prerequisites: EECS 451, EECS 501. I (odd years) (3 credits)

Introduction to abstract algebra with applications to problems in signal processing. Fast algorithms for short convolutions and the discrete Fourier transform; number theoretic transforms; multi-dimensional transforms and convolutions; filter architectures.

659. Adaptive Signal Processing

Prerequisite: EECS 559. I (even 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.

661. Discrete Even Systems

Prerequisite: EECS 560 or EECS 476 or equivalent. I (even years) (3 credits)

Modeling, analysis, and control of discrete event dynamical systems. Modeling formalisms considered include state machines, Petri nets, and recursive processes. Supervisory control theory; notions of controllable and observable languages. Analysis and control of Petri nets. Communicating sequential processes. Applications to database management, manufacturing, and communication protocols.

662(Aero 672)(MEAM 662). Advanced Nonlinear Control

Prerequisite: EECS 562 or MEAM 548 or permission of instructor. 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.

670. Advanced Topics in Computer Architecture

Prerequisites: EECS 570, graduate standing, permission of instructor. I or II (3 credits)

Advanced concepts and specialized areas in computer systems design are discussed and analyzed in depth. Topics chosen by instructor. Examples are database machines, highly reliable systems, computers for artificial intelligence, architectural support for operating system functional, high-level language architectures, object-oriented architecture, other special purpose architecture (vision, dataflow).

681. Advanced Software Engineering

Prerequisites: EECS 481, either EECS 581, EECS 582, EECS 583, or EECS 584. I (even years) (3 credits)

Problems of current research interest in software engineering such as software environments, program transformations, application generators, and very high level languages. A term project will be required.

682. Advanced System Programming

Prerequisite: EECS 482 or EECS 582. II (3 credits)

This course introduces the student to the more difficult problems and techniques of system programming. Such areas as dynamic storage allocation and relocation, interaction between central and peripheral hardware units, etc., will be discussed. The main emphasis of the course is a group project and the handling of the problems that are involved in all aspects of system design and final implementation.

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.

698. Master's Thesis

Prerequisite: election of an EECS master's thesis option. May be elected for a maximum of 6 credit hours. I, II, 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.

699. Research Work in Electrical Engineering and Computer Science

Prerequisites: graduate standing, permission of instructor. I, II, III, IIIa, IIIb (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.

700. Special Topics in System Theory

Prerequisite: permission of instructor. (to be arranged)

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.

730. Special Topics in Electromagnetics

Prerequisite: permission of instructor. (1-4 credits) (to be arranged)

731(AOSS 731). Space Terahertz Technology and Applications

Prerequisite: permission of instructor. I (1 credit)

Study and discussion of various topics related to high frequency applications in space exploration. Topics will be chosen from the following areas: planetary atmospheres and remote sensing, antennas, active and passive circuits, space instrumentation.

735. Special Topics in the Optical Sciences

Prerequisites: 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.

750. Special Topics in Communication and Information Theory

Prerequisite: permission of instructor. (to be arranged)

755. Special Topics in Signal Processing

Prerequisite: permission of instructor. (to be arranged) (1-4 credits)

760. Special Topics in Control Theory

Prerequisite: permission of instructor. (to be arranged)

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.

770. Special Topics in Computer Systems

Prerequisite: permission of instructor. (to be arranged)

820. Seminar in Solid-State Electronics

Prerequisites: 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.

874. Seminar in Theory of Computing

Prerequisite: EECS 574. I, II (2 credits)

Advanced graduate seminar devoted to new developments in theory of computing. Topics may include theory of programming languages, complexity, algorithms, AI, and applications of logic and mathematics to computer science.

880. Software Research Seminar

Prerequisite: graduate standing in EECS or permission of instructor. May be taken more than once since topics will vary each term. I, II (1-3 credits)

Seminar and current research in programming languages, operating systems, distributed computing, software engineering, databases, graphics, and other software topics. Each week a different speaker will describe his/her own research, or report on a recent published paper. Exact topics varied each term. Occasional speakers from other universities.

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.

990. Dissertation/Pre-Candidate

I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)

Election for dissertation work by a doctoral student not yet admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

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.

Engineering Division

NOTE: Eng 266 and Eng 267 are not open to College of Engineering students. These courses are open to Focus Hope students who are pursuing a Bachelor of Engineering Technology degree. The effort is part of the Greenfield Coalition for New Manufacturing Education.

266. Manufacturing Statistical Methods I

Prerequisite: college algebra. Not open to College of Engineering students. I, II (2 credits)

Multimedia instruction in the use of statistical methods in manufacturing. Topics are problem-solving tools, descriptive statistics, data collection, control charts, process capability and tolerancing systems. Statistical computer packages will be used and field studies will be required.

267. Manufacturing Statistical Methods II

Prerequisite: Eng 266. Not open to College of Engineering students. I, II (1 credit)

Multimedia instruction in the use of statistical methods in manufacturing. Topics are hypothesis testing and regression analysis. Statistical computer packages will be used and field studies will be required.

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103. Personal Computing and FORTRAN

Prerequisite: none. Credit restrictions. **Student may receive credit for only one: Eng 103, Eng 104, Eng 105, Eng 106, or Eng 107.** *I, II, IIIa (3 credits)*

Introduction to personal computers, operating systems, and applications. Productivity tools such as word processing, spreadsheeting, drawing, graphing, electronic mail, and networking. The CAEN environment. The FORTRAN language for numerical and non-numerical calculations and applications.

104. Personal Computing and "C"

Prerequisite: none. Credit restrictions. **Student may receive credit for only one: Eng 103, Eng 104, Eng 105, Eng 106, or Eng 107.** *I, II, IIIa (3 credits)*

Introduction to personal computers, operating systems, and applications. Productivity tools such as workprocessing, spreadsheeting, drawing, graphing, electronic mail, and networking. The CAEN environment. The "C" language for numerical and non-numerical calculations and manipulations.

105. Computing in the College of Engineering

*Prerequisite: knowledge of a programming language, preferably FORTRAN or Pascal. Credit restrictions. **Student may receive credit for only one: Eng 103, Eng 104, or Eng 105**. I, II (1 credit)*

Introduction to personal computers, operating systems, and applications. Word processing. Compilation and execution of computer programs. Spreadsheets, graphics, and symbolic mathematics. Networks, electronic mail, and the CAEN environment.

106. Personal Computing, Problem-Solving, and "C"

*Prerequisite: none. Credit restrictions. **Student may receive credit for only one: Eng 103, Eng 104, Eng 105, Eng 106, or Eng 107**. I, II (4 credits)*

Introduction to personal computers, operating systems, and applications. Productivity tools such as wordprocessing, spreadsheeting, drawing, graphing, electronic mail, and networking. The CAEN environment. Engineering problem-solving. Matlab and "C" for numerical and non-numerical calculations and manipulations.

107. Personal Computing, Problem-Solving, and FORTRAN

*Prerequisite: none. Credit restrictions. **Student may receive credit for only one: Eng 103, Eng 104, Eng 105, Eng 106, or Eng 107**. I, II (4 credits)*

Introduction to personal computers, operating systems, and applications. Productivity tools such as wordprocessing, spreadsheeting, drawing, graphing, electronic mail, and networking. The CAEN environment. Engineering problem-solving. Matlab and FOR-TRAN for numerical and non-numerical calculations and manipulations. All undergraduate degree programs in the College of Engineering will accept up to 4 credit hours of elective courses from this group as free and/or technical electives.

150(MSE 150). Introduction to Engineering Materials

Prerequisite: Chem 123 or Chem 124. Open only to freshmen; satisfies any program requirement of MSE 250. II (4 credits)

A course in engineering materials covering the structure, properties and processing of metals, polymers and ceramics.

160. Engineering and Technical Communications

Prerequisite: freshman standing. I, II (4 credits)

The development of oral and written communication skills are implemented through examination of the roles of quality, ethics and professionalism in engineering work. Team building and team work are emphasized. The role of the engineer in society and the role of engineering disciplines in environmentally conscious strategies are explored. Students may not elect this course until they have completed an English Composition Board assessment. Students who enroll without this assessment may be withdrawn from the course.

195. Selected Topics in Engineering

(to be arranged)

200. Study Abroad

Prerequisite: sophomore standing. I, II (no credits for this course)

This course serves as a means for students who are studying abroad to maintain their registration and student status. Credit hours for study abroad will be attained by credit transfer from the institution where the student has studied. Open to undergraduates only.

303(CEE 303). Computational Methods for Engineers and Scientists

Prerequisites: Eng 103, preceded or accompanied by Math 216. (Required for some programs; see your advisor.) I, II (3 credits)

Applications of numerical methods to problems in various areas of engineering and science; personal computer case studies; development evaluation and comparison of various techniques for roots of nonlinear equations, simultaneous linear algebraic equations, curve fitting, numerical integration and ordinary differential equations.

371(Math 371). Numerical Methods for Engineers and Scientists

Prerequisites: Eng 103 or Eng 104 or equivalent, Math 216. 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 programing.

390. Special Topics in Engineering

Prerequisite: permission of instructor. (to be arranged)

Individual or group study of 300 level, undergraduate topics of current interest.

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.

401(Mfg 401). Total Quality Management

Prerequisite: none. I, II (3 credits)

The technical and management aspects of total quality management. Topics include voice of the customer, metrics, cross-functional teams, and the systems aspects. Examples from engineering and business operations such as dimensional tolerancing, quality function deployment, process control, simultaneous engineering, lean production, purchasing, inventory control, and scheduling systems.

451(Mfg 451). Technology and Society

Prerequisite: none. Open for undergraduate credit only. I, II (3 credits)

Examines areas where contemporary technological development has substantial impact on our way of life. Effects on the environment, in medical practice, in industry and on the workplace, and on local and global politics are examples. Experts in the respective areas are engaged to participate with the class in discussion/debate.

452. Entrepreneurship for Engineers

Prerequisite: undergraduate credit only. I (3 credits)

Entrepreneurship, work styles, and life styles of a variety of business owners. Elements of personal and group development, team building, marketing, sales, management, accounting, negotiation, failure and stress management, and ethics. Development of a personal life plan. Development and defense of business plans for a new manufactured product.

477(NA477). Principles of Virtual Reality

Prerequisite: senior standing or permission of instructor. I (3 credits)

Enabling technologies (display systems, motion trackers, datagloves, haptic and acoustic devices), application categories, human factors and perception, computer graphics and geometric modeling principles, creation and evaluation of virtual environments, existing tools, VR specific algorithms. Interdisciplinary group projects will develop VR applications using the facilities in the Media Union.

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.

503. 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.

590. International Experience in Engineering

Prerequisite: seniors and grad students of engineering only. I, II, IIIa, IIIb, III, (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.

Geological Sciences [*]

(Division 377)

Department Office
1006 C.C. Little Building
(313) 764-1435

College of Literature, Science and the Arts
Professor David K. Rea, *Chair*

Professors Essene, Farrand, Fisher, Gingerich, Halliday, Kesler, Lohmann, Meyers, Moore, O'Neil, Outcalt, Owen, Peacor, Pollack, Rea, Smith, Van der Voo, Walker, Walter, Wilkinson; **Associate Professors** Baumiller, Burnham, Mukasa, Ruff, van der Pluijm; **Assistant Professors** Lange, Zhang; **Adjunct Professors** McElhinny, Simmons

Courses descriptions for geological sciences are listed in the Literature, Science, and the Arts Bulletin and the Horace H. Rackham School of Graduate Studies Bulletin.

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100. Coral Reefs
(Nat Sci) Lecture (1 credit)

101. Waves and Beaches
No credit is granted to those who have completed, or are enrolled in, GS 276. (Nat Sci) Lecture (1 credit)

102. Energy from the Earth
Prerequisite: none; a course in elementary chemistry (high school or university) would be helpful. (Nat Sci) Lecture (1 credit)

103. Dinosaurs and Other Failures
No credit is granted to those who have completed, or are enrolled in, GS 273. (Nat Sci) Lecture (1 credit)

104. Ice Ages, Past and Future
No credit is granted to those who have completed, or are enrolled in, GS 275. (Nat Sci) Lecture (1 credit)

105. Continents Adrift
No credit is granted to those who have completed, or are enrolled in, GS 205 or GS 270. (Nat Sci) Lecture (1 credit)

106. Fossils, Primates, and Human Evolution
No credit is granted to those who have completed, or are enrolled in, GS 125. (Nat Sci) Lecture (1 credit)

107. Volcanoes and Earthquakes
No credit is granted to those who have completed, or are enrolled in, GS 205, GS 270, or GS 271. (Nat Sci) Lecture (1 credit)

108. Minerals in the Modern World
(Nat Sci) Lecture (1 credit)

109. Natural and Unnatural Pollutants in Oceans, Lakes, and Rivers
No credit is granted to those who have completed, or are enrolled in, GS 206. (Nat Sci) (1 credit)

110. The History of the Oceans
No credit is granted to those who have completed, or are enrolled in, GS 222. (Nat Sci) (1 credit)

111. Climate and Mankind
No credit is granted to those who have completed, or are enrolled in, GS 201 or GS 275. (Nat Sci) (1 credit)

113. Planets and Moons
No credit is granted to those who have completed, or are enrolled in, GS 204 or GS 278. (Nat Sci) (1 credit)

114. The Elements
Prerequisites: high school math, physics, and chemistry. (Nat Sci) (1 credit)

115. Geologic Time
No credit is granted to those who have completed, or are enrolled in, GS 135. (Nat Sci) Lecture (1 credit)

116. Introductory Geology in the Field
Reduced credit is granted for GS 116 to those with credit for an introductory course in geology (GS 117, GS 118, GS 119, GS 120, GS 205, or GS 206). IIIb (8 credits)

117. Introduction to Geology
No credit is granted to those who have completed, or are enrolled in, GS 116, GS 119, or GS 120. Those with credit for GS 205 may elect GS 117 for 4 credits. I (5 credits)

118. Introductory Geology Laboratory
No credit is granted to those with credit for an introductory course in geology (GS 116, GS 117, GS 121, GS 122, or GS 218). (Nat Sci) (1 credit)

119. Introductory Geology Lectures
No credit is granted to those who have completed, or are enrolled in, GS 116, GS 117, or GS 120. No credit granted to those who have completed both GS 205 and GS 206. Those with credit for GS 205 may elect GS 119 for 3 credits. I (4 credits)

120. Geology of National Parks and Monuments

Credit is not granted for GS 120 to those with credit for an introductory course in geology (GS 116, GS 117, or GS 119). II (4 credits)

123. Life and the Global Environment

No credit is granted to those who have completed, or are enrolled in, GS 277. II (2 credits)

125. Evolution and Extinction

Those with credit for GS 106 may elect GS 125 for 2 credits. May not be included in a concentration plan in GS. II (3 credits)

130. The Physical World

Prerequisite: high school algebra. (Nat Sci) (4 credits)

135. History of the Earth

No credit is granted to those who have completed, or are enrolled in, GS 269. Those with credit for GS 115 may elect GS 135 for 2 credits. II (Nat Sci) (3 credits)

205. How the Earth Works: The Dynamic Planet

No credit is granted to those who have completed, or are enrolled in, GS 117, GS 119, or GS 270. No credit granted to those who have completed both GS 105 and GS 107. Those with credit for one of GS 105 and GS 107 may elect GS 205 for 1 credit. (Nat Sci) (2 credits)

206. How the Earth Works: The Water Cycle and the Environment

Those with credit for GS 109 may elect GS 206 for 1 credit. (Nat Sci) (2 credits)

207. How the Earth Works: A Hands on Experience

(2 credits)

222. Introductory Oceanography

No credit granted to those with credit for AOSS 203. (Nat Sci) (3 credits)

223. Introductory Oceanography, Laboratory

Concurrent enrollment in GS 222. (Nat Sci) (1 credit)

231. Elements of Mineralogy

Prerequisite: prior or concurrent enrollment in Chem 125/130 or Chem 210/211. I (Excl) (4 credits)

232. Earth Materials

Prerequisite: prior or concurrent enrollment in Chem 125/130 or 210/211. (4 credits)

267. Gems and Gem Material

Prerequisite: no previous knowledge of geology is required. (Nat Sci) (3 credits)

268. Climate Change: Peril or Pork

No credit is granted to those who have completed, or are enrolled in, GS 201. Those with credit for GS 111 may elect GS 268 for 2 credits. Prerequisite: none. (3 credits)

269. Evolution of the Earth

No credit is granted to those who have completed, or are enrolled in, GS 135. Those with credit for GS 115 may elect GS 269 for 2 credits. Prerequisite: none. (3 credits)

270. Plate Tectonics

No credit is granted to those who have completed three of GS 105, GS 107, and GS 205. Those with credit for one of GS 105 and GS 107 may elect GS 270 for 2 credits. Those with credits for GS 205, or for both GS 105 and GS 107, may elect GS 270 for 1 credit. (Nat Sci) (3 credits)

271. Natural Hazards

Those with credit for GS 107 or GS 205 may elect GS 271 for 2 credits. Those who have credit for both GS 107 and GS 205 may elect GS 271 for 1 credit. (3 credits)

272. Seminar: Environmental Geology

No credit is granted to those who have completed, or are enrolled in, GS 284. Those with credit for GS 109 may elect GS 272 for 2 credits. (3 credits)

273. Contemporary Dinosaurs

Those with credit for GS 103 may elect GS 273 for 2 credits. Prerequisite: none. (3 credits)

274. Dinosaur Extinction and Other Controversies

Prerequisite: none. (3 credits)

275. The Ice Ages: Past and Present

Those with credit for GS 104 may elect GS 275 for 2 credits. (Nat Sci) (3 credits)

276. Coastal Systems and Human Settlements

Those with credit for GS 101 may elect GS 276 for 2 credits. (Nat Sci) (3 credits)

277. Humans and the Natural World

Those with credit for GS 123 may elect GS 277 for 1 credit. (Nat Sci) (3 credits)

278. Earthlike Planets

Those with credit for GS 113 may elect GS 278 for 2 credits. (Nat Sci) (3 credits)

279. Ocean Resources

(Nat Sci) (3 credits)

280. Mineral Resources, Economics, and the Environment
No previous knowledge of geology is required for this course. I (4 credits)

283. Evolution of North America
No credit is granted to those who have completed, or are enrolled in, GS 411.
Prerequisite: none. (3 credits)

284. Environmental Geology
No credit is granted to those who have completed, or are enrolled in, GS 272. Those
with credit for GS 271 may elect GS 284 for 3 credits. Prerequisites: high school
science and math recommended. (4 credits)

305. Sedimentary Geology
Prerequisite: an introductory geological sciences laboratory course or permission
of the instructor. I (4 credits)

310. Petrology
Prerequisites: GS 231 and either an introductory geological sciences course or
GS 351 to be elected prior to, or concurrently with, GS 310. II (4 credits)

351. Structural Geology
Prerequisite: GS 305 or permission of instructor. II (4 credits)

411. Geology of Michigan
No credit to those who have completed or are enrolled in GS 283. (3 credits)

415. Introductory Economic Geology (Metals)
Prerequisites: GS 310, GS 351, or permission of instructor. I (4 credits)

417. Geology of the Great Lakes
Prerequisite: permission of instructor. (2 credits)

420. Introductory Earth Physics
Prerequisite: Math 116. I (3 credits)

422. Principles of Geochemistry
Prerequisites: GS 231, GS 305, GS 310, Chem 126. II (3 credits)

424. Introductory Cosmochemistry and Early Evolution of Planets
(Nat Sci) (3 credits)

425. Environmental Geochemistry
Prerequisite: high school or college-level introductory chemistry. (3 credits)

430. Depositional Environments
Prerequisite: permission of instructor. (Excl) (3 credits)

442. Geomorphology

I (4 credits)

446. Permafrost, Snow, and Ice

Prerequisites: Math 115, Math 116, Physics 140, Physics 141. II (3 credits)

447. Archaeological Geology

Prerequisites: GS 442 or GS 448 or equivalent and one course in archaeology
(Anthro 282 or Anthro 581 or Class Arch 323). II (3 credits)

448. Geomorphology—Glacial and Periglacial

Prerequisite: an introductory physical geology course or permission of instructor.
I (4 credits)

449. Marine Geology

Prerequisites: GS 222, GS 223 or introductory physical geology. II (3 credits)

455. Determinative Methods in Mineralogical and Inorganic Materials

Prerequisites: one term of elementary chemistry and physics. II (4 credits)

458. X-ray Analysis of Crystalline Materials

Prerequisite: GS 455 or permission of instructor. II (3 credits)

467. Stratigraphy

Prerequisites: GS 305, GS 310, GS 351. I (3 credits)

473. Fundamentals of Organic Geochemistry

Prerequisite: GS 305 or Chem 226. (3 credits)

477. Hydrogeology

Prerequisites: basic chemistry, physics, calculus (e.g., Math 115, Math 116;
Physics 140, Physics 141; Chem 125, Chem 130). (3 credits)

478. Aqueous Geochemistry

Prerequisite: Chem 365 or the equivalent. (3 credits)

479. Marine Geochemistry

Prerequisite: Chem 124 or the equivalent. (3 credits)

480(AOSS 480). The Planets: Composition, Structure, and Evolution

Prerequisites: Math 216, Physics 240, Chem 130. I (3 credits)

483. Geophysics: Seismology

Prerequisites: Math 215 at least concurrently, Physics 240, or permission of
instructor. II (4 credits)

484. Geophysics: Physical Fields of the Earth

Prerequisites: Math 216 at least concurrently, Physics 240, or permission of instructor. II (4 credits)

485. Computer Utilization in the Earth Sciences

Prerequisites: calculus and experience in computer programming. II (3 credits)

486. Geodynamics

Prerequisites: GS 420 and prior or concurrent election of Math 215, Physics 240, or permission of instructor. (3 credits)

540. Seminar in Engineering Geology

Prerequisites: CEE 445 and a 400 level course in physical geology or geomorphology. II (2 credits)

589. Global Geochemical Cycles and Fluxes

Prerequisite: permission of instructor. II (2 credits)

Industrial and Operations Engineering

(Division 272)

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  Professor and Chair

Professor

Thomas Armstrong, Ph.D.
James C. Bean, Ph.D.
Don B. Chaffin, Ph.D., P.E.,
  *G. Lawton and Louise G.
  Johnson Professor of
  Engineering*
Walton M. Hancock, D. Eng.,
  P.E.
Gary D. Herrin, Ph.D.
W. Monroe Keyserling, Ph.D.
Katta G. Murty, Ph.D.
Vijay Nair, Ph.D.
Stephen M. Pollock, Ph.D.
Romesh Saigal, Ph.D.
Robert L. Smith, Ph.D.
Daniel Teichroew, Ph.D.
Chelsea C. White III, Ph.D.
Tony C. Woo, Ph.D.
C. Jeff Wu, Ph.D.

Adjunct Professor

Seth Bonder, Ph.D.

Professor Emeritus

Herbert P. Galliher, Ph.D.
Wilbert Steffy, B.S.E.
  (Ind.-Mech.), B.S.E.
  (M.E.)
Richard C. Wilson, Ph.D.

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Tava Olsen, Ph.D.
Jianjun Shi, Ph.D.
Rachel Q. Zhang, Ph.D.

Adjunct Assistant Professor

Richard J. Coffey, Ph.D.

Lecturer

James A. Foulke, B.S.E.
  (E.E.)

Adjunct Lecturer

Glenn H. Mazur, M.B.A.

See page 225 for statement on Course Equivalence.

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301. Industrial and Operations Management

*Prerequisite: none. (Creates entry point for IOE undergraduate curriculum.) I, II
    (3 credits)*

An overview of issues important to operation of an industrial or service facility. Topics include forecasting, capacity planning, financial analysis, inventory, layout, scheduling, work methods and measurement, motivation and quality.

310. Introduction to Optimization Methods

Prerequisites: Math 215, preceded or accompanied by IOE 301. I, II (3 credits)

An introduction to deterministic models in operations research with special emphasis on linear programming; the simplex, transportation, and assignment algorithms and their engineering applications. Brief introduction to integer, dynamic, and other non-linear programming models.

315. Stochastic Industrial Processes

Prerequisites: preceded or accompanied by Math 116, IOE 301. I, II (3 credits)

Elementary concepts in discrete and continuous time Markov chains, queueing and birth/death processes, the Poisson process and underlying elements of probability. Applications to replacement strategy, machine repair strategy, inventory, and other engineering problems.

322. Project Management

Prerequisite: IOE 301. I, II (3 credits)

Engineering students will develop skills and experience in defining, planning and managing projects in a team environment. Topics include setting goals, building plans, scheduling and budgeting, team building, negotiating, written and oral communication, stress and ethical issues. Student teams will develop a detailed project plan for an outside client who will critique that plan.

333. Ergonomics

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.

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.

365(Stat 311). Engineering Statistics

Prerequisites: IOE 315 or Stat 310, Math 215 and Eng 103. I, II (4 credits)

Collection and analysis of engineering data associated with stochastic industrial processes. Topics include exploratory data analysis, describing relationships, importance of experimentation, applications of sampling distribution theory, test of hypotheses, experiments with one or more factors, and regression analysis. Students are required to use statistical packages on CAEN for problem solving.

373. Data Processing

Prerequisite: Eng 103. 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.

416. Queueing Systems

Prerequisite: IOE 315. (3 credits)

Introduction to queueing processes and their applications. The M/M/s and M/G/1 queues. Queue length, waiting time, busy period. Case studies in production, transportation, communication, and public service systems.

421. Work Organizations

Prerequisites: IOE 301, senior standing. I (3 credits)

Applications of organizational theory to the design and management of work organizations is taught through projects in real organizations, experiential exercises, case studies, and written assignments. Topics include organizational analysis, organizational culture, power, interdepartmental relations, organizational design, participative management, information and control systems and organizational change strategies.

424. Practicum in Production and Service Systems

Prerequisites: senior standing and permission of instructor; not for graduate credit. I, II (3 credits)

Student teams will work with an organization on a design project with potential benefit to the organization and the students.

425(Mfg 426). Manufacturing Strategies

Prerequisite: senior standing. I (3 credits)

Review of the manufacturing philosophies that have been successfully applied by world class manufacturers, including workflows, quality assurance, process design, inventory product throughput, maintenance, simultaneous design, voice-of-the-customer and total quality control systems. Students tour plants to analyze the extent and potential of the philosophies.

432. Industrial Engineering Instrumentation Methods

Prerequisite: IOE 365. IIIa (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.

433(EIH 556)(Mfg 433). Occupational Ergonomics

Not open to students who have credit for IOE 333. I (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.

436. Human Factors in Computer Systems
Prerequisite: IOE 333 or permission of instructor. II (3 credits)

The design and evaluation of 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.

437(CS 493)(EECS 493). User Interface Design and Analysis
Prerequisite: EECS 481. (3 credits)

Current theory and design techniques concerning how user interfaces for computer systems should be designed to be easy to learn and use. Focus on cognitive factors, such as the amount of learning required, and the information-processing load imposed on the user, rather than ergonomic factors.

439. Safety Management
Prerequisite: junior, senior or graduate standing. II (3 credits)

Standards, government regulations, accident investigation, databases, and user/operator characteristics in relation to risk/safety management. How human errors relate to design/use of machines and products, and to accident causation. Accident reconstruction examples using cases from occupational, transportation, consumer, and recreational environments.

441(Mfg 441). Production and Inventory Control
Prerequisites: IOE 310, IOE 315. I, II (3 credits)

Models and techniques for managing inventory systems and for planning production. Topics include basic deterministic and probabilistic inventory models and extensions; production loading, planning, and smoothing; and sequencing problems.

447(Mfg 447). Facility Planning
Prerequisites: IOE 310, IOE 315, IOE 373. I (3 credits)

Fundamentals in developing efficient layouts for single-story and multi-story production and service facilities. Manual procedures and computer algorithms used on mainframe and microcomputers. Algorithms to determine the optimum location of facilities. Special requirements for planning service facilities such as hospitals, airports and offices.

449(Mfg 449). Material Handling Systems
Prerequisites: IOE 310, IOE 315, IOE 373. (3 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.

451. Engineering Economy

Prerequisite: none. Not for IOE graduate credit. I (3 credits)

The logic of economic decision making common to engineering, industrial management, and personal finance is developed. Concepts of compound interest, capital growth, and equivalence are developed. Commonly used measures of worth are defined and compared. Decisions involving taxes, multiple alternatives, financing, replacement, and uncertainty are considered.

452. Capital Budgeting and Financial Engineering

Prerequisites: IOE 365, IOE 310. II (3 credits)

Framework for economic decision making and capital budgeting are developed. Decisions involving taxes, financing, international exchange rates, capital rationing, and uncertainty are considered. Examples are given from capacity expansion, equipment replacement, project evaluation, portfolio optimization, and option pricing.

460. Decision Analysis

Prerequisites: IOE 310, IOE 315, senior standing. (3 credits)

Theory and methods for the analysis of decisions under uncertainty. The use of expert judgment and value of information. The encoding of attitudes toward risk. Applications selected from capital investment, bidding, purchasing, inspection, inventory control, and other areas.

463(Mfg 463). Work Measurement and Prediction

Prerequisites: IOE 333, IOE 334, IOE 365. (3 credits)

The analysis and prediction of human performance in industrial and service man-machine systems. The use of predetermined time systems, learning curves, operator selection procedures, work sampling, and motion economy principles in the design of the work place.

465. Design and Analysis of Industrial Experiments

Prerequisite: IOE 365. I (3 credits)

Methods of design and analysis of industrial experiments. Topics include general regression and variance analysis, mixed models, efficient statistical search procedures, model assessment, and remedial measures.

466(Mfg 466)(Stat 466). Statistical Quality Control

Prerequisite: IOE 365(Stat 311). I, II (3 credits)

Design and analysis of procedures for forecasting and control of production processes. Topics include attribute and variables sampling plans; sequential sampling plans; rectifying control procedures; charting, smoothing, forecasting, and prediction of discrete time series.

472. Operations Research

Prerequisite: preceded or accompanied by Stat 310. (3 credits)

Introduction to operations research; the methodology of mathematical modeling and its relation to problems in industrial, commercial, and public systems. The use of queueing theory, linear programming, inventory theory, simulation, decision analysis. Not open to industrial and operations engineering undergraduate students.

473. Information Processing Systems

Prerequisite: IOE 373. (3 credits)

Organization of major types of information processing systems. Programming languages (COBOL, PL/1). Database management systems. Alternative system organizations. Techniques for evaluation of performance of systems.

474. Simulation

Prerequisites: IOE 315, IOE 365, IOE 373. I, II (3 credits)

Simulation of complex discrete-event systems with applications in industrial and service organizations. Course topics include modeling and programming simulations in a high-level simulation language such as ProModel or GPSS/H; input distribution modeling; generating random numbers; statistical analysis of simulation output data.

479(IPPS 479). Operations Research for Public Policy

Prerequisites: Math 413, Pub Pol 529. Not open to students with credit for IOE 460 or IOE 472. I (3 credits)

The philosophy and use of quantitative methods of analyzing public sector problems. Decision analysis as a framework for choice under uncertainty. Simulation, mathematical programming, and probabilistic methods presented with case studies and examples from the literature.

481. Practicum in Hospital Systems

Prerequisites: senior standing, permission of instructor; not for graduate credit. I, II (3 credits)

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. Faculty, administrative, and engineering personnel will be available during the term for project aid.

484(CS 484)(EECS 484). Database Management Systems

Prerequisite: EECS 380 or IOE 373. I, II (3 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, normalization, access methods, query optimization, transaction management and concurrency control, recovery, and integrity.

490. Directed Study, Research, and Special Problems I

Prerequisite: permission of department. (3 maximum) pass/fail only

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 including management, work measurement, systems, and procedures.

491. Special Topics in Industrial and Operations Engineering

(to be arranged)

Selected topics of current interest in industrial and operations engineering.

499. Senior Design Projects

Prerequisites: senior standing, permission of instructor. I, II (3 credits)

Selected design projects in industrial and operations engineering to be conducted for clients.

510(Math 561)(SMS 518). Linear Programming I

Prerequisites: 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.

511(Aero 577)(EECS 505)(Math 562). Continuous Optimization Methods

Prerequisites: Math 217, Math 417, or Math 419. I (3 credits)

Survey of continuous optimization problems. Unconstrained optimization problems; uni-directional search techniques; gradient, conjugate direction, quasi-Newtonian methods. Introduction to constrained optimization using techniques of unconstrained optimization through penalty transformations, augmented Lagrangians, and others. Discussion of computer programs for various algorithms.

512. Dynamic Programming

Prerequisite: EECS 503 or IOE 515. (3 credits)

The techniques of recursive optimization and their use in solving multistage decision problems, applications to various types of problems. Algorithms for solving Markovian programming problems and their applications.

515. Stochastic Processes

Prerequisite: IOE 315 or Stat 310. (3 credits)

Introduction to non-measure theoretic stochastic processes. Poisson processes, renewal processes, and discrete time Markov chains. Applications in queueing systems, reliability, and inventory control.

517(EECS 509). Traffic Modeling

Prerequisites: IOE 315, Stat 310, or EECS 401. II (3 credits)

Traffic Models and their analysis in the context of ITS (Intelligent Transportation Systems). Those aspects of traffic theory relevant to ITS are presented including traffic flow and signalized intersections, with particular emphasis on the optimization via route guidance and signal control of large scale traffic networks.

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.

533(Mfg 535). Human Factors in Engineering Systems I

Prerequisites: IOE 365, IOE 333, IOE 433(EIH 556). I (3 credits)

Principles of engineering psychology applied to engineering and industrial production systems. Visual task measurement and design, psychophysical measurements, signal detection theory and applications to industrial process control. Human information processing, mental workload evaluation, human memory and motor control processes.

534(BiomedE 534)(Mfg 534). Occupational Biomechanics

Prerequisites: 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.

536. Cognitive Ergonomics

Prerequisite: IOE 333 or IOE 433. I (alternate years) (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.

539(Mfg 539). Occupational Safety Engineering

Prerequisite: IOE 365 or Biostat 500. II (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.

541(Mfg 541). Inventory Analysis and Control

Prerequisites: IOE 310, IOE 315, IOE 365, IOE 441. II (3 credits)

Review of basic inventory models. Models and solution techniques in various problems related to multi-stage production and distribution systems. Topics include assembly systems, material requirements planning, hierarchical production planning, flexible manufacturing systems, distribution systems. Readings will include classic works and recent papers on techniques and applications.

543(Mfg 543). Theory of Scheduling

Prerequisites: IOE 315 or IOE 515, and 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.

545(Mfg 545). Queueing Networks in Manufacturing

Prerequisite: IOE 315 or EECS 401. I (3 credits)

This course is an introduction to queueing networks and their applications in manufacturing. Topics include product and non-product form networks, exact results and heavy and light traffic approximations, analysis of "pull" manufacturing systems, and polling systems with and without set-ups. Applications to several industries including semiconductor manufacturing are emphasized.

547(Mfg 548). Plant Flow Systems

Prerequisites: 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.

560(Stat 550)(SMS 603). Bayesian Decision Analysis

Prerequisite: Stat 425. (3 credits)

Axiomatic foundations for personal probability and utility; interpretation and assessment of personal probability and utility; formulation of Bayesian decision problems; risk functions, admissibility; likelihood principle and properties of likelihood functions; natural conjugate prior distributions; improper and finitely additive prior distributions; examples of posterior distributions, including the general regression model and contingency tables; Bayesian credible intervals and hypothesis tests; applications to a variety of decision-making situations.

563. Labor and Legal Issues in Industrial Engineering

Prerequisite: IOE 433 or IOE 463. (3 credits)

A case study approach to engineering related issues in union-management relations, professional and product liability, and worker rights legislation.

564(ME 554). Computer Aided Design Methods

Prerequisite: ME 454 or AM 501 or IOE 373. (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.

565. Forecasting and Time Series Analysis

Prerequisite: IOE 465. II (3 credits)

Forecasting and prediction of time series including regression, moving averages, exponential smoothing, direct smoothing, adaptive control procedures, Bayesian methods, and Box/Jenkins models with applications to production, inventory, and quality control.

566(Mfg 569). 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.

567(Mfg 568). Advanced Work Measurement and Design

Prerequisite: IOE 433 or IOE 463. II (3 credits)

Nontraditional approaches to job evaluation are applied to a variety of manufacturing and service jobs. Topics include computer-aided job analyses and design, ergonomic work measurement, evaluation of "white collar" productivity, and high level predetermined time systems. Case studies are used extensively to develop observational, analytical, and design skills.

573. Analysis, Design, and Management of Large-Scale Administrative Information Processing Systems

Prerequisite: IOE 473. I (3 credits)

Introduction to informal and formal techniques or analysis, design, and management of large scale information processing systems in administrative environments; presentation of techniques to control and aid in the process by which computer systems are developed with major emphasis on the collection and analysis of user requirements.

574. Simulation Analysis

Prerequisite: IOE 474. (3 credits)

Underlying probabilistic aspects of simulation and statistical methodology of designing simulation experiments and out-put interpretation. Random number generators, variate and process generation, output analysis, regenerative method, variance reduction techniques, multiple comparisons, ranking and selection problems as applied to simulation.

575. Information Processing System Engineering

Prerequisite: IOE 473. II (3 credits)

Software design methodologies for development of large-scale information processing systems. Application of database management systems, distributed processing, microprocessors and communication networks. Design and use of computer-aided software development systems. Software engineering and project management. Ergonomics aspects of information systems. Emphasis is placed on practical experience in software design projects.

578(CS 588)(EECS 588)(Mfg 588)(ME 551). Geometric Modeling

Prerequisite: EECS 487(IOE 478) or ME 454 or permission of instructor. II (3 credits)

Individual or group study of topics in geometric modeling and computer graphics. Geometric data structures for curves, surfaces, and volume parameterization, and topological data structures for vertices, edges, faces, and bodies. Algorithms for set operations, Euler operations and deformations. Design and experimentation with geometric modeling facilities.

590. Directed Study, Research, and Special Problems II

Prerequisite: permission of instructor. (3 credits maximum)

Continuation of IOE 490.

591. Special Topics

Prerequisite: permission of instructor. (to be arranged)

Selected topics of current interest in industrial and operations engineering.

593. Ergonomics Professional Project

Prerequisites: 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.

600(Aero 651)(EECS 600). Function Space Methods in System Theory

Prerequisite: EECS 400 or Math 419. I, 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.

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.

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.

612. Network Flows

Prerequisite: IOE 510. (3 credits)

Flow problems on networks. Maximum flow minimum cut theorem. Labelling 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.

614. Integer Programming

Prerequisite: IOE 510. (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.

616. Queueing Theory

Prerequisite: IOE 515. (3 credits)

Methods and analytical techniques of queueing theory. Markovian queues: finite queue size, finite population, bulk arrivals and departures, Jackson networks. The M/G/l and GI/M/s queues. Preemptive and non-preemptive priority systems.

633(Mfg 634). Man-Machine Systems

Prerequisite: IOE 533 or equivalent. (3 credits)

Introduction to advanced concepts in the identification, design, analysis, development, and implementation of human operated systems; existing and emerging systems identified from industrial and service organizations. Students handle case examples. Relevant theories of communication, decision, and control augmented by readings and laboratory demonstrations where appropriate.

634(EIH 705). Work-Related Upper Limb Disorders

Prerequisites: graduate standing and previous ergonomics, biomechanics or work physiology course. II (2 credits)

For students with an advanced interest in the causes of work-related muscle, tendon, and nerve disorders and in the analysis and design of jobs. The course format includes (1) lectures, discussions, and readings for an overview; (2) work site visits with written and oral reports on analysis and design of jobs; and (3) oral and written reports comparing published papers chosen by the students.

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) musculo-skeletal 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.

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.

639. Research Topics in Safety Engineering

Prerequisite: IOE 439 or IOE 539 or permission of instructor. (3 credits)

Selected topics studied in depth necessary to critique existing and to propose future research. Topics from accident model; safety performance measurement; accident prevention philosophies; hazard analysis and systems safety techniques; expert systems; warnings and instructions; machine, tool, and consumer product safety; slips/falls/climbing; vehicle operator visibility; robotics/automated systems.

640. Concepts in Mathematical Modeling of Large Scale Systems

Prerequisites: IOE 310, IOE 365, IOE 515. (3 credits)

Application or engineering, operations research, and economic concepts to the operational analysis and planning for large-scale systems. Practice in mathematical modeling and critical evaluation of various aspects of existing and proposed models of systems in the public and private sector.

641. Seminar in Production Systems

Prerequisite: IOE 541 or permission of instructor. (3 credits)

Analysis and discussion of classic and state-of-the-art research papers on production and service systems. Research issues and research methodology will be emphasized.

645(Mfg 645). Reliability, Replacement, and Maintenance

Prerequisite: IOE 515. (3 credits)

Analytic stochastic models for the failure of components and systems. Analysis of policies for optimal reliability, including strategies for surveillance, inspection, maintenance, repair, and replacement.

690. Graduate Study in Selected Problems I

Prerequisite: permission of graduate committee. (to be arranged)

691. Special Topics

Prerequisite: permission of instructor. (to be arranged)

Selected topics of current interest in industrial and operations engineering.

712. Infinite Horizon Optimization

Prerequisite: IOE 510 or IOE 512. II (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.

790. Graduate Study in Selected Problems II

Prerequisite: permission of graduate committee. (to be arranged)

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.

801. Directed Research

Prerequisites: IOE 800, concurrent with IOE 802. (1-3 credits)

Directed research on a topic of mutual interest to the student and the instructor. This course complements IOE 800, First-Year Doctoral Seminar. Research presented in IOE 802.

802. Research Presentation

Prerequisites: IOE 800, concurrent with IOE 801. II (1 credit)

Students present oral and written technical material, including research in IOE 801.

810(Math 861). Seminar in Mathematical Programming

Prerequisite: permission of instructor. (1-2 credits)

815. Seminar in Stochastic Service Systems

Prerequisite: permission of instructor. (1-3 credits)

A working seminar for researchers in stochastic service systems.

825. Seminar in Design and Manufacturing

Prerequisite: graduate standing. I, II (1 credit)

Invited speakers present advanced concepts in manufacturing.

836. Seminar in Human Performance

Prerequisite: graduate standing. (1-2 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.

837. Seminar in Occupational Health and Safety Engineering

Prerequisite: graduate standing. (1-2 credits)

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.

843. Seminar in Operations Research

(1-2 credits)

Study of recent developments and on-going research in OR methodology, operational science and OR practice.

873. Seminar in Administrative Information Processing Systems

Prerequisite: IOE 575. (1-3 credits)

Recent developments, case studies, and individual or group development projects in administrative information processing systems.

878. Seminar in Computer Graphics

Prerequisite: IOE 578. (1-3 credits)

Selected lectures and readings on recent developments in computer graphics.

899. Seminar in Industrial and Operations Engineering

Prerequisite: permission of instructor; not for master's degree. I, II (1 credit)

Presentation by IOE faculty members and outside speakers on current and future research activities in industrial and operations engineering.

906. Master's Thesis Project

Prerequisite: permission of department. (6 maximum total—may be spread over several terms)

916. Professional Thesis Project

Prerequisite: permission of department. (to be arranged)

990. Dissertation/Pre-Candidate

Prerequisite: permission of department. I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)

Election for dissertation work by doctoral student not yet admitted to status of candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

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 doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Macromolecular Science and Engineering * ** (Division 425)

Department Office
2541 Chemistry Building
(313) 763-2316

College of Literature, Science and the Arts
**College of Engineering*

Professor Richard E. Robertson, Ph.D., *Director*

Professor
A. Ziyu Akcasu, Ph.D.
M. David Curtis, Ph.D.
Frank E. Filisko, Ph.D.
Ronald Gibala, Ph.D.
Erdogan Gulari, Ph.D.
Samuel Krimm, Ph.D.
Paul G. Rasmussen, Ph.D.
Alan S. Wineman, Ph.D.
Aibert F. Yee, Ph.D.
Robert Zand, Ph.D.

Associate Professor
T. Carter Gilmer, Ph.D.
Richard M. Laine, Ph.D.
Robert M. Ziff, Ph.D.

Assistant Professor
Ellen Arruda, Ph.D.
Stacy G. Bike, Ph.D.
David C. Martin, Ph.D.
Coleen Pugh, Ph.D.

See page 225 for statement on Course Equivalence.

412(ChemE 412)(MSE 412). Polymeric Materials
Prerequisite: MSE 350. II (3 credits)
The synthesis, characterization, morphology, structure, and rheology of polymers. Polymers in solution and in the bulk liquid and glassy states. Engineering and design properties including viscoelasticity, creep, stress relaxation, yielding, crazing, and fracture. Forming and processing methods.

414(ChemE 414)(MSE 414). Applied Polymer Processing
Prerequisite: MSE 350. II (3 credits)
Theory and practice of polymer melt processing. Non-Newtonian flow; extrusion, injection and molding operations; fiber, film, and rubber processing; kinetics of solidification; mechanical orientation; product characterization; structure-property relations.

418(Physics 418). Structural Macromolecular Physics
Prerequisites: Math 216, Physics 242 or by permission of instructor. I (3 credits)
An intensive study of macromolecular structural problems and their solutions: thermodynamics and statistical mechanics of chain molecules; conformational influencing conformational transitions; denaturation; statistical nature of physical properties; nature

of general organization and folding in macromolecules; case studies of structural problems in bio- and macro-molecules.

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.

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.

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.

515(MSE 515). Mechanical Behavior of Solid Polymeric Materials

Prerequisites: 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.

517(AM 517)(ME 517). Theory of Linear Viscoelasticity I

Prerequisite: AM 407 or permission of instructor. II (3 credits)

Constitutive equation for linear isothermal viscoelastic response; constant stress or strain rate response; sinusoidal oscillations and the complex modulus, bending and torsion; three-dimensional response; correspondence theorem and boundary value problems for elastic and viscoelastic response; Laplace transform and numerical solution methods.

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.

536(Chem 536). Laboratory in Macromolecular Chemistry

Prerequisite: Chem 535 or Physics 418 or permission of instruction. I (alternate years) (2 credits)

Experimental methods for the study of macromolecular materials in solution and in bulk state.

538(Chem 538). Organic Chemistry of Macromolecules

Prerequisites: 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.

751. Special Topics in Macromolecular Science

I, II (2 credits)

790. Faculty Activities Research Survey

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.

800. Macromolecular Seminar

I, II (2 credits)

Student presentation of selected seminar topics in macromolecular science and engineering.

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.

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.

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.

Manufacturing (Division 275)

Program Office
2219 G.G.Brown Building
(313) 764-3312

A. Galip Ulsoy, Ph.D., *W.C. Clay Ford Professor of Manufacturing; Professor of Mechanical Engineering and Applied Mechanics; and Director of Program in Manufacturing*

See page 225 for statement on Course Equivalence.

401(Eng 401). Total Quality Management
Prerequisite: none. I, II (3 credits)
The technical and management aspects of total quality management. Topics include voice of the customer, metrics, cross-functional teams, and systems aspects. Examples from engineering and business operations such as dimensional tolerancing, quality function deployment, process control, simultaneous engineering, lean production, purchasing, inventory control, and scheduling systems.

402(AM 401)(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.

414(ChemE 414)(MacroSE 414)(MSE 414). Applied Polymer Processing
Prerequisite: MSE 350. I (3 credits)
Theory and practice of polymer melt processing. Non-Newtonian flow; extrusion, injection and molding operations; fiber, film and rubber processing; kinetics of solidification; mechanical orientation; product characterization; structure-property relations.

417(ChemE 417). Biochemical Technology
Prerequisite: organic chemistry. I (3 credits)
Concepts necessary in the adaptation of biological and biochemical principles to industrial processes and technology of the biochemical engineering industries. Lectures, problems, and library study will be used to develop the ideas presented.

423(EECS 423). Solid-State Device Laboratory
Prerequisite: EECS 320. I (3 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.

424(EECS 424). Integrated Circuit Process Technology and Process Integration

Prerequisites: EECS 317, EECS 320. I (3 credits)

Integrated circuit processing techniques: oxidation, diffusion, ion implantation, epitaxy, deposition, etching, process integration for silicon CMOS and bipolar technologies. Relationship between processing, device design, and device performance.

425(EECS 425). Integrated Circuit Laboratory

Prerequisites: EECS 320, EECS 427. II (2 credits)

Integrated circuit fabrication; mask design, photographic reduction; photoresist application, exposure, development, and etching, oxidation; diffusion; metal film deposition by evaporation and sputtering; die bonding, wire bonding, and encapsulation; testing of completed integrated circuits.

426(IOE 425). Manufacturing Strategies

Prerequisite: senior standing. I (3 credits)

Review of the manufacturing philosophies that have been successfully applied by world manufacturers, including work-flows, quality assurance, process design, inventory product throughput maintenance, simultaneous design, voice-of-the-customer and total quality control systems. Students tour plants to analyze the extent and potential of the philosophies.

427(EECS 427). VLSI Design I

Prerequisite: EECS 317. 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.

433(EIH 556)(IOE 433). Occupational Ergonomics

Not open to students who have credits for IOE 333. I (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, musculoskeletal disorders noise, vibration, heat stress, and the analysis and design of work.

436(EECS 436). Optical Radiation and Detector Technology

Prerequisites: Physics 240, Math 216. I (3 credits)

Theory and instrumentation for sensing and measuring visible and infrared radiation. Topics include black body radiation, radiometric concepts; radiative transfer through the atmosphere; basic optics of semiconductors; photon detectors (photoconductive, photo-voltaic, and photoemissive); thermal detectors; detector noise sources and figures of merit; imaging detectors (pyroelectric arrays and CCDs); LEDs and diode laser sources.

441(IOE 441). Production and Inventory Control

Prerequisites: IOE 310, IOE 315. I, II (3 credits)

Models and techniques for managing inventory systems and for planning production. Topics include basic deterministic and probabilistic inventory models and extensions; production loading, planning, and smoothing; and sequencing problems.

447(IOE 447). Facility Planning

Prerequisites: IOE 310, IOE 315, and IOE 373. I (3 credits)

Fundamentals in developing efficient lay-outs for single-story and multi-story production and service facilities. Manual procedures and computer algorithms used on mainframe and microcomputers. Algorithms to determine the optimum location of facilities. Special requirements for planning service facilities such as hospitals, airports and offices.

448(ChemE 447). Waste Management in Chemical Engineering

Prerequisites: 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.

449(IOE 449). Material Handling Systems

Prerequisites: IOE 310, IOE 315, and IOE 373. II (3 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.

451(Eng 451). Technology and Society

Prerequisite: none. I, II (3 credits)

Examines areas where contemporary technological development has substantial impact on our way of life. Effects on the environment, in medical practice, in industry and on the workplace, and on local and global politics are examples. Experts in the respective areas are engaged to participate with the class in discussion/debate.

452(ME 452). Design for Manufacturability

Prerequisite: ME 350. I (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.

453(ME 451). Properties of Advanced Materials for Design Engineering

Prerequisite: ME 281. 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.

454(ME 454). Computer Aided Mechanical Design

Prerequisites: Eng 103, ME 360. I, II (3 credits)

Introduction to the use of the digital computers 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.

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. 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.

459(EECS 459). Advanced Electronic Instrumentation

Prerequisite: EECS 360 or EECS 359 or EECS 453 or EECS 458. I (3 credits)

Systematic design of optimum measuring instruments which give maximum confidence in results. Analog and digital signal processing, transducer modeling. A/D and D/A conversion, survey of modern instrumentation components.

460(NA 460). Ship Production Planning and Control

Prerequisites: NA 275, preceded or accompanied by NA 470. I (3 credits)

Overview of ship production systems; shipyard organization and arrangement; product standardization and work simplification systems; performance measurement; use of models and composites; PERT/CPM and other control techniques; the design and use of Information Systems for Production Control.

463(IOE 463). Work Measurement and Prediction

Prerequisites: IOE 333, IOE 334, and IOE 365. I (3 credits)

The analysis and prediction of human performance in industrial and service machine systems. The use of predetermined time systems, learning curves, operator selection procedures, work sampling, and motion economy principles in the design of the work place.

464(EECS 463)(ME 463). Modern Control Systems Design

Prerequisite: EECS 460 or ME 461 or Aero 471. I, II (4 credits)

The class is organized into teams of four to five students. Each team must select, plan and complete a design project within the general theme of automatic control systems. The project accounts for approximately 75% of the course grade. Lectures will cover state space analysis techniques, system ID basics and state space feedback design methods.

466(IOE 466)(Stat 466). Statistical Quality Control
Prerequisite: IOE 365(Stat 311). I, II (3 credits)
Design and analysis of procedures for forecasting and control of production processes. Topics include attribute and variable sampling plans; sequential sampling plans; rectifying control procedures; charting, smoothing, forecasting, and prediction of discrete time series.

467(EECS 467)(ME 467). Robotics: Theory, Design and Application
Prerequisites: ME 360 or EECS 360 and senior standing. I, II (3 credits)
Basic concepts underlying the design and application of computer-controlled manipulators: Manipulator geometry, work volume, sensors, feedback control of manipulator linkages, kinematics, trajectory planning, programming, robot system architecture, design and application. Lab experiments cover kinematics, dynamics, trajectory planning, control of manipulators and motion by fixed robots and mobile robots.

480(MSE 480). Materials Science in 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.

481(Aero 481). Airplane Design
Prerequisite: senior standing. (4 credits)
Power-required and power-available characteristics of aircraft on a comparative basis, calculation of preliminary performance, stability, and control characteristics. Design procedure, including lay-outs and preliminary structural design. Subsonic and supersonic designs. Emphasis on design techniques and systems approach. Lectures and laboratory.

482(EECS 481). Software Engineering
Prerequisite: EECS 380. I, II (3 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.

483(Aero 483). Aerospace System Design
Prerequisite: senior standing. II (4 credits)
Aerospace system design, analysis and integration. Consideration of launch facilities, booster systems, spacecraft systems, communications, data processing, and project management. Lectures and laboratory.

484(Aero 484). Computer Aided Design

Prerequisites: Aero 414, senior standing. I (4 credits)

Computer generation of geometric models. Calculation of design parameters. Finite element modeling and analysis. Each student will complete a structural component design project using industry standard applications software.

488(ME 487). Welding

Prerequisite: ME 281. 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.

489(MSE 489). Materials Process Design

Prerequisites: preceded or accompanied by MSE 430 and MSE 435. II (3 credits)

The design of production and refining systems for engineering materials. Unit processes in the extraction and refining of metals. Production and processing of ceramic and polymeric materials, and electronic materials and devices.

490(Eng 490). Special Topics in Engineering

(to be arranged)

Individual or group study of topics of current interest selected by the faculty.

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.

493(EECS 493)(IOE 437). User Interface Design and Analysis

Prerequisite: EECS 481. I (3 credits)

Current theory and design techniques concerning how user interfaces for computer systems should be designed to be easy to learn and use. Focus on cognitive factors, such as the amount of learning required, and the information-processing load imposed on the user, rather than ergonomic factors.

497(EECS 497). Analysis and Design Projects

Prerequisite: successful completion of at least two-thirds of the credit hours required for the program subjects. A student may elect this course more than once ONLY with the explicit approval of the Chief Program Advisor. I, II, III (1-4 credits)

Professional problem-solving methods developed through intensive group and individual studies. Normally, two or three significant engineering analysis and design projects

will be carefully chosen from devices, software tools, and systems. Use of analytic, computer, design, and experimental techniques where applicable. Lecture and laboratory sessions will be arranged.

499. Special Topics
Prerequisite: to be specified by department. (to be arranged)

501. Manufacturing Seminar I
Prerequisite: graduate standing in PIM. I (1 credit)
This seminar course is intended to provide students with a wide variety of subjects related to manufacturing at an introductory level and a broad exposure across engineering and business disciplines.

502. Manufacturing Seminar II
Prerequisite: Mfg 501 or permission of instructor. II (2 credits)
This seminar course is intended to provide students with a broad exposure to manufacturing related topics from both academic and industrial perspectives.

503. Manufacturing Project
Prerequisite: Mfg 501 or Mfg 502. III, IIIa, IIIb (3 credits)
This project course in intended to provide students with an industrially-relevant team project experience in manufacturing.

504(CEE 502). Artificial Intelligence Applications in Civil Engineering
Prerequisite: senior or graduate standing. I (3 credits)
Introduction to artificial intelligence for engineers; theoretical concepts of AI explored and illustrated with applications in civil engineering and construction management, such as facilities design, site layout, planning and scheduling, selection of construction equipment and operation methods, construction automation. Students acquire hands-on experience with expert systems in final project.

510(Aero 510). Finite Elements in Technical and Structural Analysis I
Prerequisite: Aero 414. I (3 credits)
Introductory level. Development of the linear finite element displacement method. Virtual work. Application to trusses, beams, plates, shells, and solids. Stress, displacement, strain energy. Computer laboratory based on a general purpose finite element code. Term project.

511(Aero 511). Finite Elements in Mechanical and Structural Analysis II
Prerequisite: Aero 510 or AM 505(ME 505). II (3 credits)
Intermediate level. Finite element solutions for structural solutions for structural dynamics and non-linear problems. Normal modes, forced vibration, Euler buckling (bi-furcation), large deflections, nonlinear elasticity, transient heat conduction. Computer laboratory based on a general purpose finite element code.

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.

516(Aero 516). Mechanics of Fibrous Composites

Prerequisite: Aero 414 or AM 412(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.

523(EECS 523). Digital Integrated Circuits

Prerequisites: EECS 317, EECS 320; and either EECS 412 or EECS 423 or EECS 427 or EECS 512. I (3 credits)

Device technologies for LSI circuits. Approaches to logic implementation, including gate arrays, master-slices, PLAs. Non-volatile semiconductor memory structures, including ROM, PROM, EPROM and EAROM. Static and dynamic random access memory and microcomputers. Relationship of terminal performance to the design, layout and fabrication techniques used. Circuit layout and computer simulation.

524(EECS 524). Field-Effect-Transistors and Microwave Monolithic Integrated Circuits Technology

Prerequisites: EECS 420; and EECS 525 or EECS 528; and graduate standing. II (3 credits)

Physical and electrical properties of III-V Physical and electrical properties materials, epitaxy and ion-implantation, GaAs and InP based devices (MESFETs and HEMTs varactors) and Microwave Monolithic Integrated Circuits (MMICs) Cleaning, Photolithography, metal and dielectric deposition, wet and dry etching. Device isolation, ohmic and Schottky contacts, dielectrics, passive component technology, interconnects, via holes, dicing and mounting. Study of the above processes by DC characterization.

527(EECS 527). Computer-Aided Design for VLSI System

Prerequisite: EECS 478. II (3 credits)

Theory of circuit layout partitioning and placement algorithms. Routing algorithms, parallel design automation on shared memory and distributed memory multiprocessors, simulated annealing and other optimization techniques and their applications in CAD, layout transformation and compaction, fault-repair algorithms for RAMs & PLAs hardware synthesis from behavioral modeling, artificial intelligence based CAD.

528(EECS 528). Principles of Microelectronics Process Technology
Prerequisites: EECS 422, EECS 424. I (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, photoresist models, thin film deposition, chemical etching, plasma etching, electrical contact formation, microstructure processing and process modeling.

533(CEE 533). Construction Performance Management
Prerequisite: senior or graduate standing. I, II, IIIa (3 credits)
Ergonomics, job analysis, and job design. Work physiology, environmental factors. Repetitive motion disorders, overexertion, and traumatic injuries. Occupational health and safety with focus on underlying causes and prevention of illnesses and injuries rather than or regulation. Risk, safety, and loss management.

534(BiomedE 534)(IOE 534). Occupational Biomechanics
Prerequisites: 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.

535(IOE 533). Human Factors in Engineering Systems I
Prerequisites: IOE 333, IOE 365 or IOE 433(EIH 556) 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.

536(CEE 536). Critical Path Methods
Prerequisite: senior or graduate standing. I, II, 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.

539(IOE 539). Occupational Safety Engineering
Prerequisite: IOE 365 or BioStat 500. II (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.

541(IOE 541). Inventory Analysis and Control

Prerequisites: IOE 310, IOE 315, IOE 365, and IOE 441. II (3 credits)

Review of basic inventory models. Models and solution techniques in various problems related to multi-stage production and distribution systems. Topics include assembly systems, material requirements planning, hierarchical production planning, flexible manufacturing systems, distribution systems. Readings will include classic works and recent papers on techniques and applications.

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.

543(IOE 543). Theory and Scheduling

Prerequisites: IOE 315 or IOE 515, 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.

545(IOE 545). Queueing Networks in Manufacturing

Prerequisite: IOE 315 or EECS 401. I (3 credits)

This course is an introduction to queueing networks and their applications in manufacturing. Topics include product and non-product form networks, exact results and heavy and light traffic approximations, analysis of "pull" manufacturing systems, and polling systems with and without set-ups. Applications to several industries including semiconductor manufacturing are emphasized.

548(IOE 547). Plant Flow Systems

Prerequisites: 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.

550(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.

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.

553(ME 553). Management of Product and Manufacturing Process Design
Prerequisite: ME 450 or equivalent. I (3 credits)

Meets with ME 450, plus additional hour. Topics include theory of concurrent engineering; manufacturing system organization; leadership; basic marketing and finance; the use of engineering models to organize complex design tasks. ME students normally manage large ME 450 teams, while non-MEs provide staff expertise in a semester-long project.

554(IOE 564)(ME 554). Computer Aided Design Methods
Prerequisite: ME 454 or AM 501(ME 501) or IOE 373. 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.

555(ME 555). Engineering Design Optimization
Prerequisite: graduate standing. II (3 credits)

Mathematical modeling of engineering design problems for optimization. Boundedness and monotonicity analysis of models. Differential optimization theory of nonlinear models selected numerical algorithms. Emphasis on the interaction between proper modeling and computation. Students propose design term projects from various disciplines and apply course methodology to optimize designs.

556(ME 556). 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.

557(ME 557). 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.

561(ME 563). Time Series Analysis for Manufacturing Systems

Prerequisites: controls course plus one from Stat 310, Stat 402, or EECS 401. II (3 credits)

Principles for identifying parametric time series models from discrete data and the relationship to autovariance, spectrum, and the Green's function from linear system theory are considered. Theory is developed for application to prediction, characterization, signature analysis, and process identification and control.

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.

563(NA 562). Concurrent Marine Design

Prerequisite: NA 460. II (3 credits)

Emphasis on explicit product and process definition. Includes view of product components as systems, parts, assemblies, etc. tied to particular processes. IDEFO methodology for process description. Data and process integration through 3-D computer product modeling concepts. Trade-off and risk production analysis considers accuracy, scheduling, costs, through-put, etc.

564(Aero 564). Computer Aided Design and Manufacturing

Prerequisite: Aero 484 or ME 454 or permission of instructor based on familiarity with industrial standard CAE software. II (3 credits)

Computer generation of geometric models, optimal design for manufacturing, manufacturing methods based on geometric models such as numerical control tool path generation, plastic mold design and rapid prototyping using stereolithography. Testing and redesign.

565(Aero 565)(AM 565). Optimal Structural Design

Prerequisites: Aero 350, Aero 414. I (3 credits)

Optimal design of structural elements (bar, 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.

566(ChemE 566). Process Control in Chemical Industries

Prerequisites: 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.

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.

568(IOE 567). Advanced Work Measurement and Design

Prerequisite: IOE 433 or IOE 463. II (3 credits)

Non-traditional approaches to job evaluation are applied to a variety of manufacturing and service jobs. Topics include: computer-aided job analyses and design, ergonomic work measurement, evaluation of "white collar" productivity, and high level predetermined time systems. Case studies are used extensively to develop observational, analytical, and design skills.

569(IOE 566). Advanced Quality Control

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.

570(EECS 568). Process Control for Microelectronics Manufacturing

Prerequisite: graduate standing or permission of instructor. I (3 credits)

Selected processing steps in microelectronics manufacturing, design of experiments, process and substrate sensors, statistical process control, run-to-run control, real-time control, failure diagnostics, computer implementation of control systems.

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.

574(NA 574). Computer-Aided Hull Design and Production
Prerequisites: graduate standing and permission. I (3 credits)

Hull surface representation, creation, distortion, fairing. Computer-aided arrangement, piping, structures. Computer systems for structural detailing, production, manufacturing.

575(NA 575). Computer-Aided Marine Design Project
Prerequisite: NA 574. I, II, III, IIIa, IIIb (2-6 credits)

Development of computer-aided design tools. Projects consisting of formulation, design, programming, testing, and documentation of programs for marine design and constructional use.

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.

580(ME 580). Rheology and Fracture
Prerequisite: ME 281. 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. Surface stress and energy states, wetting, solid adhesion, friction. Ductile, creep, brittle, and fatigue failure mechanisms.

581(ME 581). Friction and Wear
Prerequisites: 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.

582(MSE 523)(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.

583(ME 583). Sensing and Modeling for Manufacturing Control
Prerequisite: ME 461. I (3 credits)

Fundamental concepts in manufacturing with emphasis on welding, machining, and forming. Input and output variables for process control. Characteristics of sensors for feedback in manufacturing. Fiber optics, interferometry, infrared thermal imagery, tactile

sensing, force/torque sensing for robots, force dynamometers, acoustic emission. Signal processing. Process modeling for control.

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.

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.

586(MSE 580). Materials Science and Engineering Design

I (2 credits)

Design of materials processing systems. Selection and utilization of materials in engineering applications, economic aspects of design, estimating procedures.

588(CS 588)(EECS 588)(IOE 578)(ME 551). Geometric Modeling

Prerequisite: EECS 487(IOE 478) or ME 454 or permission of instructor. II (3 credits)

Individual or group study of topics in geometric modeling and computer graphics. Geometric data structures for curves, surfaces, and volume parameterization, and topological data structures for vertices, edges, faces and bodies. Algorithms for set operations, Euler operations and deformations. Design and experimentation with geometric modeling facilities.

589(ME 589). Failure Analysis Case Studies

Prerequisite: preceded or accompanied by ME 350. II (3 credits)

Detailed case study of a variety of service failures in engineering structures such as vehicles, medical implants, hoisting equipment, machinery, and consumer products such as ladders, mowers, and tools. Procedures for analysis include applications of optical and electron microscopy; load history, dynamics, and stress analysis; indentation hardness analysis; accident investigation and reconstruction techniques; specification and standards; fracture mechanics. The expert's role in product liability litigation.

590. Directed Study and Research

Prerequisite: see individual department requirements. I, II (3 maximum)

591(IOE 591). Queuing Networks in Manufacturing (Special Topics)

Prerequisite: permission of instructor. (to be arranged)

This is a special topics course in the area of queuing networks.

594(EECS 594). Introduction to Adaptive Systems

Prerequisites: EECS 303, Math 425(Stat 425). I (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 service.

598(EECS 598). Control of Semiconductor Manufacturing Equipment (Special topics)

Prerequisite: none. I, II, III, IIIa, IIIb (1-4 credits)

This is a special topics course in the area of applications of control technology to semiconductor manufacturing.

599. Special Topics

Prerequisite: see individual department requirements. I, II (to be arranged)

617(ChemE 617). Advanced Biochemical Technology

Prerequisite: ChemE 417 or permission of instructor. II (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.

622(MSE 622)(NERS 622). Ion Beam Modification and Analysis of Materials

Prerequisite: NERS 421, NERS 521 or MSE 350 or permission of instructor. I (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.

623(EECS 623). Integrated Sensors and Sensing Systems

Prerequisites: EECS 413 and either EECS 423 or EECS 424 or EECS 425 or EECS 523. I (4 credits)

Fundamental principles and design of integrated solid-state sensors and sensing systems. Micro machining and wafer bonding. Micro structures for the measurement of visible and infrared radiation, pressure, acceleration, temperature, gas purity, ion

concentrations. Merged process technologies for sensors and circuits. Data acquisition circuits, micro actuators and integrated micro systems.

627(EECS 627). VLSI Design II

Prerequisite: EECS 427. II (4 credits)

Advanced very large scale integrated (VLSI) circuit design: VLSI CAD tools and techniques. IC failure modes: testing. Design for testability. Self-checking circuits. Automated layout. Design and verifications; placement and compaction; routing. Gate arrays, silicon compilers. Advanced projects in chip design and CAD tool development. Testing of chips fabricated in EECS 427. Three hours lecture plus design laboratory.

634(IOE 633). Man-Machine Systems

Prerequisite: IOE 533 or equivalent. II (3 credits)

Introduction to advanced concepts in the identification, design, analysis, development, and implementation of human operated systems; existing and emerging systems identified from industrial and service organizations. Students handle case examples. Relevant theories of communication, decision, and control augmented by reading and laboratory demonstrations where appropriate.

645(IOE 645). Reliability, Replacement, and Maintenance

Prerequisite: IOE 515. II (3 credits)

Analytic stochastic models for the failure of components and systems. Analysis of policies for optimal reliability, including strategies for surveillance, inspection, maintenance, repair, and replacement.

990. Dissertation/Pre-Candidate

Prerequisite: permission of thesis committee. I, II, III (2-8 credits);
IIIa, IIIb (1-4 credits)

Election for dissertation work by doctoral student not yet admitted to status of candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

995. Dissertation/Candidate

Prerequisite: College of Engineering authorization for admission as a doctoral
candidate. I, II, III (8 credits); IIIa, IIIb (4 credits)

Election for dissertation work by doctoral student who has been admitted as a doctoral candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Materials Science and Engineering
(Division 281)

Department Office
3062 H.H. Dow Building
(313) 763-4970

Albert F. Yee, Ph.D., Professor and Chair; *also Macromolecular Science and Engineering*

Professor

John C. Bilello, Ph.D.; *also Applied Physics*
I-Wei Chen, Ph.D.
Frank E. Filisko, Ph.D., P.E.; *also Macromolecular Science and Engineering*
Amit K. Ghosh, Ph.D.
Ronald Gibala, Ph.D.; *also Macromolecular Science and Engineering*
John W. Halloran, Ph.D.
William F. Hosford, Jr., Sc.D.
J. Wayne Jones, Ph.D.; *also Associate Dean for Undergraduate Education*
Robert D. Pehlke, Sc.D., P.E.

Richard E. Robertson, Ph.D.; *also Macromolecular Science and Engineering*
David J. Srolovitz, Ph.D.; *also Applied Physics*
Gary S. Was, Sc.D.; *also Nuclear Engineering and Radiological Sciences*

Professor Emeritus

Wilbur C. Bigelow, Ph.D.
Edward E. Hucke, Sc.D.
William Cairns Leslie, Ph.D.
Tseng-Ying Tien, Ph.D.
Lawrence H. Van Vlack, Ph.D., P.E.

Edwin Harold Young, M.S.E., P.E.; *also Chemical Engineering*

Associate Professor

Michael Atzmon, Ph.D.; *also Nuclear Engineering and Radiological Sciences*
Richard M. Laine, Ph.D.; *also Chemistry; Macromolecular Science and Engineering*
David C. Martin, Ph.D.; *also Macromolecular Science and Engineering*
John E. Sanchez, Jr., Ph.D.
Steven M. Yalisove, Ph.D.

See page 225 for statement on Course Equivalence.

150(Eng 150). Introduction to Engineering Materials

Prerequisite: Chem 130 or Chem 210. Open only to freshmen. Satisfies any program requirement for MSE 250. II (4 credits)

Engineering materials, covering the structure, properties, and processing aspects of metals, polymers, and ceramics.

250. Principles of Engineering Materials

Prerequisites: Chem 130 or Chem 210, preceded or accompanied by Physics 240. (3 credits)

An introductory course in the science of engineering materials. The engineering properties (mechanical, thermal, and electrical) of metals, polymers, and ceramics are correlated with: (1) their internal structures (atomic, molecular, crystalline, micro-, and macro-); and (2) service conditions (mechanical, thermal, chemical, electrical, magnetic, and radiative). Two lectures and two recitations.

350. Principles of Engineering Materials II

Prerequisite: MSE 250. I (4 credits)

Structure and reaction kinetics of crystalline and amorphous engineering materials. Phase diagrams. Equilibrium and non-equilibrium phase transformations. Crystal chemistry. Defects. Surfaces. Diffusion. Sintering.

356. Materials Laboratory I

Prerequisite: MSE 250. I (2 credits)

Experimental techniques for the quantification of microstructure and physical properties of metals, ceramics, polymers and selected composites. Techniques for sample preparation and proper use of optical microscopy.

400. Electronic, Magnetic, and Optical Properties of Materials

Prerequisites: Physics 242, MSE 250. II (3 credits)

The fundamentals of quantum mechanics and electronic theory that apply to electronic, magnetic and optical materials. Engineering aspects of these materials and their use in solid state devices, hard and soft magnets, superconductors and optical devices.

410(BiomedE 410). Biomedical Materials Considerations

Prerequisite: MSE 250 or permission. I (2 credits)

Interactions of materials implanted in the body. Histological and hematological considerations include general foreign body reactions, inflammation and reparation, carcinogenicity, thrombosis, hemolysis, protein and cellular issues, immunogenic and toxic properties. Basic discussion of implants vs. transplants and relevant biological components. Tours of relevant university facilities.

412(ChemE 412)(MacroSE 412). Polymeric Materials

Prerequisite: MSE 350. II (3 credits)

The synthesis, characterization, morphology, structure and rheology of polymers. Polymers in solution and in the bulk liquid and glassy states. Engineering and design properties including viscoelasticity, creep, stress relaxation, yielding, crazing and fracture. Forming and processing methods.

414(ChemE 414)(MacroSE 414)(Mfg 414). Applied Polymer Processing

Prerequisite: MSE 350. (3 credits)

Theory and practice of polymer melt processing. Non-Newtonian flow; extrusion, injection and molding operations; fiber, film and rubber processing; kinetics of solidification; mechanical orientation; product characterization; structure-property relations.

420. Mechanical Behavior of Materials

Prerequisites: 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.

430. Thermodynamics of Materials

Prerequisites: Chem 210, Phys 140-141, Math 215 or Math 285, MSE 350. 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.

435. Kinetics and Transport in Materials Engineering

Prerequisites: Math 216, MSE 250. I (4 credits)

Principles of reaction kinetics. Fluid, energy, and mass transport, with applications to materials systems.

440. Ceramic Materials

Prerequisite: MSE 350. II (3 credits)

Chemistry, structure, processing, micro-structure and property relationships, and their applications in the design and production of ceramic materials.

456. Materials Laboratory II

Prerequisite: MSE 356. II (2 credits)

Phase transformations, recrystallization and diffusion in metals, ceramics and polymers. Fracture mechanics concepts and experimental determination of fracture properties.

460. X-ray Methods and Crystallography

Prerequisite: MSE 250. I (3 credits)

The methods of x-ray diffraction and spectroscopy and the principles of crystallography of importance in materials engineering. X-ray spectroscopy. X-ray diffraction, the powder and Laue methods. Stereographic projection, pole figures. Crystal symmetry, point groups and space groups. Diffraction intensities and their relation to crystal structure. Lectures and laboratory.

470. Advanced 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.

480(Mfg 480). Materials Science in 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.

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.

489(Mfg 489). Materials Process Design

Prerequisites: preceded or accompanied by MSE 430 and MSE 435. II (3 credits)

The design of production and refining systems for engineering materials. Unit processes in the extraction and refining of metals. Production and processing of ceramic and polymeric materials, and electronic materials and devices.

490. Research Problems in Materials Science and Engineering

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.

493. Special Topics in Materials Processing and Applications

Prerequisite: MSE 350 (to be arranged)

Selected topics of current interest for students entering industry.

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.

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.

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.

514(MacroSE 514)(Mfg 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 chemical and physical processes currently employed and expected to guide the future development of the technology.

515(MacroSE 515). Mechanical Behavior of Solid Polymeric Materials

Prerequisites: 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.

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.

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 hardening and friction, temperature, strain rate, and anisotropy.

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.

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.

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.

535. Kinetics, Phase Transformations, and Transport
Prerequisite: MSE 430 or equivalent. I (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.

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.

543. Structures of Ceramic Compounds
Prerequisite: MSE 440 or graduate standing. (3 credits)
Structures and crystal chemistry of ceramic compounds.

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.

550. Fundamentals of Materials Science and Engineering
Prerequisites: senior or graduate standing and permission of instructor. I (3 credits)
An advanced level survey of the fundamental principles underlying the structures, properties, processing, and uses of engineering materials.

555. Physical Properties of Materials
Prerequisite: MSE 400 or MSE 550. II (3 credits)
An introduction to the quantum and statistical mechanics and the mathematics of crystal physics. Application of these methods to the electronic and vibrational properties of solids. The relationship of these to the thermodynamic properties of solids will be emphasized.

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.

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.

573(ChemE 573). Corrosion Engineering

Prerequisite: course in materials engineering. (3 credits)

Fundamentals involved in choosing materials in corroding media, corrosion control methods, and corrosion-failure analysis.

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.

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.

580(Mfg 586). Materials Science and Engineering Design

Prerequisite: none. Not open to students who have taken MSE 480. I (2 credits)

Design of materials processing systems. Selection and use of materials in engineering applications; economic aspects of design; estimating procedures.

583(BiomedE 583)(ChemE 583). Biocompatibility of Materials

Prerequisites: 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.

585. Materials or Metallurgical Design Problem

Prerequisite: MSE 480 or to be taken concurrently with MSE 580. 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.

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.

622(Mfg 622)(NERS 622). Ion Beam Modification and Analysis of Materials

Prerequisites: NERS 421, NERS 521 or MSE 350 or permission of instructor. I (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.

662. Electron Microscopy II

Prerequisite: MSE 562. (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.

690. Research Problems in Materials Science and Engineering

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.

693. Special Topics in Materials Science and Engineering

(to be arranged)

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.

890. Seminar in Materials Science and Engineering

(to be arranged)

Selected seminar topics in metallurgy, ceramics, polymers, or electronic materials.

990. Dissertation/Pre-Candidate

I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)

Election for 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.

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 doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Mathematics *

Department Office
2072 East Hall
(313) 764-0337

College of Literature, Science and the Arts

Professor B.A. Taylor, *Chair*

Professors Barrett, Blass, Brown, Burns, Conlon, Doering, Dolgachev, Duren, Federbush, Fornaess, Griess, Hanlon, Higman, Hinman, Hochster (R.W. and L.H. Browne Professor of Science), Huntington, Kister, Krause, Milne, Montgomery, Prasad, Ramanujan, Rauch, Raymond, G.P. Scott, Simon, Smoller, Spatzier, Stafford, Stembridge, Storer, B.A. Taylor, Uribe-Ahumada, Wasserman, Weinstein, Winter, Woodroofe; **Associate Professors** Bloch, Goldberg, Hales, Harabetian, Heinonen, Krasny, Kriz, Lott, Megginson, Moy, Schwartz, Shih, Stensones, Wooley; **Assistant Professors** Aarsvold, Barvinok, Bean, Bennett, Canary, Cherry, Chow, Cole, Delfino, Gasharov, Gitik, Gockenbach, Gong, Ji, Jordan, Kra, Lawrence, Mpacko, Naddaf, Nicolaescu, Ouyang, Saveliev, Smereka, Smith, Song, Staniszkis, E. Taylor, Tin, Wang, Werner, Whitney; **Hildebrandt Research Assistant Professors** Emmanouil, Hsu, Lauter, Nica, Ramachandran, Yang; **Adjunct Professor** Young; **Lecturer** Shure; **Professors Emeriti** Bartels, Dickson, Gehring, Harary, Hay, D. Jones, P. Jones, Kaplan, Kincaid, Lee, Lewis, McLaughlin, Nesbitt, Pearcy, Piranian, Reade, Rosen, Titus, and Wendel.

Course descriptions for mathematics are listed in the Literature, Science, and the Arts Bulletin *and the Horace H. Rackham School of Graduate Studies* Bulletin.

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105. Data, Functions, and Graphs
Prerequisite: three to four years of high school mathematics; four years strongly recommended. See LS&A Bulletin. (4 credits)

110. Pre-calculus
(self-study)
Prerequisite: three to four years of high school mathematics; four years strongly recommended. See LS&A Bulletin. (2 credits)

115. Calculus I
Prerequisite: four years high school mathematics. Credit usually is granted for only one course from among Math 112, Math 115, Math 185, and Math 295. (4 credits)

116. Calculus II
Prerequisite: Math 115. Credit is granted for only one course from among Math 116, Math 186, and Math 296. (4 credits)

119. Calculus II Using Maple
Math 115 or AP credit for AB calculus. (4 credits)

156. Applied Honors Calculus II
Prerequisite: Score of 4 or 5 on the AB or BC Advanced Placement calculus exam

175. Combinatorics and Calculus
Prerequisites: permission of a counselor. I (4 credits)

176. Dynamic Systems and Calculus
Prerequisite: Math 175 or permission of instructor. (4 credits)

185. Honors Analytic Geometry and Calculus I
Prerequisite: permission of a counselor. I (4 credits)

186. Honors Analytic Geometry and Calculus II
Prerequisite: Math 185 or permission of a counselor. II (4 credits)

203. Introduction to Maple and Mathematica
Prerequisite: one semester of calculus; may be concurrent, or equivalent. (1 credit)

215. Calculus III
Prerequisite: Math 116 (4 credits)

216. Introduction to Differential Equations
Prerequisite: Math 215. I, II, IIIa, IIIb (4 credits; no credit after Math 316)

217. Linear Algebra
Prerequisite: Math 215 or Math 285. I, II (3 credits; no credit after Math 417)

219. Calculus III Using Maple
Prerequisite: Math 119. (4 credits)

255. Applied Honors Calculus III
Prerequisite: Math 156 or permission of instructor.

256. Applied Honors Calculus IV
Prerequisite: Math 255 or permission of instructor.

285. Honors Analytic Geometry and Calculus III
Prerequisite: Math 186 or permission. I (4 credits)

286. Honors Differential Equations
Prerequisite: Math 285. II (3 credits)

288. Math Modelling Workshop

Prerequisites: Math 216, Math 316, or Math 286 and Math 217, Math 417, or Math 419. I (1 credit). Offered mandatory credit/no credit. May be elected for a total of 3 credits.

289. Problem Solving

Prerequisite: permission of instructor. I, II (1 credit) May be repeated for credit with permission of advisor.

295. Honors Mathematics I

Prerequisite: permission of the Honors Counselor. (4 credits)

296. Honors Mathematics II

Prerequisite: permission of the Honors Counselor. (4 credits)

312. Applied Modern Algebra

Prerequisite: Math 217. I, II, and occasionally IIIa (3 credits)

316. Differential Equations

Prerequisites: Math 215, Math 217 or equivalent. I, II (3 credits) Credit can be received for only one of Math 216 or Math 316, and credit can be received for only one of Math 316 or Math 404.

350(Aero 350). Aerospace Engineering Analysis

Prerequisite: Math 216 or Math 316 or equivalent. I, II (3 credits)

354. Fourier Analysis and Its Applications

Prerequisites: Math 216, Math 316, or Math 286. (3 credits)

362. Applications of Calculus and Linear Algebra

Prerequisite: Math 216 or Math 217. (3 credits)

371(Eng 371). Numerical Methods for Engineers and Scientists

Prerequisites: Eng 103 or Eng 104, or equivalent; and Math 216. I, II (3 credits)

395. Honors Analysis I

Prerequisite: Math 296 or permission of the Honors Counselor. (4 credits)

396. Honors Analysis II

Prerequisite: Math 395. (4 credits)

403. Mathematical Modeling Using Computer Algebra Systems

Prerequisites: one year of calculus and junior standing. (3 credits)

404. Intermediate Differential Equations

Prerequisite: Math 216. I, II, IIIa, IIIb. (3 credits; no credit after Math 286 or Math 316)

412. Introduction to Modern Algebra

Prerequisites: Math 215 or Math 285 and prior or concurrent election of Math 217, Math 417, or Math 419 recommended. No credit granted to those who have completed or are enrolled in Math 512. Students with credit for Math 312 should take Math 512 rather than Math 412. One credit granted to those who have completed Math 312. I, II (3 credits)

416. Theory of Algorithms

Prerequisites: Math 312 or Math 412 or EECS 303, and EECS 308 or permission. I, II (3 credits)

417. Matrix Algebra I

Prerequisites: three courses beyond Math 110. I, II, IIIa, IIIb (3 credits; none after Math 217)

419(EECS 400). Linear Spaces and Matrix Theory

Prerequisite: four semesters of college math beyond Math 110. I, II (3 credits) Not open to students with credit for Math 417 or Math 513.

420. Matrix Algebra II

Prerequisite: Math 417 or Math 419. II (3 credits)

425. Introduction to Probability

Prerequisite: Math 215 or Math 285. I, II, IIIb (3 credits)

433. Introduction to Differential Geometry

Prerequisite: Math 215. II (3 credits)

450. Advanced Mathematics for Engineers I

Prerequisites: Math 216, Math 316 or Math 286. I, II, IIIa, IIIb (4 credits)

451. Advanced Calculus I

Prerequisites: Math 215, or Math 285 and one subsequent course. I, II, IIIa (3 credits)

452. Advanced Calculus II

Prerequisites: Math 217, Math 417, or Math 419 (may be concurrent) and Math 451. (3 credits)

454. Boundary Value Problems for Partial Differential Equations

Prerequisites: Math 216, Math 316, or Math 286. I, II, IIIa, IIIb (3 credits)

462. Mathematical Models

Prerequisites: Math 216, Math 286, or Math 316; and Math 217, Math 417, or Math 419. II (3 credits)

471. Introduction to Numerical Methods

Prerequisites: Math 216, Math 316, or Math 286; and Math 217, Math 417, or Math 419; and a working knowledge of one high-level computer language. I, II (3 credits)

481. Introduction to Mathematical Logic

Prerequisite: Math 412 or Math 451 or equivalent experience with abstract mathematics. I (3 credits)

490. Introduction to Topology

Prerequisite: Math 412 or Math 451 or equivalent experience with abstract mathematics. I (3 credits)

512. Algebraic Structures

Prerequisite: Math 285 or one 400-level course or permission of instructor. Math 512 requires more mathematical maturity than Math 412. Credit is not given for both Math 412 and Math 512. I (3 credits)

513. Introduction to Linear Algebra

Prerequisite: Math 412. I, II (3 credits)

516. Topics in the Theory of Algorithms

Prerequisites: Math 416, Math 417, EECS 480, or equivalent. (3 credits)

525(Stat 525). Probability

Prerequisite: Math 450 or Math 451; or permission of the instructor. I, II (3 credits)

550(PSCS 510). Introduction to Adaptive Systems

Prerequisite: permission of instructor or enrollment in Certificate Program.

552(PSCS 520). Empirical Analysis of Nonlinear Systems

Prerequisite: enrollment in Certificate Program or permission of instructor.

555. Introduction to Complex Variables

Prerequisite: Math 450 or Math 451. I, II, IIIa, IIIb (3 credits; 1 after Math 554)

556. Methods of Applied Mathematics I

Prerequisites: Math 554 or Math 555. I (3 credits)

557. Methods of Applied Mathematics II

Prerequisites: Math 217, Math 419, or Math 513; Math 454 and Math 555. II (3 credits)

558(658). Ordinary Differential Equations

Prerequisite: Math 450 or Math 451.

559. Selected Topics in Mathematics
Prerequisites: Math 419, Math 451 or equivalent. I (3 credits)

561(IOE 510)(SMS 518). Linear Programming I
Prerequisites: Math 217, Math 417 or Math 419. I, II, IIIa (3 credits)

562(Aero 577)(EECS 505)(IOE 511). Continuous Optimization Methods
Prerequisites: Math 217, Math 417, or Math 419. (3 credits)

565. Combinatorics and Graph Theory
Prerequisite: Math 412 or Math 451 or equivalent experience with abstract mathematics. I (3 credits)

566. Combinatorial Theory
Prerequisites: Math 216, Math 316, or Math 286 or permission of instructor. (3 credits)

571. Numerical Methods for Scientific Computing I
Prerequisites: Math 217, Math 419, or Math 513 and Math 454 or permission. I, II (3 credits)

572. Numerical Methods for Scientific Computing II
Prerequisites: Math 217, Math 419, or Math 513 and Math 454 or permission. II (3 credits)

593. Algebra I
Prerequisite: Math 513. I (3 credits)

594. Algebra II
Prerequisite: Math 593. (3 credits)

596. Analysis I
Prerequisite: Math 451. (3 credits; 2 hours credit for those with credit for Math 555)

597. Analysis II
Prerequisites: Math 451, Math 513. I (3 credits)

602. Real Analysis II
Prerequisites: Math 590, Math 597. II (3 credits)

604. Complex Analysis II
Prerequisite: Math 596. I (3 credits)

607. Theory of Distributions
Prerequisite: Math 597. (3 credits)

625(Stat 625). Probability and Random Processes I
Prerequisite: Math 597. II (3 credits)

626(Stat 626). Probability and Random Processes II
Prerequisite: Math 625. I (3 credits)

651. Topics in Applied Mathematics I
Prerequisites: Math 451, Math 555, and one other 500 level course in analysis or differential equations. I (3 credits)

652. Topics in Applied Mathematics II
Prerequisites: Math 451, Math 555, and one other 500 level course in analysis or differential equations. (3 credits)

656. Introduction to Partial Differential Equations
Prerequisites: Math 558, Math 596, and Math 597 or permission of instructor. (3 credits)

657. Nonlinear Partial Differential Equations
Prerequisite: Math 656 or permission of instructor.

660(IOE 610). Linear Programming II
Prerequisite: Math 561(IOE 510). II (3 credits)

663(IOE 611). Non-linear Programming I
Prerequisite: Math 561(IOE 510). I (3 credits)

664. Combinatorial Theory I
Prerequisite: Math 512. I (3 credits)

665. Combinatorial Theory II
Prerequisite: Math 664 or equivalent. II (3 credits)

669. Topics in Combinatorial Theory
Prerequisite: Math 565 or Math 566 or permission of instructor. (3 credits)

671. Analysis of Numerical Methods I
Prerequisites: Math 571, Math 572, or permission of instructor. (3 credits)

Mechanical Engineering and Applied Mechanics **(Division 280)**

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Leland J. Quackenbush, M.S.E. (M.E.)
Leonard Segel, M.S.
Hadley J. Smith, Ph.D.
Chia-Shun Yih, Ph.D.,
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Adjunct Professor

Thomas D. Gillespie, Ph.D.

Associate Professor

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Gregory M. Hulbert, Ph.D.
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Noel Perkins, Ph.D.
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Joint Research Scientist

Robert D. Ervin, M.S.

Associate Research Scientist

Johann Borenstein, D.Sc.
Zheng-Dong Ma, Ph.D.

Assistant Research Scientist

Dariusz Ceglarek
Zoren Filipi
Nestor F. Michelena, Ph.D.
Xin Wu, Ph.D.
Jingxia Yuan, Ph.D.

See page 225 for statement on Course Equivalence.

101. Introduction to Computer Aided Design
Not open to Mechanical Engineering students. I, II (2 credits)
High end engineering computer workstations and CAD software with 3-D wireframe, surfacing and solids. Use of such computers and software to generate the necessary geometry and engineering data for the analysis/design/manufacturing process.

211. Introduction to Solid Mechanics
Prerequisites: 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.

235. Thermodynamics I
Prerequisites: Chem 130, Chem 125, or Chem 210, Chem 211, and Math 116. I, II, IIIa (3 credits)

Basic course in engineering thermodynamics. First law, second law, system and control volume analyses; properties and behavior of pure substances, ideal gases and mixtures; application to thermodynamic systems.

240. Introduction to Dynamics
Prerequisites: Physics 140, preceded or accompanied by Math 216. I, II (3 credits)

Vector description of force, position, velocity and acceleration in fixed and moving reference frames. Kinetics of particles, assemblies of particles and of rigid bodies, energy and momentum concepts. Euler's equations. Moment of inertia properties. The simple oscillator and its applications. Three lecture-recitation classes per week.

250. Introduction to Design and Manufacturing
Prerequisites: Math 116, Eng 103. I, II (4 credits)

Basics of mechanical design: visual thinking, engineering drawing, and machine anatomy. Basics of manufacturing: processes, materials, and thermo-fluid 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.

281. Mechanical Behavior of Engineering Materials
Prerequisites: MSE 250, ME 211. I, II (3 credits)

Fundamentals of the mechanical behavior of metals, polymers, ceramics and composites. The relationship between microstructure and mechanical behavior at ambient and elevated temperatures. Strength, fatigue, creep and viscoelastic behavior of engineering materials.

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.

311. Strength of Materials

Prerequisites: ME 211, Math 216. I, II, IIIa (3 credits)

Energy methods; buckling of columns, including approximate methods; bending of beams of unsymmetrical 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.

320. Fluid Mechanics I

Prerequisites: ME 235, ME 240. I, II (3 credits)

Control volume analysis; continuity, momentum, angular momentum, and energy equation. Dimensional analysis and similitude. Introduction to differential analysis; kinematics; fluid statics; inviscid flow; potential flow; simple viscous incompressible flow; lift and drag. Steady one-dimensional compressible flow.

336. Thermodynamics II

Prerequisite: ME 235. 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.

350. Mechanical Design I

Prerequisites: ME 211, ME 281. I, II (4 credits)

Principles of mechanical design; synthesis and selection of machine components. Design project. Three hours lecture and one hour discussion.

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.

370. Heat Transfer

Prerequisite: ME 320. I, II, IIIa (3 credits)

Mechanisms of heat transfer. Steady and transient conduction in solids; approximate and exact solution procedure. Convection processes; laminar and turbulent dimensional analysis. Heat exchanger design and performance. Thermal radiation.

381. Manufacturing Processes

Prerequisite: ME 281. I, II (3 credits)

Modeling and quantitative analysis of the processes used to manufacture mechanical systems; process costs and limits, influence of processes on the final mechanical properties of the product. Two recitations and one two-hour laboratory.

395. Thermal-Fluid Science Laboratory

Prerequisites: ME 320, preceded or accompanied by ME 370. I, II (3 credits)

Principles and experimental techniques in thermal fluid sciences are explored in lectures and experiments. Basic topics include measurements of fundamental quantities and error sources as applied to devices involving thermodynamics, fluid mechanics and heat transfer. Midterm and final projects are required and include design aspects of thermal systems. One lecture and one three-hour laboratory per week.

396. Mechanical Science Laboratory

Prerequisites: ME 211, ME 281, ME 360. I, II (3 credits)

Principles and experimental techniques in mechanical sciences are explored in lectures and experiments. Basic topics include: measurements of fundamental quantities and error sources as applied to solid mechanics, strength of materials, dynamics and controls. One lecture and one three-hour laboratory per week.

400. Mechanical Engineering Analysis

Prerequisites: 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.

401(AM 401)(Mfg 402). 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.

402(AM 402). Experimental Stress Analysis

Prerequisites: ME 211, Math 216. I (3 credits)

Review of plane stress-strain relationships; fundamentals of photoelastic methods of stress determination using transmission polariscope and methods of separating principal stresses; theory and application of brittle coatings; fundamental of Moire fringe method of strain analysis; techniques of mechanical, optical, and electric resistance strain gages and related circuitry. Lectures and laboratory experiments.

404(AM 404). Coherent Optical Measurement Techniques

Prerequisite: senior or graduate standing. II (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.

412(AM 412). Advanced Strength of Materials

Prerequisite: ME 311. I (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.

419(AM 419). Mechanics of Composite Materials

Prerequisites: ME 211, ME 240. II (3 credits)

Classification and characterization of composite materials. Behavior in the elastic range. Stress-strain relations for anisotropic media. Orthotropic laminae. Plane problems, theory of anisotropic plates. Bending, buckling and vibrations of laminated plates.

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.

424(EECS 415). Engineering Acoustics

Prerequisites: Math 216, Physics 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.

432. Combustion

Prerequisites: ME 336, preceded or accompanied by ME 370. I (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.

435. Design of Thermai-Fluid Systems

Prerequisites: ME 336, ME 370. II (3 credits)

System design concepts, models and simulation; optimization; mathematical techniques; economic considerations. Applications to various thermal-fluid systems. Design term projects.

436. Direct Energy Conversion

Prerequisite: ME 336. I (3 credits)

Thermodynamic and operational analysis of direct energy conversion devices. Topics include fuel cells, thermoelectric generators and coolers, thermionic, photovoltaic, and magneto hydrodynamic converters; demonstration of selected devices.

437. Applied Energy Conversion

Prerequisite: ME 336. 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 conversion of natural energy sources to electricity, treating both the technical and economic aspects of fossil, nuclear, solar, and geothermal power production.

438. Internal Combustion Engines

Prerequisite: ME 336. 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.

441(AM 441). Intermediate Vibrations

Prerequisite: ME 240. I, II, IIIa (3 credits)

Transient and forced single-degree-of-freedom linear vibrations: support motion, rotating unbalance, vibration isolation. Linear multiple-degree-of-freedom systems, analysis by matrix and approximate methods. Lagrange formulation. Continuous systems, modal summation.

442(AM 442). Analysis and Synthesis of Motion

Prerequisite: ME 240. II (3 credits)

Particle and rigid body kinematics in 3-D rotating reference frames. Algebraic and graphical analysis and synthesis of planar mechanisms. Coordinate translations and rotations, homogeneous displacement matrices. Solution of direct kinematics problem. Euler and Rodrigues parameters. Solution of indirect kinematics problem. Computer projects. Applications to robotics.

443(AM 443). Intermediate Dynamics

Prerequisite: ME 240. I, II (3 credits)

Vector kinematics in 3-D, rotating coordinate systems. Systems of particles. Rigid body inertial properties. Rigid body dynamics: Euler equations, direct and inverse dynamic problems, bearing reactions, tops and gyroscopes.

450. Mechanical Design II

Prerequisites: ME 350, ME 360. I, II, IIIa (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 lectures and two laboratories.

451(Mfg 453). Properties of Advanced Materials for Design Engineers

Prerequisite: ME 281. 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.

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.

454(Mfg 454). Computer Aided Mechanical Design

Prerequisites: Eng 103, 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.

456(AM 456)(BiomedE 456). Biomechanics

Prerequisites: ME 211, ME 240. II (3 credits)

Definition of biological tissue behaviors, including elastic, viscoelastic and plastic properties, with emphasis on bone; dynamics of gait; impact and tolerance criteria in vehicle design for human safety; prosthetic and orthotic mechanics and design.

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.

461. Automatic Control

Prerequisite: ME 360. I, II (4 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. Three one-hour lectures and one three-hour laboratory per week.

463(EECS 463)(Mfg 464). Modern Control Systems Design

Prerequisite: EECS 460 or ME 461 or Aero 471. I, II (4 credits)

The class is organized into teams of four to five students. Each team must select, plan and complete a design project within the general theme of automatic control systems.

The project accounts for approximately 75% of the course grade. Lectures will cover state space analysis techniques, system ID basics and state space feedback design methods.

467(EECS 467)(Mfg 467). Robotics: Theory, Design, and Application

Prerequisites: ME 360 or EECS 360 and senior standing. I, II (3 credits)

Basic concepts underlying the design and application of computer-controlled manipulators: Manipulator geometry, work volume, sensors, feedback control of manipulator linkages, kinematics, trajectory planning, programming, robot system architecture, design and application. Lab experiments cover kinematics, dynamics, trajectory planning, control of manipulators and motion by fixed robots and mobile robots.

471. Computational Heat Transfer

Prerequisite: ME 370. I, 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.

476(BiomedE 476). Thermal-Fluid Sciences in Bioengineering

I (3 credits)

Dynamics, measurements and simulation of vascular pressure and flow in health and disease, microcirculation, design of prosthetic flow-regulation devices, cellular energetics and body metabolism, thermal modeling and measurements, cell hyperthermia and hypothermia, design of blood heat exchangers thermal probes, cryoprobes, prosthetic mass transfer devices, medical visualization and medical image processing.

482(Mfg 492). 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 lecture and one two-hour laboratory.

487(Mfg 488). Welding

Prerequisite: ME 281. 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 apabilities of the various processes.

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.*

491. Independent Study

Prerequisites: ME 490, permission of instructor. I, II, III, IIIa, IIIb (1-3 credits) P/F only.

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.*

499. Special Topics in Mechanical Engineering

Prerequisite: permission of instructor. I, II, IIIa, IIIb (to be arranged)

Selected topics pertinent to mechanical engineering.

501(AM 501). Analytical Methods in Mechanics

Prerequisites: ME 211, ME 240, Math 216. I, 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.

502(AM 502). Methods of Differential Equations in Mechanics

Prerequisite: Math 454. II (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.

503(AM 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.

504(AM 504). Principles and Applications of Variational Methods

Prerequisite: ME 443(AM 443). 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.

505(AM 505). Finite Element Methods in Mechanical Engineering and Applied Mechanics

Prerequisites: ME 501(AM 501), ME 311 , ME 320, or ME 370. 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.

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 and radiation heat transfer, and fluid and solid mechanics.

508. Law for Engineers

Prerequisite: senior or graduate standing. I (3 credits)

Provide engineering students and professionals with some background in areas of law that affect engineering practice such as contracts, product liability, government regulation, and intellectual property. Case law of engineering relevance will be used throughout the course.

511(AM 511). Theory of Solid Continua

Prerequisites: 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.

512(AM 512). Theory of Elasticity

Prerequisites: ME 412(AM 412), ME 511(AM 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.

514(AM 514). Nonlinear Fracture Mechanics

Prerequisite: ME 412(AM 412). II (3 credits)

Elements of solid mechanics, historical development of fracture mechanics, energy release rate of cracked solids, linear elastic fracture mechanics, elastic-plastic fracture mechanics.

515(AM 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.

517(AM 517)(MacroSE 517). Theory of Linear Viscoelasticity I

Prerequisite: AM 511(ME 511) or permission of instructor. II (3 credits)

Constitutive equation for linear isothermal viscoelastic response; constant stress or strain rate response; sinusoidal oscillations and the complex modulus, bending and torsion; three-dimensional response; correspondence theorem and boundary value problems for elastic and viscoelastic response; Laplace transform and numerical solution methods.

519(AM 519). Theory of Plasticity I

Prerequisite: ME 511(AM 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.

520(AM 520). Advanced Fluid Mechanics I

Prerequisite: ME 320. I, II (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.

521(AM 521). Advanced Fluid Mechanics II

Prerequisite: ME 520(AM 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.

523(Aero 523)(AM 523). Computational Fluid Dynamics I

Prerequisite: preceded or accompanied by Aero 520 or ME 520(AM 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.

524. Advanced Engineering Acoustics

Prerequisite: ME 424(EECS 415). I (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.

527(AM 527). Multiphase Flow

Prerequisite: ME 520(AM 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.

532. 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.

534. 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.

535. Thermodynamics III

Prerequisite: ME 336. I (3 credits)

Definitions and scope of thermodynamics; first and second laws. Maxwell's relations. Capeyron relation, equation of state, thermodynamics of chemical reactions, availability.

541(AM 541). Mechanical Vibrations

Prerequisite: ME 441(AM 441). I (3 credits)

Time and frequency domain mathematical techniques for linear system vibrations. Equations of motion of discrete nonconservative 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.

543(AM 543). Analytical and Computational Dynamics I

Prerequisite: ME 443(AM 443). 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.

551(CS 588)(EECS 588)(IOE 578)(Mfg 588). Geometric Modeling

Prerequisite: EECS 487(IOE 478) or ME 454 or permission of instructor. II (3 credits)

Individual or group study of topics in geometric modeling and computer graphics. Geometric data structures for curves, surfaces, and volume parameterization, and topological data structures for vertices, edges, faces and bodies. Algorithms for set operations, Euler operations and deformations. Design and experimentation with geometric modeling facilities.

553(Mfg 553). Management of Product and Manufacturing System Design

Prerequisite: ME 450 or equivalent. I (3 credits)

Meets with ME 450, plus additional hour. Topics include theory of concurrent engineering; manufacturing system organization; leadership; basic marketing and finance; the use of engineering models to organize complex design tasks. ME students normally manage large ME 450 teams, while non-MEs provide staff expertise in a semester-long project.

554(IOE 564)(Mfg 554). Computer Aided Design Methods

Prerequisite: ME 454 or ME 501(AM 501) or IOE 373. 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.

555(Mfg 555). Engineering Design Optimization

Prerequisite: graduate standing. II (3 credits)

Mathematical modeling of engineering design problems for optimization. Boundedness and monotonicity analysis of models. Differential optimization theory of nonlinear models selected numerical algorithms. Emphasis on the interaction between proper modeling and computation. Students propose a design term project from various disciplines and apply course methodology to optimize designs.

556(Mfg 556). 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.

557(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.

558. Vehicle Dynamics

Prerequisite: ME 441(AM 441) or ME 443(AM 443). I, 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.

560(Mfg 562). 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.

561(Aero 571)(EECS 561). Design of Digital Control Systems

Prerequisites: EECS 460 or Aero 471 or ME 461. I, II (4 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. Computer simulations and laboratory implementation of real-time control systems.

562. Dynamic Behavior of Thermal-Fluid Processes

Prerequisites: ME 320, ME 370. 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.

563(Mfg 561). Time Series Analysis for Manufacturing Systems

Prerequisites: controls course, plus one from Stat 310, Stat 402, or EECS 401. II (3 credits)

Principles for identifying parametric time series models from discrete data and the relationship to autovariance, spectrum, and the Green's function from linear system theory are considered. Theory is developed for application to prediction, characterization, signature analysis, and process identification and control.

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.

567(EECS 567)(Mfg 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.

568. Vehicle Control Systems

Prerequisites: ME 240, ME 461. II (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). Factors considerations such as driver modeling, occupant comfort and driver interfaces. This course can be used as part of the IVHS certificate program.

571. Conduction Heat Transfer

Prerequisite: ME 370. 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.

572. Convection Heat Transfer

Prerequisite: ME 370. 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.

573. Radiative Heat Transfer
Prerequisite: ME 370. 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.

574. Phase Change Dynamics
Prerequisites: ME 336, ME 370. 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.

575. Heat Transfer in Porous Media
Prerequisite: ME 370 or equivalent. I (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.

580(Mfg 580). Rheology and Fracture
Prerequisite: ME 281. 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. Surface stress and energy states, wetting, solid adhesion, friction. Ductile, creep, brittle, and fatigue failure mechanisms.

581(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.

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.

583(Mfg 583). Sensing and Modeling for Manufacturing Control

Prerequisite: ME 461. I (3 credits)

Fundamental concepts in manufacturing with emphasis on welding, machining, and forming. Input and output variables for process control. Characteristics of sensors for feedback in manufacturing. Fiber optics, interferometry, infrared thermal imagery, tactile sensing, force/torque sensing for robots, force dynamometers, acoustic emission. Signal processing. Process modeling for control.

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.

585(Mfg 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.

589(Mfg 589). Failure Analysis Case Studies

Prerequisite: preceded or accompanied by ME 350. II (3 credits)

Detailed case study of a variety of service failures in engineering structures such as vehicles, medical implants, hoisting equipment, machinery, and consumer products such as ladders, mowers, and tools. Procedures for analysis include applications of optical and electron microscopy; load history, dynamics, and stress analysis; indentation hardness analysis; accident investigation and reconstruction techniques; specifications and standards; fracture mechanics. The expert's role in product liability litigation.

590. Study of Research in Selected Mechanical Engineering Topics

Prerequisites: graduate standing; permission of the instructor who will guide the work. 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 his project and give an oral presentation to a panel of

faculty members at the close of the term. Course grade will be reported as "Satisfactory" or "Unsatisfactory."

591. Automotive Engineering Seminar I
Prerequisite: graduate standing. I (1 credit)

A series of invited speakers from industry, academia, and government will present seminars on various aspects of automotive engineering. Speakers will emphasize systems engineering, design and manufacturing, team building practices, business and management issues, and other topics which would broaden the student's perspective. Term paper required.

592. Automotive Engineering Seminar II
Prerequisite: graduate standing. II (1 credit)

A series of invited speakers from industry, academia, and government will present seminars on various aspects of automotive engineering. Speakers will emphasize systems engineering, design and manufacturing, team building practices, business and management issues, and other topics which would broaden the student's perspective. Term paper required.

593. Automotive Engineering Project
Prerequisites: ME 591, ME 592 or permission of instructor. III (4 credits)

Students will carry out a project in interdisciplinary teams, and where possible, in conjunction with an internship held during the summer with an industrial or government sponsor. An MEAM faculty member will follow the progress and serve as an advisor to the project teams.

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 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.

599. Special Topics in Mechanical Engineering
Prerequisite: permission of instructor. I, II, IIIa, IIIb (to be arranged)
Selected topics pertinent to mechanical engineering.

605(AM 605). Advanced Finite Element Methods in Mechanics
Prerequisite: ME 505(AM 505) or CEE 510(NA 512). II (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.

619(AM 619). Theory of Plasticity II

Prerequisite: ME 519(AM 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.

622(AM 622). Inviscid Fluids

Prerequisite: ME 520(AM 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.

623(AM 623). Hydrodynamic Stability

Prerequisite: ME 520(AM 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.

624(AM 624). Turbulent Flow

Prerequisite: ME 520(AM 520). I (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.

625(AM 625). Nonhomogeneous Fluids

Prerequisite: ME 520(AM 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.

626(AM 626). Perturbation Methods for Fluids

Prerequisite: ME 520(AM 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.

627(AM 627)(NA 627). Wave Motion in Fluids

Prerequisite: ME 520(AM 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.

631. Statistical Thermodynamics

Prerequisite: ME 235 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.

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 thermodynamics of irreversible processes with applications to heat and mass transfer, relaxation phenomena and chemical reactions.

641(AM 641). Advanced Vibrations of Structures

Prerequisite: ME 541(AM 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.

643(AM 643). Analytical and Computational Dynamics II

Prerequisite: ME 543(AM 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.

645(AM 645). Wave Propagation in Elastic Solids

Prerequisite: ME 541(AM 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.

648(AM 648). Nonlinear Oscillations and Stability of Mechanical Systems

Prerequisite: ME 541(AM 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.

649(Aero 615)(AM 649)(CEE 615). Random Vibrations

Prerequisite: CEE 513 or ME 541(AM 541) or Aero 543. II (3 credits)

Accelerated coverage of elements of probability theory. Characterization of random processes and fields. Correlation and spectral density functions. Response of linear discrete and continuous systems to random excitation. Introduction to problems involving random systems. Maxima and minima of random processes. Applications to problems of engineering interest.

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.

662(Aero 672)(EECS 662). Advanced Nonlinear Control

Prerequisite: EECS 562 or MEAM 548 or permission of instructor. 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.

663. Estimation of Stochastic Signals and Systems

Prerequisite: ME 563 or IOE 565 or equivalent. I (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.

672. Turbulent Transport of Momentum, Heat and Mass

Prerequisite: ME 572. 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.

695. Master's Thesis Research

Prerequisite: ME 595. 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.

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.

790(AM 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 requested 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.

990. Dissertation/Pre-Candidate

I, II, III (1-8 credits); IIIa, IIIb (1-4 credits)

Election for 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.

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 doctoral student who has been admitted to status as a candidate. 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

(Division 284)

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Klaus-Peter Beier, Dr. Ing.
Thomas Lamb, M.B.A., P.E.
Richard C. Moore, M.S.E.

Adjunct Assistant Professor
Zissimos P. Mourelatos,
   Ph.D.

Adjunct Lecturer
Randel H. Visintainer, M.S.E.

Adjunct Associate Research Scientist
David R. Lyzenga, Ph.D.

Assistant Research Scientist
Stuart B. Cohen, Ph.D.

102(NS 201). Introduction to Ship Systems
II (3 credits)
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. Not open for credit to students in Naval Architecture and Marine Engineering.

270. Marine Design

Prerequisite: none. I, II (3 credits)

Overview of world trade, shipping, and shipbuilding, with particular attention to U.S. position. Ship and marine system design process. Weight, buoyancy, stability, powering, and engineering economics. Each student designs an offshore vessel to satisfy performance specifications. Hull lines are created and faired.

275. Marine Systems Manufacturing

Prerequisite: preceded by or taken concurrently with NA 270. II (3 credits)

Overview of marine vehicle and marine production processes and systems; shipyard arrangements and organizations affecting ship production; breakdown of ship designs for production; product standardization and work simplification systems; design integration supporting production; example work package instructions are prepared.

310. Marine Structures I

Prerequisite: ME 211. I (4 credits)

Quasi-static analysis of ship hulls and offshore structures. Hull primary response. Introduction to probabilistic approach. Plated structures and ship structural components. Combined stresses and failure theories. Framing systems. Brittle fracture and fatigue failure modes; structural details. Midship section synthesis, classification society rules, stress superposition. Material and fabrication considerations.

320. Marine Hydrodynamics I

Prerequisites: NA 270, ME 211, preceded or accompanied by ME 240. I (4 credits)

Fluid fundamentals applied to marine problems. Hydrostatics with moments and forces by pressure integration. Curves of form, static, intact and damage stability of ships. Fluid dynamics using control volume analysis, continuity, moment, Bernoulli and energy equations. Laminar and turbulent flow. Dimensional analysis, similitude and ship model extrapolation. Pipe flow.

321. Marine Hydrodynamics II

Prerequisite: NA 320, preceded or accompanied by MA 350. II (4 credits)

Viscous fluid theory applied to ships. Ideal fluid theory. Water waves. Ship resistance components: skin friction, separation, form drag, wave resistance. Resistance prediction from standard series. Two-dimensional and three-dimensional airfoil theory. Propeller geometry and design. Hull-propeller interaction, propeller charts, powering prediction.

330. Marine Power Systems I

Prerequisites: ME 235, preceded or accompanied by NA 320. I (4 credits)

Diesel engines, steam turbines, and gas turbines as marine prime movers. Ratings, matching to loads. Electrical and mechanical transmission of power to marine loads. Energy conservation by means of bottoming cycles. Principles of fluid system design. Characteristics of electrical generators, motors, and distribution systems.

340. Marine Dynamics I

Prerequisites: NA 320, preceded or accompanied by NA 321. II (4 credits)

Structural vibration, one and multi-degree of freedom models. Forced steady-state response. Fourier Series. Propeller excitation. Rigid body motions of floating structures. Sea wave excitation. Hydrodynamic added mass and damping. Vibration absorbers; anti-roll tanks. Ship maneuvering; controls fixed stability and turning circle radius.

391. Marine Engineering Laboratory

Prerequisites: concurrent or previous enrollment in NA 310, NA 321, NA 330, NA 340. II (3 credits)

Instruction in laboratory techniques and instrumentation. Use of computers in data analysis. Technical report writing. Investigation of fluid concepts, hydro-elasticity, marine dynamics, wave mechanics, ship hydrodynamics, and extrapolation of model test to full scale.

401. Small Craft Design

Prerequisite: preceded or accompanied by NA 321. II (3 credits)

Design of planing craft, hydrofoils, and other small high performance craft.

403. Sailing Craft Design Principles

Prerequisite: preceded or accompanied by NA 321. I (3 credits)

Application of hydrodynamic and aerodynamic principles to the design of sailing craft.

410. Marine Structures II

Prerequisites: NA 310, preceded or accompanied by NA 340. I (3 credits)

Equilibrium methods, energy methods and matrix methods are applied to problems in linear elastic beam theory. Solutions for classic beam problems include static bending, torsion, buckling, and vibration. Modeling and analysis techniques for ship and marine structural design are reviewed. Introduction to finite element analysis.

411(Aero 411)(CEE 411). Finite Element Applications

Prerequisites: Eng 103, ME 211. I, II, IIIa (3 credits)

The application of user-oriented finite element computer programs for solving practical structural mechanics problems of frames, 2-D and 3-D solids, plates, shells, etc., and displaying the solutions graphically. Students learn to prepare input data and interpret results. A short introduction to the underlying theory is also presented.

421. Ship Model Testing

Prerequisites: 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.

425(AOSS 425). Environmental Ocean Dynamics

Prerequisite: NA 321 or CEE 325 or AOSS 305 or permission of instructor.
I (4 credits)

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

430. Marine Power Systems II

Prerequisite: NA 330. II (3 credits)

Alignment analyses of marine propulsion systems. Power and speed interactions among engines, propellers, and hulls. Characteristics of electrical generators, motors, and distribution systems, with emphasis on marine ship-service and propulsion systems. Propulsion shaft torsional vibration analysis, with emphasis on application to reciprocating propulsion engines.

440. Marine Dynamics II

Prerequisites: NA 340, Math 350. II (3 credits)

Wave spectra formulations, determination of ship motions and loads in a seaway. Linearized equations of motion for a ship in six degrees of freedom. Damping. Analytical treatment of added mass, introduction to strip theory. Hull surface forces and vibratory response.

455. Environmental Nearshore Dynamics

Prerequisite: NA 425 or AOSS 425. II (3 credits)

Fundamentals of current and shallow water wave motions are investigated in terms of nearshore processes including water waves (generation, propagation, refraction and breaking); tides and long-term sea level changes; longshore current generation and prediction of sediment and pollutant transport. Beach response to these processes is examined. Environmentally conscious coastal design is emphasized.

460(Mfg 460). Ship Production Planning and Control

Prerequisites: NA 275, preceded or accompanied by NA 470. I (3 credits)

Overview of ship production systems; shipyard organization and arrangement; product standardization and work simplification systems; performance measurement; use of models and composites; PERT/CPM and other control techniques; the design and use of Information Systems for Production Control.

469(AOSS 469). Underwater Operations

Prerequisite: permission of instructor. II (3 credits)

Survey of manned undersea activities in oceanography and ocean engineering. The tools of underwater operations: decompression chambers, habitats, submarines, diving apparatus; pertinent design criteria and applications as based on human hyperbaric physiology and performance. Topics in research diving for engineering and oceanographic studies.

470. Ship Design

*Prerequisites: NA 321, NA 330, preceded or accompanied by NA 481. Only one of
NA 470 and NA 471 may be taken for credit. I, II (3 credits)*

Preliminary design methods for sizing and form, powering, maneuvering, sea-keeping,
arrangements, and safety of ships. Computer-aided design computations and validation.
Given the owner's general requirements, the student creates the conceptual/preliminary
design for a displacement ship.

471. Offshore Engineering Design

*Prerequisites: NA 321, NA 330, preceded or accompanied by NA 481. Only one of NA
470 and NA 471 may be taken for credit. II (3 credits)*

Preliminary design methods for sizing and form, transport, mooring, seakeeping,
arrangements, and safety of offshore projects. Computer-aided design computations
and validation. Given the owner's general requirements, the student creates the
conceptual/preliminary design for a semisubmersible, tension-leg platform or
similar offshore engineering project.

475. Design Project

Prerequisite: NA 470 or NA 471. I, II, IIIa (3 credits)

Teams of several students conceive and complete a marine design project—most often
a ship, yacht or offshore system. Oral presentation and written report required.

477(Eng 477). Principles of Virtual Reality

Prerequisite: senior standing or permission of instructor. I (3 credits)

Enabling technologies (display systems, motion trackers, datagloves, haptic and
acoustic devices), application categories, human factors and perception, computer
graphics and geometric modeling principles, creation and evaluation of virtual environ-
ments, existing tools, VR specific algorithms. Interdisciplinary group projects will
develop VR applications using the facilities in the Media Union.

481. Probabilistic Methods in Marine Systems

Prerequisites: Math 350, preceded or accompanied by NA 340. I (3 credits)

Basic concepts of probability and statistics. Random processes, Fourier transforms and
series, and spectral analysis. Marine linear systems and several formulations of ocean
wave spectra for fully-arisen, fetch- and duration-limited, and design-seas. Prediction
of sea surface amplitude, period, and maxima.

490. Directed Study, Research and Special Problems

Prerequisites: 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.

510. Marine Structural Mechanics
Prerequisite: NA 310 or CEE 312 or ME 311 or Aero 314. II (4 credits)
Von Karman plate equations. Strip-beam and plate solutions with geometric and material non-linearities. Application to ship and platform analysis in damage condition. The flange tripping non-linearity. Elastic and plastic analysis of flat plates. Effects of aspect ratio. Ship main-deck buckling example.

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.

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.

518. Strength Reliability of Ship and Offshore Structures
Prerequisites: 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.

520. Intermediate Marine Hydrodynamics
Prerequisite: NA 321 or CEE 325 or ME 320 or Aero 420. I (4 credits)
Fundamentals of marine hydrodynamics. Kinematics, conservation principles, free-surface and body boundary conditions. Navier-Stokes equations, inviscid flow, Bernoulli equation, potential flow and applications. Linear water waves, wave forces on bodies, free-surface Green functions. Laminar boundary layers, introduction to turbulence. Introduction to non-linear waves.

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.

522. Experimental Marine Engineering
Prerequisites: 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.

528. Remote Sensing of Ocean Dynamics

Prerequisite: NA 425(AOSS 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.

531. Marine Vibrations

Prerequisite: NA 540. II (4 credits)

Vibration of marine structures and propulsion systems. Excitation from marine diesel engines and propellers. Propeller design to minimize excitation. Fluid-structure interaction including bearings. Applications to hulls, deck houses, marine engines, and torsional, axial, and lateral vibration of shafting systems. Structural reliability treatment of marine shafting systems. Extensive computer usage.

532. Acoustics and Noise Control

Prerequisite: NA 340 or ME 441. I (3 credits)

The human perception of sound and vibrations. Plane and spherical wave equation derivations. Interior acoustics. Diesel engine noise sources. Noise control techniques including materials and isolation systems.

540. Marine Dynamical Systems

Prerequisite: NA 340 or ME 441. I (4 credits)

Fundamental analysis of marine dynamical systems. Mathematical determination of hydrodynamic coefficients, linear frequency and time-domain seakeeping, second order gravity wave forces, and statistical representation of excitation. Normal mode analysis, matrix methods, and non-linear stability and bifurcation theory applied to vessel capsizing, bi-linear stiff moored systems, propeller-induced vibrations, and ship maneuvering. Extensive computer usage.

550(AOSS 550). Offshore Engineering Analysis II

Prerequisites: NA 425. 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.

562(Mfg 563). Concurrent Marine Design

Prerequisite: NA 460. II (3 credits)

Emphasis on explicit product and process definition. Includes view of product components as systems, parts, assemblies, etc., tied to particular processes. IDEFO

methodology for process description. Data and process integration through 3-D computer product modeling concepts. Trade-off and risk production analysis considers accuracy, scheduling, costs, through-put, etc.

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.

574(Mfg 574). Computer-Aided Hull Design and Production
Prerequisite: graduate standing or permission. I (3 credits)
Hull surface representation, creation, distortion, fairing. Computer-aided arrangement, piping, structures. Computer systems for structural detailing, production, manufacturing.

575(Mfg 575). Computer-Aided Marine Design Project
Prerequisite: NA 574. I, II, IIIa, IIIb (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.

578. Concurrent Marine Design Seminar
Prerequisite: none. I, II (1 credit)
Integrating seminar for Master's of Engineering. Concurrent Marine Design degree program. Emphasis on team building, relevant research activity, presentations from industry, definition of and preparation for team projects.

579. Concurrent Marine Design Team Project
Prerequisite: NA 578. III (4 credits)
Industrial related team project for Master's of Engineering. Concurrent Marine Design degree program. Student teams will conduct concurrent design project for and in conjunction with industrial or government customer.

582. Reliability and Safety of Marine Systems
Prerequisite: EECS 401 or Math 425 or Stat 412. IIIa (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.

585. Optimization and Management of Marine Systems
Prerequisite: NA 481 or equivalent. II (3 credits)
Optimization methods (linear, integer, nonlinear, sequential), concepts and applications in the design, production, and operations of marine systems. Elements of maritime management: risk and utility theory; fleet deployment optimization; rate formation in liner conferences; Maritime policy.

586. Shipbuilding and Shipping Markets and Forecasting

Prerequisite: NA 481 or equivalent. I (3 credits)

Elements of maritime management: International Trade and Shipping. Maritime policy and law. Forecasting methods concepts and applications to strategic planning shipyard decisions. Economics of merchant shipbuilding and ship scrapping. Maritime forecasting and its problems: market research; case studies (tankers, containerships).

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.

592. Master's Thesis

(3 credits)

615. Ship Structure Analysis

Prerequisites: NA 510, prior arrangement with instructor. (to be arranged)

Advances in specific areas of ship structure analysis as revealed by recent research. Lectures, discussions, and assigned readings.

622. Real Flows of Marine Hydrodynamics

Prerequisite: NA 520. I (3 credits)

Review of the basic equations: Stokes equations, Helmholtz vorticity equation, Biot-Savart law. Boundary layer theory, stability considerations. Simple models for turbulence: eddy viscosity and mixing length theories. The integro-differential velocity-vorticity formulation. Degeneration to the Green's theorem formulation of ideal flows at infinite Reynolds number; some approximate solutions.

623. Boundary Layer Theory

Prerequisite: NA 520 or ME 520. II (3 credits)

Thin-shear-layer equations applied to boundary layers and wakes. Exact solutions, approximate solution techniques and separation for laminar flow. Unsteady boundary layers. Free-surface effects, wave-boundary layer interaction. Linear stability, transition, turbulent flow. Integral methods, turbulence closure models, numerical simulation. Three-dimensional and axisymmetric wakes and boundary layers.

624. Marine Propulsors

Prerequisites: NA 425, NA 520, graduate standing. II (3 credits)

Propeller series, momentum analysis, geometry, hull/propeller interaction. Lifting line and lifting surface theory. Operation in non-uniform flow. Propeller noise. Compound propulsors: tandem, contra-rotating, preswirl, ducted.

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.

627(AM 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.

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.

650. Dynamics of Offshore Facilities

Prerequisites: 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.

655. Special Topics in Offshore Engineering

Prerequisites: 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.

685. Special Topics in Marine Systems

Prerequisite: permission of instructor. I, II (to be arranged)

Advances in specific areas of marine systems engineering as revealed by recent research. Lectures, discussions, and assigned readings.

792. Professional Degree Thesis

I, II, III (2-8 credits); IIIa, IIIb (1-6 credits)

990. Dissertation/Pre-Candidate

I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)

Election for 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.

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 doctoral student who has been admitted to status as a candidate. 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 (Division 288)

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Michael Atzmon, Ph.D.
Mary L. Brake, Ph.D.
James P. Holloway, Ph.D.
David K. Wehe, Ph.D.

See page 225 for statement on Course Equivalence.

100. Radiation and the Environment

Prerequisite: none. I, II (2 credits)

Sources of natural and human-made radiation (including radioactivity and electromagnetic radiation) and its effect on the environment. The course will include examples of applications of radiation such as nuclear power, nuclear medicine, food irradiation, radon, and electronmagnetic fields. Discussions of societal issues concerning radiation. Class participation in demonstrations.

211. Introduction to Nuclear Engineering and Radiological Sciences

Prerequisite: preceded or accompanied by Math 216. II (3 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.

311. Elements of Nuclear Engineering I

Prerequisites: Physics 240, preceded or accompanied by Math 450. I (3 credits)

Properties and structure of nuclear atom, special relativity, interaction of charged particles with matter, introduction to quantum mechanics and statistical physics. Engineering applications of radiation.

312. Elements of Nuclear Engineering II

Prerequisite: NERS 311. II (3 credits)

Properties and structure of nuclei; radioactivity and alpha-, beta-, and gamma-decay. Nuclear reactions including fission and fusion. One-speed neutron diffusion; criticality constant for an infinite reactor. Engineering applications of radiation.

315. Nuclear Instrumentation Laboratory

Prerequisite: 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.

400. Elements of Nuclear Energy

Prerequisite: junior standing. I, II (3 credits)

Ideas and concepts important to the development of nuclear energy for peaceful purposes — designed for those in fields other than nuclear engineering. Principal emphasis upon fission reactors and fusion reactor research. History of the nuclear energy program, elementary nuclear physics, radiologic health physics, and nuclear medicine.

421. Nuclear Engineering Materials

Prerequisite: NERS 312. I (3 credits)

An introduction to materials for nuclear fuels, nuclear reactors, and nuclear radiation detection, including radiation effects in these materials due to neutrons, charged particles, and gamma radiation.

425. Applied Nuclear Radiation

Prerequisite: NERS 315. I (4 credits)

Nuclear methods for materials analysis, including activation analysis, neutron diffraction and neutron radiography, tracer methods, ion beam analysis, Mössbauer spectroscopy. Lectures and laboratory.

441. Introduction to Nuclear Fission Reactors
Prerequisites: NERS 312, Math 450. I (4 credits)

An introduction to the theory of nuclear fission reactors including such topics as neutron diffusion, the one-speed theory of nuclear reactors, reactor kinetics, multi-group diffusion theory and criticality calculations, and neutron slowing down and thermalization.

442. Nuclear Power Reactors
Prerequisite: NERS 441. II (3 credits)

Analysis of nuclear fission power systems including an introduction to nuclear reactor design, reactivity control, core thermal-hydraulics and feedback, fuel depletion, nuclear fuel management, environmental impact and plant siting, and nuclear systems analysis.

445. Nuclear Reactor Laboratory
Prerequisites: NERS 315, NERS 441. II, IIIa (4 credits)

Measurements of nuclear reactor performance: activation methods, rod worth, critical loading, power and flux distributions, void and temperature coefficients of reactivity, xenon transient, diffusion length, pulsed neutrons.

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 siting, reactor containment, engineered safeguards, transient behavior and accident analysis for representative reactor types. NRC regulations and procedures. Typical reactor hazards analyses.

471. Introduction to Plasmas
Prerequisite: 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. Analysis of simple laboratory plasmas and devices. Magnetic confinement systems.

472. Fusion Reactor Technology
Prerequisite: NERS 471. II (3 credits)

Study of technological topics relevant to the engineering feasibility of thermonuclear fusion reactors as power sources; including energy and particle balances in fusion reactors; neutronics including tritium breeding and neutron damage; various approaches to plasma fueling and heating; adiabatic compression and reactor ignition; dynamics and control; and special topics including environmental aspects.

480(BiomedE 480). Computational Projects for Engineering Aspects of Radiology and Nuclear Medicine
Prerequisite: preceded or accompanied by NERS 481. II (1 credit)

Computational projects illustrate the principles of radiation imaging from NERS/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. Projects will be 3 to 4 weeks in duration.

481(BiomedE 481). Engineering Aspects of Radiology and Nuclear Medicine

Prerequisite: none. II (2 credits)

Radiation sources, image formation, and visual performance of radiation imaging is covered with an emphasis on statistical processes. Film/screen radiography, digital radiography, computed tomography, Anger camera, and positron emission tomography systems are considered. While emphasis is placed on medical imaging, the imaging concepts covered apply to industrial inspection.

484(BiomedE 484). Radiological Health Engineering Fundamentals

Prerequisite: NERS 312 or equivalent or permission of instructor. I (3 credits)

This course presents quantitative radiation protection design through lectures, problem solving, and group projects. Topics covered include radiation quantities, regulations, external and internal dose estimation, and health effects. Special topics such as non-ionizing radiation, radioactive waste, radon gas, and emergencies will be included dependent upon class interests.

490. Special Topics in Nuclear Engineering I

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.

499. Research in Nuclear Engineering

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.

511. Quantum Mechanics in Neutron-Nuclear Reactions

Prerequisites: 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.

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.

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.

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.

522. Nuclear Fuels

Prerequisite: permission of instructor. II (3 credits)

Nuclear reactor fuels; physical properties, radiation damage, thermal response. Fuel behavior; densification, fission-gas release, swelling, burn-up. Cladding; metallurgy, mechanical properties, corrosion behavior, radiation effects. Fuel design and fabrication, fuel behavior. Fusion reactor fuels.

541. Nuclear Reactor Theory I

Prerequisites: Math 454 or equivalent and NERS 312 or NERS 511 concurrently. I (3 credits)

A graduate level course on the principles of nuclear fission reactors including neutron transport theory, the Pn approximation, multigroup diffusion methods, fast and thermal group constant generation, core lattice analysis. A strong emphasis will be placed on numerical analysis and computer methods.

542. Nuclear Reactor Theory II

Prerequisite: NERS 541. II (3 credits)

A continuation of NERS 541 including neutron resonance absorption and thermalization, perturbation and variational methods, flux synthesis, and numerical methods for solving the neutron transport equation including Sn and Bn methods, collision probabilities, and Monte Carlo methods.

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 and inhour equation; reactor transfer function; physical origin and mathematical description

of feedback. Linear and non-linear stability of reactors, and the derivation of the stability criteria. Lyapunov's theory with reactor applications. Space-dependent reactor kinetics and xenon oscillations, coupled core analysis, introduction to reactor noise analysis.

554. Radiation Shielding

Prerequisite: preceded or accompanied by NERS 441. II (3 credits)

A macroscopic study of the absorption of nuclear radiation in dense material with applications to radiation shielding. Topics considered include radiation sources, permissible radiation levels, gamma-ray attenuation, neutron attenuation, shield optimization, heat generation and removal in shields, and other related problems.

561. Nuclear Core Design and Analysis I

Prerequisite: preceded or accompanied by NERS 542. 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.

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.

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.

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 microinstabilities; BGK mode and nonlinear Landau damping; macroscopic instabilities and their stabilization; non-ideal MHD effects.

575(EECS 519). Plasma Generation and Diagnostics Laboratory

Prerequisite: preceded or accompanied by a course covering electromagnetism.
*   II (3 credits)*

Laboratory techniques for plasma ionization and diagnosis relevant to plasma processing, propulsion, vacuum electronics, lasers, 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.

576. Charged Particle Accelerators and Beams

Prerequisites: 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.

577. Plasma Spectroscopy

Prerequisites: 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.

582(BiomedE 582). Medical Radiological Health Engineering

Prerequisite: NERS 484(BiomedE 484) or permission of instructor. 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.

588. Radiological Health Engineering Practicum

Prerequisite: permission of instructor. 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, staff member, and facility personnel. This course may be repeated for up to 12 credit hours.

589. Radiological Health Engineering Project

Prerequisite: permission of instructor. I, II, III, IIIa, IIIb (1-12 credits)

Group investigations on a topic involving Radiological Health Engineering. Specific topics will be selected upon mutual agreement between students and a staff member, and should be of practical significance to medical, nuclear, or radiation protection industry. This course may be repeated for up to 12 credit hours.

590. Special Topics in Nuclear Engineering 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.

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.

622(Mfg 622)(MSE 622). Ion Beam Modification and Analysis of Materials

*Prerequisites: NERS 421, NERS 521 or MSE 351 or permission of instructor.
I (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.

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.

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.

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.

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.

674(Appl Phys 674). High Intensity Laser-Plasma Interactions

Prerequisites: 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.

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.

990. Dissertation/Pre-Candidate

I, II, III (2-8 credits); IIIa, IIIb (1-4 credits)

Election for dissertation work by doctoral student not yet admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

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 doctoral student who has been admitted to status as a candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

Physics * (Division 444)

Department Office
2071 Randall
(313) 764-4437

*College of Literature, Science, and the Arts
Professor Ctirad Uher, *Chair*

Professors Akerlof, Allen, Axelrod, Becchetti, Berman, Bretz, Bucksbaum, Chapman, Chupp, Clarke, Coffin, Einhorn, Ford, Gidley, Hecht, Hegyi, Janecke, Jones, Kane, Kopelman, Krimm, A. Krisch, Longo, Merlin, Meyer, Neal, Roe, Ross, Sander, Sanders, Savit, Steel, Tarlé, Thun, Tickle, Tomozawa, Uher, Veltman, Ward, Williams, A. Wu, Yao, Zakharov, Zorn; **Associate Professors** Adams, Akhoury, Amidei, Aronson, Campbell, Dierker, Evrard, Freese, Gray, J. Krisch, Nori, Orr, Rand; **Assistant Professors** MacKintosh, McKay, Qian, Riles, Rojo, Schmidt, Stuart; **Instructor** Dershem.

Course descriptions for physics are listed in the Literature, Science, and the Arts Bulletin *and the Horace H. Rackham School of Graduate Studies* Bulletin.

140. General Physics I
Prerequisites: Calculus and Physics 141 to be taken concurrently. I, II, IIIa (4 credits)

141. Elementary Laboratory I
To be taken concurrently with Physics 140. I, II, IIIa (1 credit)

160. Honors Physics I
Prerequisite: Math 115 or equivalent, or permission of instructor. No credit granted to those who have completed or are enrolled in Physics 140. I, II (4 credits)

240. General Physics II
Prerequisites: Physics 140 or equivalent; Physics 241 to be taken concurrently. I, II, IIIa (4 credits)

241. Elementary Laboratory II
To be taken concurrently with Physics 240. I, II, IIIa (1 credit)

242. General Physics III
Prerequisites: Physics 240, Physics 241, or equivalent. I, II (3 credits)

250. Introduction to Quantitative Study of the Environment
Prerequisite: two and one-half years high school math or any college course in math or natural science. II (3 credits)

260. Honors Physics II

Prerequisite: Physics 140 or Math 115, or equivalent, or permission of instructor. No credit granted to those who have completed or are enrolled in Physics 240. I, II (4 credits)

262. Honors Physics III

Prerequisites: Physics 240 or equivalent, concurrent enrollment in Math 216 or equivalent, or permission of instructor. No credit granted to those who have completed or are enrolled in Physics 242. I (4 credits)

288. Physics of Music

II (3 credits)

333. Keller Tutor 140

Prerequisite: permission of instructor. I, II (1-3 credits)

334. Keller Tutor 240

Prerequisite: permission of instructor. I, II (1-3 credits)

401. Intermediate Mechanics

Prerequisites: Physics 126 or Physics 240, Physics 241 and Math 216 or equivalent. I, II (3 credits)

402. Light

Prerequisites: Physics 126 or Physics 240, Physics 241 and Math 216 or equivalent. I (3 credits)

403. Optics Laboratory

Prerequisite: Physics 242 or permission of instructor. I, II (2 credits)

405. Intermediate Electricity and Magnetism

Prerequisites: Physics 126 or Physics 240, Physics 241 and Math 216 or equivalent. I, II (3 credits)

406. Statistical and Thermal Physics

Prerequisites: Physics 126 or Physics 240, Physics 241 and Math 216. I, II (3 credits)

407. Thermodynamics Laboratory

Prerequisites: Physics 126 or Physics 240, and Physics 241. I, II (2 credits)

409. Modern Physics Laboratory

Prerequisite: admission primarily to science majors in the junior year. I, II (2 credits)

411. Introduction to Computational Physics

Prerequisites: Physics 242, Calculus, some knowledge of BASIC, FORTRAN or Pascal. I (3 credits)

413. Physics of Complexities

Prerequisites: Physics 401 or equivalent and familiarity with programming in BASIC.
II (3 credits)

415. Special Problems

Prerequisite: permission of instructor. I, II, III, IIIa, IIIb (arranged)

417. Dynamical Processes in Biophysics

Prerequisites: Math 216, Physics 242, Chem 468 or by permission of instructor.
II (3 credits)

418. Structural Macromolecular Physics

Prerequisites: Math 216, Physics 242 or by permission of instructor. I (3 credits)

419. Energy Demand

(to be arranged)

435. Gravitational Physics

Prerequisites: Physics 242, Physics 401, Physics 405 or equivalent. I (3 credits)

438. Electromagnetic Radiation

Prerequisite: Physics 405. II (3 credits)

451, 452. Methods of Theoretical Physics

Prerequisites: Physics 401, Math 450 or equivalent; Math 451. I; Math 452.
II (3 credits each)

453. Quantum Mechanics

Prerequisites: Physics 242; Physics 401 or Physics 405 recommended. I, II (3 credits)

454. Electronic Acquisition and Processing of Physics Data

Prerequisite: basic knowledge of computer structure helpful. I (3 credits)

455. Electronic Devices and Circuits

Prerequisites: Physics 240, Physics 241. I (5 credits)

457. Nuclear Physics

Prerequisite: Physics 453. II (3 credits)

459. Nuclear Laboratory

Prerequisites: Physics 242 and one 400 level physics laboratory course, or by
permission. I, II (2 credits)

460. Atomic Physics

Prerequisite: Physics 453. II (2 credits)

461. Atomic Laboratory
Prerequisites: Physics 242 and one 400 level physics laboratory course or by permission. I, II (2 credits)

463. Introduction to Solid State Physics
Prerequisite: Physics 453 or permission of instructor. II (3 credits)

464. Solid State Laboratory
Prerequisites: Physics 242, Physics 406: Physics 463 to be taken concurrently or previously, or permission of instructor. I (2 credits)

468. Elementary Particles
Prerequisite: Physics 453, or Physics 453 taken concurrently. I (3 credits)

505, 506. Electricity and Magnetism
Prerequisites: Physics 405, Math 450: Math 505. I (2 credits); Math 506. II (3 credits)

507. Theoretical Mechanics
Prerequisite: an adequate knowledge of differential equations; an introductory course in mechanics is desirable. I (3 credits)

510. Statistical Physics
I (3 credits)

511, 512. Quantum Mechanics I and II
Prerequisite: Physics 453. Physics 511 is a prerequisite for Physics 512; Physics 511. I; Physics 512. II (3 credits each)

513. Advanced Quantum Mechanics
I, II (3 credits)

515, 516. Supervised Research
Prerequisite: permission. I, II (4-6 credits each term)

517. Graduate Physics Laboratory
Prerequisite: graduate standing. I (3 credits)

518. Microcomputers in Experimental Research
Prerequisite: graduate standing. II (3 credits)

519. Group Theory
(to be arranged)

520. Condensed Matter Physics
Prerequisites: Physics 510, Physics 511 or equivalent. II (3 credits)

521. Elementary Particle Physics
Prerequisites: Physics 506, Physics 512, or equivalent. II (3 credits)

522. Atomic Physics
(to be arranged)

523. Advanced Quantum Mechanics II
Prerequisite: relativistic quantum mechanics at the level of Physics 513. II (3 credits)

525. Introductory Topics in Astrophysics
(3 credits)

526. Introductory Topics in Astrophysics II
II (3 credits)

527. Introductory Topics in Astrophysics III
I (3 credits)

529. Techniques of Experimental Physics
(3 credits)

530. Statistical Physics II
(to be arranged)

540. Advanced Condensed Matter
Prerequisite: Physics 520 or equivalent. (3 credits)

541. Particle Physics II
(to be arranged)

542(EECS 638)(Physics 609). Quantum Theory of Light
Prerequisite: quantum mechanics electrodynamics and atom physics. I (even years) (3 credits)

601, 602. Particles and Fields

603, 604. Magnetic Monopoles

605, 606. Applied Group Theory

611(EECS 634). Nonlinear Optics
Prerequisite: EECS 537 or EECS 538 or EECS 530. II (3 credits)

613, 614. Advanced Quantum Theory

615, 616. Advanced Classical Mechanics

617, 618. Physics of Continuous Media

619, 620. Solid State

621, 622. Theory of Fields

623, 624. Advanced Statistical Physics

625, 626. Elementary Particles

627, 628. Experimental High Energy Physics

631, 632. Advanced Mathematical Physics

633, 634. Fluid Dynamics

635, 636. Theory of Relativity

637, 638. Advanced Nuclear Physics

639, 640. Low Temperature Physics

643, 644. Advanced Atomic Physics

650(Appl Phys 550)(EECS 538). Lasers and Electro-Optics I
Prerequisite: EECS 434. I (3 credits)

651(Appl Phys 551)(EECS 539). Lasers and Electro-Optics II
Prerequisite: Physics 650(AP 550)(EECS 538). II (3 credits)

653, 654. Advanced Accelerator Physics

655, 656. Advanced Molecular Physics

665, 666. Contemporary Physics

667, 668. Advanced Astrophysics

670. Fundamentals of Plasma Physics

671. Advanced Electroweak Theory and Constraints on Extensions of the Standard Model

673. Accelerators-Users

674, 675. Medical Physics

715. Special Problems

751. Topics in Macromolecular Science

990. Dissertation/Pre-Candidacy

995. Dissertation/Candidacy
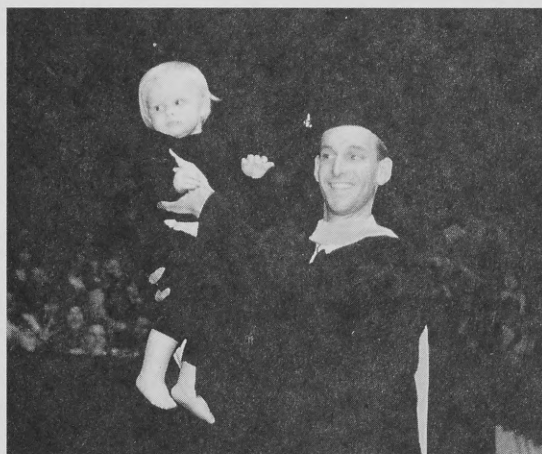
Timothy J. Decker (MSE '93 CivilE, PhD '96 EnvironE) and fifteen-month old daughter Andrea strode eagerly across the stage to accept Daddy's diploma at College of Engineering's 1996 Spring Commencement—well, Daddy strode, Andrea rode.

Statistics* (Division 489)

Department Office
1440 Mason Hall
(313) 763-3519

*College of Literature, Science, and the Arts
Professor Wu, *Chair*

Professors Csorgo, Hill, Howrey, Keener, Muirhead, Nair, Rothman, Woodroofe; **Associate Professors** Faraway and Jeganathan; **Assistant Professors** Hardwick, Kou, Sun, and Wu; **Lecturer** Gunderson; **Adjunct Associate Professor** Aliaga

Course descriptions for statistics are listed in the Literature, Science, and the Arts Bulletin *and the Horace H. Rackham School of Graduate Studies* Bulletin.

100. Introduction to Statistical Reasoning
Prerequisite: none. I, II, IIIa, IIIb (4 credits)

125. Games, Gambling, and Coincidences
Prerequisite: none. I (3 credits)

170. The Art of Scientific Investigation
Prerequisite: none. II (4 credits)

190. The History of Chance
Prerequisite: none. II (3 credits)

301. Introduction to Decision Theory
Prerequisite: none. II (3 credits)

310. Elements of Probability
Prerequisite: taken concurrently with Math 215. I, II (3 credits)

311(IOE 365). Engineering Statistics
Prerequisites: IOE 315 or Stat 310 and Math 215, Eng 103. I, II (4 credits)

402. Introduction to Statistics and Data Analysis
Prerequisite: none. No credit granted to those who have completed or enrolled in Econ 404 or Stat 311, Stat 405 or Stat 412. I, II, IIIa, IIIb (4 credits) (NS)

403. Introduction to Statistics and Data Analysis II
Prerequisite: Stat 402. II (4 credits) (Excl)

404. Problem Solving in Medical Statistics
Prerequisite: enrollment in Inteflex or permission of instructor. I (3 credits) (Excl)

405(Econ 405). Introduction to Statistics

Prerequisite: Math 115 or permission of instructor. Juniors and seniors may elect concurrently with Econ 201 and Econ 202. No credit granted to those who have completed or are enrolled in Stat 311 or Stat 412. Students with credit for Econ 404 can only elect Stat 405 for 2 credits and must have permission of instructor. I, II (4 credits) (Excl)

406. Introduction to Statistical Computing

Prerequisites: Stat 402, Stat 425(Math 425). II (4 credits) (Excl)

407. Data Analysis—A Computer Approach

Prerequisite: Stat 402 or permission. IIIa (2 credits)

412. Introduction to Probability and Statistics

Prerequisites: taken concurrently with Math 215 and either EECS 283 or Eng 103. I, II, IIIa (3 credits)

413. The General Linear Model and Its Applications

Prerequisites: Stat 402, Math 217, co-registration in Stat 425(Math 425) (or concurrent enrollment in Stat 425 (Math 425). Only two credits if student has taken Stat 403. I (4 credits) (Excl)

414. Topics in Applied Statistics

Prerequisites: Stat 413 or Stat 403 and permission and concurrent or previous enrollment in Stat 426. II (4 credits) (Excl)

425(Math 425). Introduction to Probability

Prerequisite: Math 215. I, II, IIIb (3 credits) (N. Excl)

426. Introduction to Mathematical Statistics

Prerequisite: Stat 425. I, II (3 credits) (NS)

466. Statistical Quality Control

Prerequisite: Stat 311 or IOE 365. I, II (3 credits) (Excl)

470. Experimental Design

Prerequisite: Stat 402. I (4 credits) (Excl)

480. Survey Sampling Techniques

Prerequisite: Stat 402. I (4 credits) (Excl)

499. Honors Seminar

Prerequisite: permission of departmental honors advisor. I, II, IIIa, IIIb (2-3 credits)

500. Applied Statistics I

Prerequisites: Math 417 and a course in statistics (Stat 402 or Stat 426 or permission of instructor). I (3 credits)

501. Applied Statistics II
Prerequisite: Stat 500 or permission of the instructor. II (3 credits)

502. Analysis of Categorical Data
Prerequisite: Stat 426. I, II (3 credits)

503. Applied Multivariate Analysis
Prerequisite: Stat 500 or permission. I (3 credits)

504. Seminar on Statistical Consulting
Prerequisite: Stat 403 or Stat 500. I, II (1-4 credits)

505(Econ 673). Econometric Analysis
Prerequisite: permission of instructor. (3 credits)

506. Statistical Computing
Prerequisites: Stat 426 or Stat 500 and Computer Science 380 or Computer Science 383 or permission of instructor. II (3 credits)

510. Mathematical Statistics I
Prerequisites: Math 450 or Math 451 and a course in probability or statistics, or permission. I (3 credits)

511. Mathematical Statistics II
Prerequisite: Stat 510. II (3 credits)

525(Math 525). Probability
Prerequisite: Math 450 or Math 451 or permission of the instructor. I, II (3 credits)

526. Discrete State Stochastic Processes
Prerequisite: Math 525 or Stat 510. (3 credits)

531. Statistical Analysis of Time Series
Prerequisite: Stat 426. I, II (3 credits)

550(IOE 560)(SMS 603). Bayesian Decision Analysis
Prerequisite: Stat 425. (3 credits)

551. Bayesian Inference
Prerequisite: Stat 550. II (3 credits)

552. Sequential Analysis and Design
Prerequisite: Stat 426 or equivalent. I, II (3 credits)

560(BioStat 685). Introduction to Non-parametric Statistics
Prerequisites: Stat 511, permission of the instructor. I, II (3 credits)

561. Topics in Nonparametric Modeling
Prerequisites: Stat 510, Stat 511 or permission. (3 credits)

570. Experimental Design
Prerequisites: Stat 426 and basic knowledge of matrix theory or permission of the instructor. I, II (3 credits)

575(Econ 775). Econometric Theory
Prerequisites: Stat 425, Math 417; or Econ 653 and Econ 673 or equivalent. (3 credits)

576(Econ 776). Econometric Theory
Prerequisite: Econ 775 or the equivalent. II (3 credits)

580. Theory of Sampling
Prerequisites: Stat 426, permission of instructor. II (3 credits)

581. Topics in Nonparametric Modeling
Prerequisites: Stat 510, Stat 511 or permission. I or II (3 credits)

600, 601. Advanced Topics in Applied Statistics I and II
Prerequisite: Stat 501 or permission. 600, I; 601, II (3 credits each)

610, 611. Mathematical Statistics I and II
Prerequisites: Math 601, Math 610, 625, I; 611, II (3 credits each)

620. Theory of Probability I
Prerequisite: Math 451 or the equivalent. I (3 credits)

621. Theory of Probability II
Prerequisite: Stat 620. II (3 credits)

625, 626(Math 625, 626). Probability and Random Processes I and II
Prerequisite: Math 601 for I; Stat 624 for II (3 credits each)

628, 629. Probability
Prerequisites: Stat 625, Stat 628, I; Stat 629, II (3 credits each)

630. Topics in Applied Probability
Prerequisite: Stat 526 or Math 626. I (3 credits)

Technical Communication

(Division 291)

Department Office
301 Engineering Programs
Building
(313) 764-1427

Leslie A. Olsen, Ph.D.,
  *Professor and Director of the Technical
    Communication Program*

Professor
J. C. Mathes, Ph.D.
Dwight W. Stevenson, Ph.D.

Professor Emeritus
Thomas M. Sawyer, Ph.D.

Associate Professor Emeritus
Peter R. Klaver, Ph.D.
Rudolf B. Schmerl, Ph.D.

Adjunct Associate Professor
Robert DiGiovanni, Ph.D.
Barbara Mirel, D.A.

Lecturer
Marthalee S. Barton, Ph.D.
Jack Fishstrom, M.A.
Kara Heinrichs, M.S.
Sheryl Leicher, M.A.
Margaret Luebs, Ph.D.
Mary Jane Northrop, M.S.
Fred C. Ward, Jr., M.S.

College of Engineering students usually will take a three-hour technical communication course in their senior year; however, students are expected to maintain satisfactory standards of English in all courses. Failing to do so, students may be directed to the Assistant Dean who, with the students' program advisors and Technical Communication faculty representatives, may prescribe additional study.

The following courses provide senior year and graduate students with intensive training in communication. One of the following courses must be elected to satisfy the requirement for a writing course in the senior year: Tech Comm 486, 492, or 498.

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400. Information and Communication Resources
I, II (1 credit)
Overview of information resources in printed, electronic, and verbal form; use of the information research process to explore communication among scientists and engineers.

486. Design of Computer Documentation
Prerequisite: senior or graduate standing. I, II (3 credits)
Principles, methods, and skill development for effective computer documentation and related professional communication. Documentation coverage includes current techniques of audience, task, and content analysis; principles of effective document

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organization; and training in clear technical writing. Professional communication coverage includes preparation of effective memos, reports, and oral presentations.

490. Technical Information Resources and Research
I (3 credits)

Description and demonstration of all forms of technical information resources now available to engineers. Access to a wide variety of sources and systems, with primary emphasis on on-line networks, and use of conferencing and database systems.

492. Communication of Technical Information
Prerequisite: senior or graduate standing. I (3 credits)

Theory and research on effective design of visual representations in science and technology. Application of principles of visual representation to the design of written and oral discourse. Topics include the relation of word and image; and the perceptual, cognitive, and aesthetic bases of visual design. Written and oral term project.

497. Argument and Persuasion
Prerequisite: senior standing. (3 credits)

Logical argument and its role in persuasive discourse, especially writing. The nature of a reasoned argument; the formulation and analysis of problems; and methods of selecting, arranging, writing, and editing information on the basis of the intended effect on a particular audience.

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.

499. Scientific and Technical Communication
Prerequisite: senior or graduate standing. (3 credits)

Directed Study Courses in Technical Communication

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.

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. These courses are not intended as substitutes for regularly scheduled courses. Students who wish to elect Directed Study must confer with an instructor about the proposed study. If the instructor agrees to accept the student for this study, the two prepare a contract and submit it for approval. Directed study contracts must be approved before the student may enroll. (Directed Study contract forms and additional information are available from the Technical Communication office.)

475. 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.

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.

675. Directed Study

Prerequisites: 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.

Graduate Courses in Technical Communication

520. Technical and Scientific Editing

II (3 credits)

A general overview of the roles, responsibilities, and practices of an editor of technical and scientific information. Application of these variables to editing proposals, scientific and technical papers, design reports, users' manuals, and group writing projects. Includes practice and applications in computer-based editing.

530. Graphic Design for Technical Communicators

Prerequisite: senior or graduate standing. IIIa (alternate years) (3 credits)

Linguistic and design principles for proportion, typography, visual logic, layout, sequence of units, composition, and visual-to-text relations. State-of-the-art design and printing technology, including paper milling, electronic image-setting, pre-press color separating, and lithographic printing. Design solutions within available production technologies to applied problems and an independent project.

570. Comprehension of Technical Prose

II (3 credits)

A survey of research literature from cognitive psychology, psycholinguistics, and artificial intelligence on how written text is comprehended, with emphasis on technical text, such as scientific writing, computer documentation, and equipment manuals.

580. Theory of Scientific and Technical Rhetoric: Contemporary Approaches

Prerequisite: senior or graduate standing. I (alternate years) (3 credits)

Survey of current schools of theory that underlie technical and scientific discourse, including psycholinguistics, structuralism, semiotics, narratology, deconstruction, and cultural criticism, including the contribution of feminist and Marxist theorists. Attention also paid to the seminal contributions of visual theorists.

585. Theory of Documentation

I (3 credits)

A survey of the scientific research and theory that yields principles and guidelines for effective documentation for equipment such as computer systems. Topics covered include the choice of documentation content, effective presentation, and readability. Emphasis on science base rather than design experience.

586. Design of Documentation

II (3 credits)

A design course that applies theories of documentation to actual development and testing of documentation, especially computer documentation. A brief review of documentation theory, analysis of current industry guidelines and procedures for producing

documentation, actual writing of documentation, and testing of documentation in a laboratory environment.

590. Internship in Technical and Professional Communication
Prerequisites: Tech Comm 498 or Tech Comm 499 and permission of instructor. I, II, IIIa, IIIb (to be arranged)

Advanced instruction and on-the-job experience in technical writing for students interested in preparing for careers as technical communicators or in enhancing their qualifications for administrative roles in industry and government.

595. Communication, Technology, and Public Policy
I (3 credits)

Analysis of the public policy decision making process involving technology management. The structure and techniques of policy discussions from the engineering management perspective. Communication in social decision analysis for engineering projects. Design of specific types of policy statements such as the position paper, legislative testimony, and environmental impact statement.

598. Management and Administrative Communication Processes
Prerequisite: Tech Comm 498 or equivalent, or permission of instructor. II (3 credits)

Description, analysis, and assessment of written and oral communication processes in organizations. Establishing and managing effective communication procedures and practices. The role of communication in organizational and decision making processes. The contribution of communication to production efficiency and productivity.

610. Dissertation, Dissertation Proposal, and Thesis Writing
Prerequisite: graduate standing. I, II (1-3 credits)

Intended for American and international 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.

620. Teaching and Supervising Technical Writing
Prerequisite: graduate standing. I (3 credits)

For graduate students of two types: those planning academic careers in technical contexts, and those planning administrative and project management careers in industry. The objectives, methods, and resources necessary to teach technical writing and to supervise technical personnel who write.

Selected Topics in Technical Communication

Study of selected topics. When offered, the course or courses will be announced in the Time Schedule.

401. Selected Topics
Prerequisite: junior standing. I, II (to be arranged)
Study of selected topics. May be taken for 1–4 credit hours as arranged by the instructor.

501. Selected Topics
Prerequisite: graduate standing. (to be arranged)
Study of selected topics. May be taken for 1–4 credit hours as arranged by the instructor.

601. Selected Topics
Prerequisite: graduate standing. (to be arranged)
Study of selected topics. May be taken for 1–3 credit hours as arranged by the instructor.
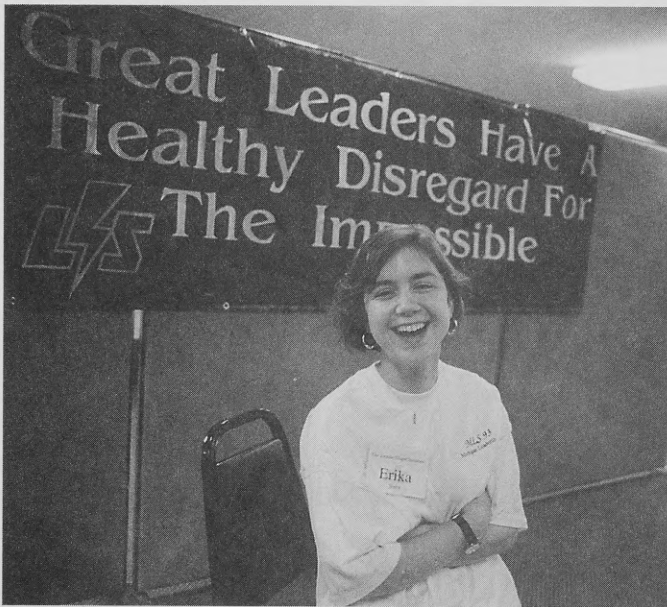
Michigan LeaderShape®
The annual Michigan LeaderShip Institute is an opportunity for undergraduate student society leaders to introduce and enhance important leadership skills.

Committees of the College

Executive Committee

Dean Stephen W. Director, Chair
R. Gibala
E. Gulari
L. Katehi
A. Nagy

Committee on Combined Degrees

with the College of Literature, Science, and the Arts
G.E. Smith, Chair
J. Wilkes, *ex-officio*

Committee on Curriculum

K. Hayes, Chair
M. Burns
M.A. Carroll
D. Martin
N. Perkins
S. Rand

Committee on Discipline

J. Stein, Chair
M. Atzmon*
W. Birmingham
W. Hansen
A. Hero
S. Pollock
D. Srolovitz

*On sabbatical, 1996-97.

Committee on Faculty Rules

A. Hero, Chair
L. Thompson
A. Waas

Committee on Freshman Counseling

M.G. Barcia, Chair
C. Borgnakke
G. Herrin
K. Hill
W. Hosford
A. Monterio
L. Payton
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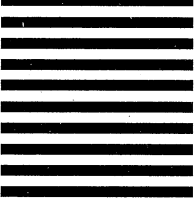
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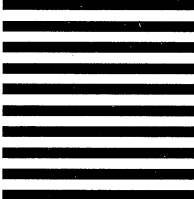
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