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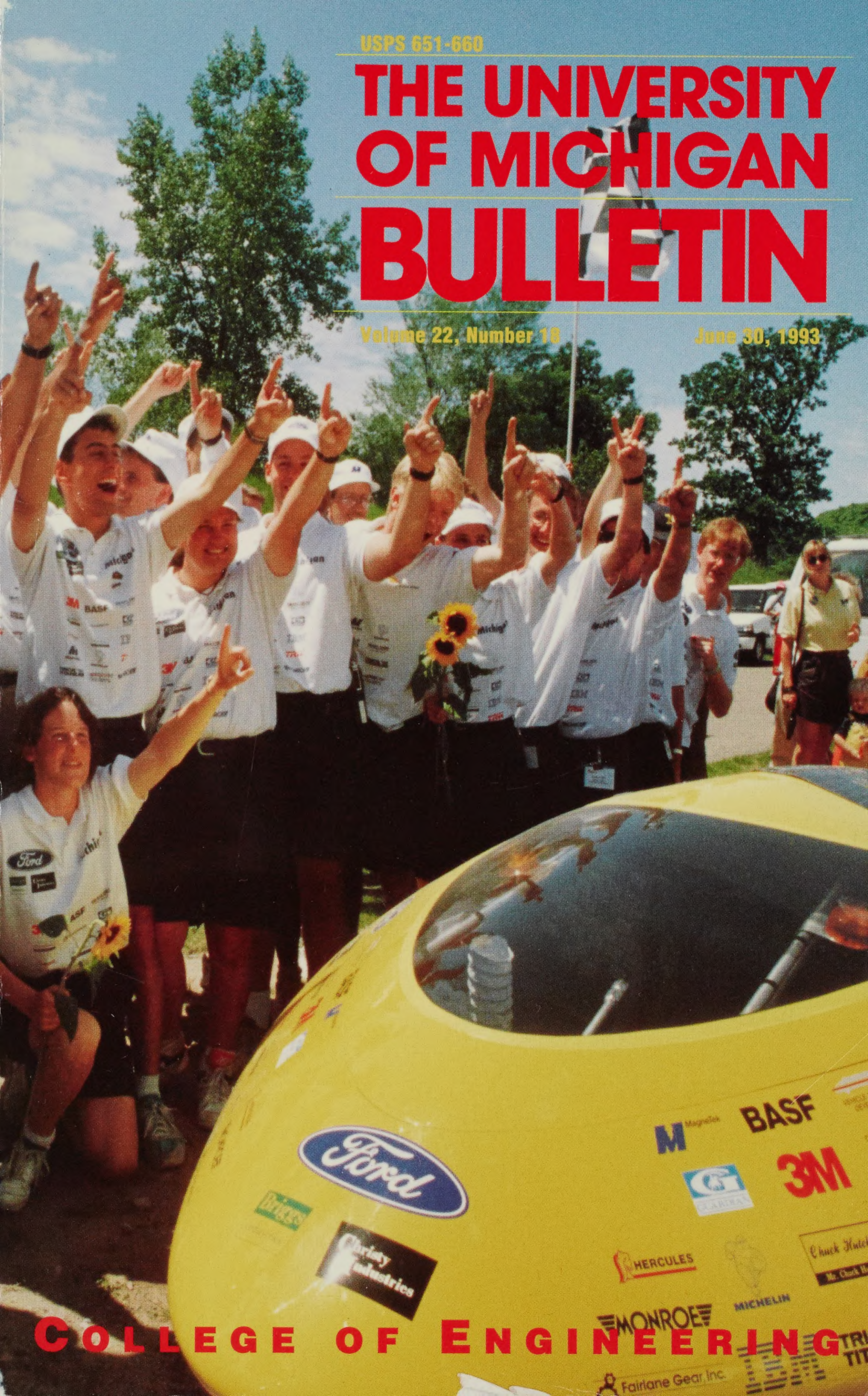

COLLEGE OF ENGINEERING

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College of Engineering 1993-94
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ON THE COVER:

We're Number One! Maize & Blue crosses the finish line for first place in the 1993 Sunrayce USA competition. The 1,000-mile, seven-day race was sponsored by the U.S. Department of Energy, General Motors Corporation, the Society of Automotive Engineers, and the National Renewable Energy Laboratory. This is the second Sunrayce USA competition—and the second first-place win for Michigan. More than half of the 100 students participating in this hands-on project are in Engineering.

Next, it's on to the World Solar Challenge—and the 1,800-mile trip across the heartland of Australia.

Photo: *Dick Kelly, Visual Communications*

Cover design: *Marie Howard*

Summer 1993

Dear Prospective Student,

It's a pleasure and a privilege to introduce you to the University of Michigan College of Engineering. By almost any standard—the size and quality of its libraries and laboratories, the originality and extent of its research and publications, the distinction of its faculty, or the achievement level of its students—the College is one of the leading institutions of its kind in the world.

But it takes more than bricks, books, and test scores to attain true greatness. In addition to providing a solid foundation in mathematics and science, the College of Engineering has long been committed to the education, in its broadest sense, of the whole student. Dr. Julian Earls, chief of the Health, Safety, and Security Division at NASA-Lewis Research Center, told a group of College students on a visit here, "You make a *living* by what you get; you make a *life* by what you give."

The College believes that the leaders of the future need to be as expert in ethical and cultural concerns as they are in their disciplines. In addition to learning from some of the world's most respected scholars, students here find numerous opportunities for involvement, engagement, and service through professional organizations, honor societies, student publications, and student government. Take advantage of all that Michigan has to offer.

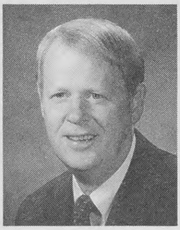
This course catalogue contains much important information, including general degree program requirements, basic course descriptions, admission criteria, and academic rules and procedures. Like many other such documents, however, it is a beginning, not an end. Please ask professors, academic counselors, program advisors, other students, and staff members for help with your questions. The best answers you'll get will be from people, not books.

The College has many avenues for you to explore and the resources to support your explorations. Its broad curriculum reflects the wide variety of fields of expertise of the faculty, which is known for being open and available to students at both the professional and personal levels. But the journey is up to you.

Jennifer Starrman

Jennifer Starrman
President
*University of Michigan Engineering Council (UMEC)**

*UMEC is the College of Engineering's student government. There are more than 25 student societies in which Engineering students can get involved.



Letter from the President

The University of Michigan is committed to building a racially, ethnically, and religiously heterogeneous community. This commitment stems from many sources, including the conviction that such diversity is essential to creating an intellectual and social climate which promotes the freedom of thought, innovation, and creativity so fundamental to an academic community. Further, I believe that the University has a special responsibility to seek this diversity and to nurture the sensitivity, tolerance, and mutual respect that are such necessary characteristics of a community in which all may thrive.

Each one of us as a member of the University community bears a special and continuing responsibility to articulate, reinforce, and reflect those values that support our highest aspirations as a scholarly and humane society. I hope you, as a prospective member of this community, will recognize the important role that you will play in helping to achieve our common goals.

Sincerely,

James J. Duderstadt
President

Letter from the Dean

Current, new, and prospective College of Engineering students:

On behalf of the College, I am pleased to present this comprehensive overview containing important facts about the College, our outstanding programs, and excellent facility resources supporting those activities. It is a testament to the commitment our faculty and staff hold to excellence in engineering education.

The team of highly motivated professionals at the College are dedicated to preparing young men and women like yourself to meet the technological—as well as the basic human needs—of contemporary society and be of service to the community, while maintaining the best research and technology facilities that the country has to offer.

From our nationally acclaimed Centers of Excellence, to the quality of life maintained for undergraduate and graduate students, we can be proud of the outstanding achievements we have accomplished, and look forward to having you be a part of our bright future of continued excellence.

Congratulations and welcome to our newest class of Engineers!

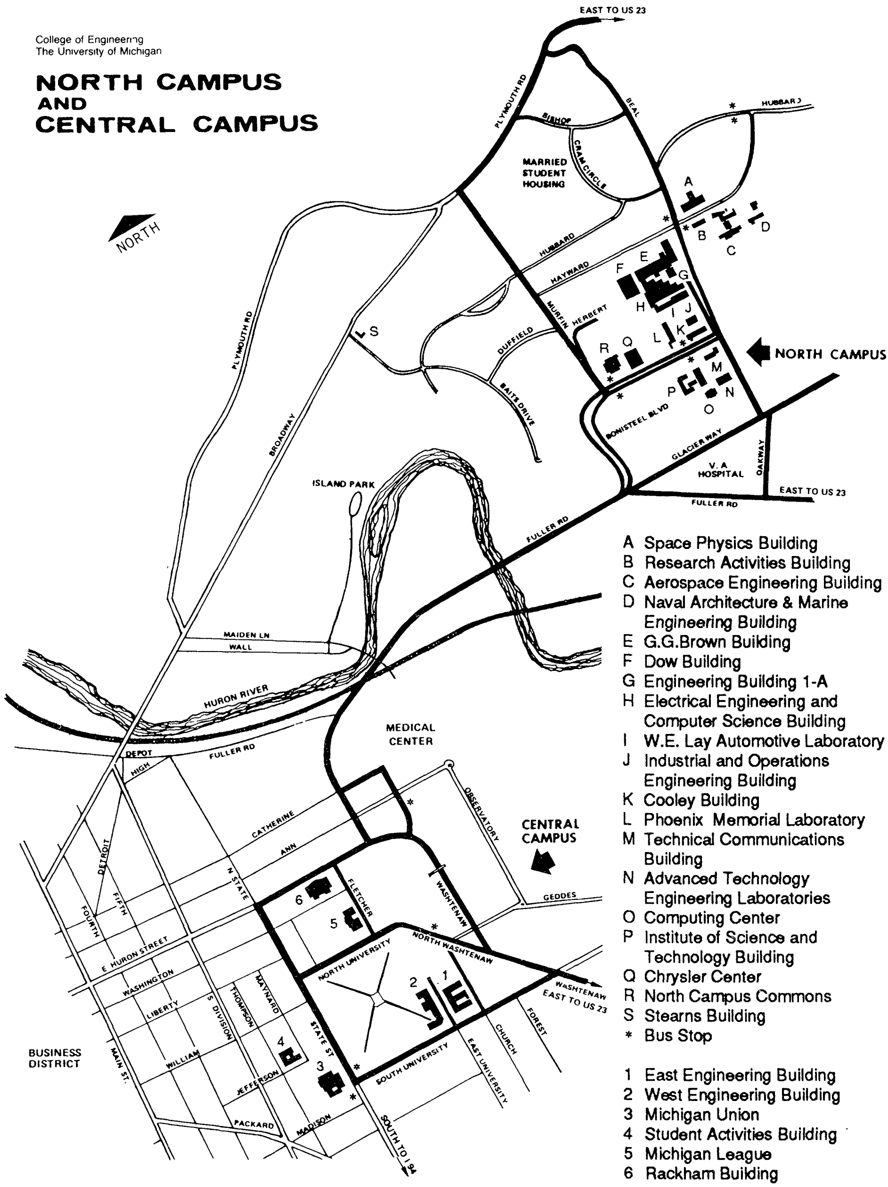
With best regards,

Peter Banks

Peter M. Banks, Dean
College of Engineering

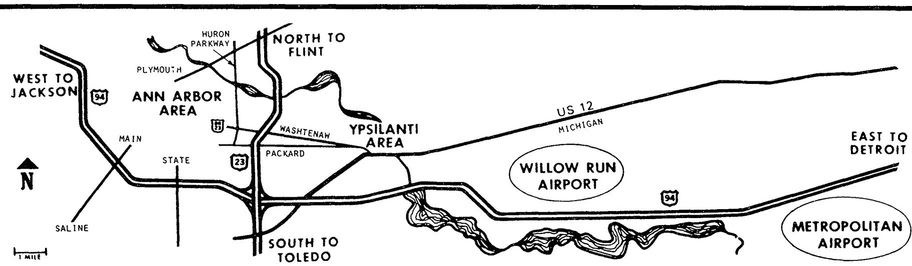
College of Engineering
The University of Michigan

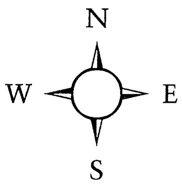
NORTH CAMPUS AND CENTRAL CAMPUS



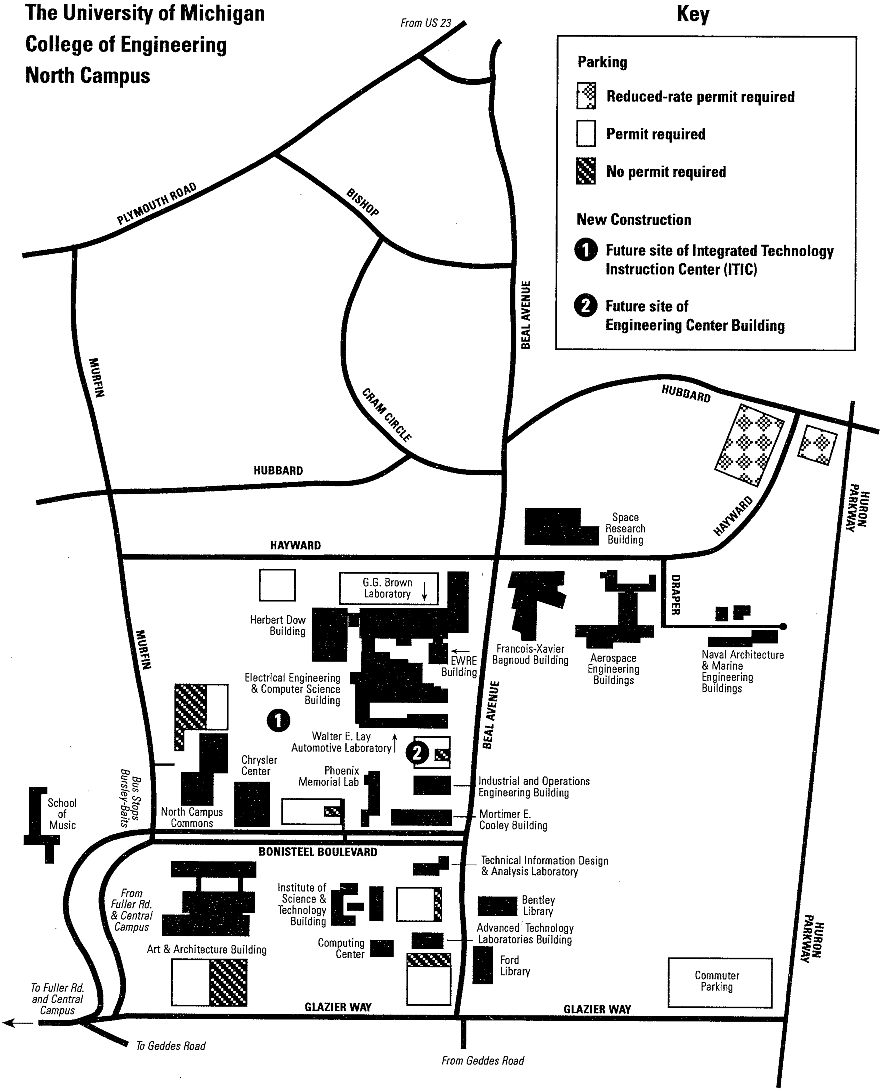
A Space Physics Building
B Research Activities Building
C Aerospace Engineering Building
D Naval Architecture & Marine Engineering Building
E G.G.Brown Building
F Dow Building
G Engineering Building 1-A
H Electrical Engineering and Computer Science Building
I W.E. Lay Automotive Laboratory
J Industrial and Operations Engineering Building
K Cooley Building
L Phoenix Memorial Laboratory
M Technical Communications Building
N Advanced Technology Engineering Laboratories
O Computing Center
P Institute of Science and Technology Building
Q Chrysler Center
R North Campus Commons
S Stearns Building
* Bus Stop

1 East Engineering Building
2 West Engineering Building
3 Michigan Union
4 Student Activities Building
5 Michigan League
6 Rackham Building





The University of Michigan
College of Engineering
North Campus



The University of Michigan Bulletin

College of Engineering

1993–94

The University of Michigan

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Derrick E. Scott, *Director of Minority Engineering Programs,* 2316 EECS, 763-4256

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Fall Term, 1993

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

Orientation	September 5-8	Sunday-Wednesday
Labor Day (Holiday)	September 6	Monday
* **Registration**	**September 7-8**	**Tuesday-Wednesday**
Classes begin	September 9	Thursday
Thanksgiving recess 5 p.m.	November 24	Wednesday
Classes resume 8 a.m.	November 29	Monday
Classes end	December 10	Friday
Study Days	December 11-13	Saturday-Monday
Examinations	**December 14-17, 20-21**	**Tuesday-Friday, Monday-Tuesday**
Commencement	December 12	Sunday

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

Registration	August 30-31	Monday-Tuesday
Classes begin	September 8	Wednesday

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

Registration	August 31	Tuesday
Classes begin	September 1	Wednesday

Winter Term, 1994

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

Orientation	January 2-4	Sunday-Tuesday
* **Registration**	**January 3-4**	**Monday-Tuesday**
Classes begin	January 5	Wednesday
Martin Luther King, Jr. Birthday	January 17	Monday
(University Symposia.	**No Regular Classes)**	
Vacation begins 12:00 noon	February 19	Saturday
Classes resume 8:00 a.m.	February 28	Monday
University Honors Convocation	March 20	Sunday
Classes end	April 19	Tuesday
Study Days	April 21, 24-25	Wednesday, Saturday-Sunday
Examinations	**April 21-22, 25-28**	**Thursday-Friday, Monday-Thursday**
Commencement Days	April 29-30	Friday-Saturday

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

Registration	December 15-16	Wednesday-Thursday
Classes begin	January 5	Wednesday

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

Registration	January 3-4	Monday-Tuesday
Classes begin	January 5	Wednesday

Spring-Summer Term, 1994

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

Orientation	May 1-3	Sunday-Tuesday
* **Registration** (Full Term & Spr. Half)	**May 2-3**	**Monday-Tuesday**
Classes begin	May 4	Wednesday
Memorial Day (Holiday)	May 30	Monday
Classes end (Spring Half)	June 21	Tuesday
Study Day	June 22	Wednesday
Examinations	**June 23-24**	**Thursday-Friday**
Spring Half Term ends	June 24	Friday
Orientation (Summer Half)	June 26-28	Sunday-Tuesday
* **Registration** (Summer Half)	**June 27-28**	**Monday-Tuesday**
Summer Half Term classes begin	June 29	Wednesday
Independence Day (Holiday)	July 4	Monday
Classes end	August 16	Tuesday
Study Day	August 17	Wednesday
Examinations	**August 18-19**	**Thursday-Friday**
Full Term & Summer Half Term end	August 19	Friday

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

Registration	May 2-3	Monday-Tuesday
Classes begin	May 4	Wednesday
Summer Half Term		
Registration	June 27-28	Monday-Tuesday
Classes begin	July 5	Tuesday

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

Registration	April 29	Friday
Classes begin	May 2	Monday
Summer Half Term		
Registration	June 23	Thursday
Classes begin	June 27	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
North Campus Information Center: 763-NCIC

Academic Affairs (Provost's Office), 3068 Fleming Bldg., 764-9290
Admission of Freshmen, 1220 Student Activities Bldg. (SAB), 764-7433
Career Planning & Placement, 3200 Student Activities Bldg., 764-7460
Cashier's Office, 1015 Literature, Science, and the Arts Bldg. (LS&A), 764-8233
Employment:
- Student, 2503 Student Activities Bldg., 763-4128
- Hospital, 300 N. Ingalls Bldg. (NIB), Room 8A04, 747-2375
- Campus, 2031 Ad Services & 1020 LS&A, 764-7280

Extension Service, 200 Hill Street, 764-5310
Financial Aid, 2011 Student Activities Bldg., 763-6600
Foreign Student Counselors, International Center, 603 E. Madison, 764-9310
Graduate School, 110 Rackham Bldg., 764-8129
76-GUIDE, 24-hr. Telephone Counseling Svc. 3100 Union, 764-8433
Health Services, 207 Fletcher, 764-8325
Housing, 1011 Student Activities Bldg.
- Residence Halls Assignments, 763-3164
- Family Housing Assignments, 763-3164
- Off-Campus Housing, 763-3205
- Off Campus Housing (cooperatives, fraternities, sororities), 662-4414
- Fees, payment of, Cashier's Ofc., 1015 LS&A Bldg., 764-8233

International Center, 603 E. Madison, 764-9310
Ombudsman, 3000 Union, 763-3545
Orientation, 3011 Student Activities Bldg., 764-6290
President's Office, 2074 Fleming Bldg., 764-6270
Secretary of the University/Vice President for Govt. Relations, 2014 Fleming, 763-5553
Student Accounts; Room, Board and Tuition, 2226 Student Activities Bldg., 764-7447
Student Locator, 764-2330
Student Organizations Development Center, 2202 Union, 763-5900
Student Legal Services, 3409 Union, 763-9920
Veterans Affairs, 1514 LS&A Bldg., 764-1575

U-M College of Engineering Offices

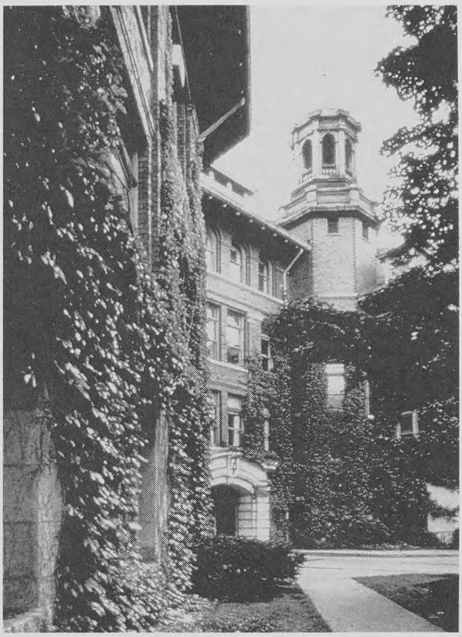
General Information: (313) 764-8470

Student Information: (313) 763-3170

Freshmen Admissions: 1220 Student Activities Bldg., 764-7433
Transfer Admissions: 2417 Electrical Engineering
and Computer Science Bldg. (EECS), 763-6841
(Includes foreign, guest, special, and
undergraduate admissions)
Cooperative Education, 2423 EECS Bldg., 763-5086
Engineering Council, 1230 EECS Bldg., 764-8511
Engineering Learning Resource Center, 2327 EECS Bldg., 764-6489
Freshman Advising, 2419 EECS Bldg., 764-5158
Lost and Found, 3415 EECS Bldg., 763-2305
Minority Engineering Program Office (MEPO), 2316 EECS Bldg., 764-6497
Placement (student and alumni), 201 Stearns Bldg., 764-8483
Records Office, 2420 EECS Bldg., 763-3170
Scholarships, 2420 EECS Bldg., 764-8477
Society of Minority Engineering Students (SMES), 1232 EECS Bldg., 764-7252
Society of Women Engineers (SWE), 1226 EECS Bldg., 763-5027
Withdrawal/Disenrollment, 2417 EECS Bldg., 763-6857

History of the College

The College of Engineering was founded in 1853-54. In 1857, when the first engineering degree was awarded, there were only a few other colleges around the country providing opportunities for study in engineering.



As early as 1852, President Henry P. Tappan of the University of Michigan 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 leading engineering school with a number of important firsts. Michigan established the nation's first program in Metallurgical Engineering (1854), Naval Architecture and Marine Engineering (1881), Chemical Engineering (1898), Aeronautical Engineering (1914), Nuclear Engineering (1953), and Computer Engineering (1965).

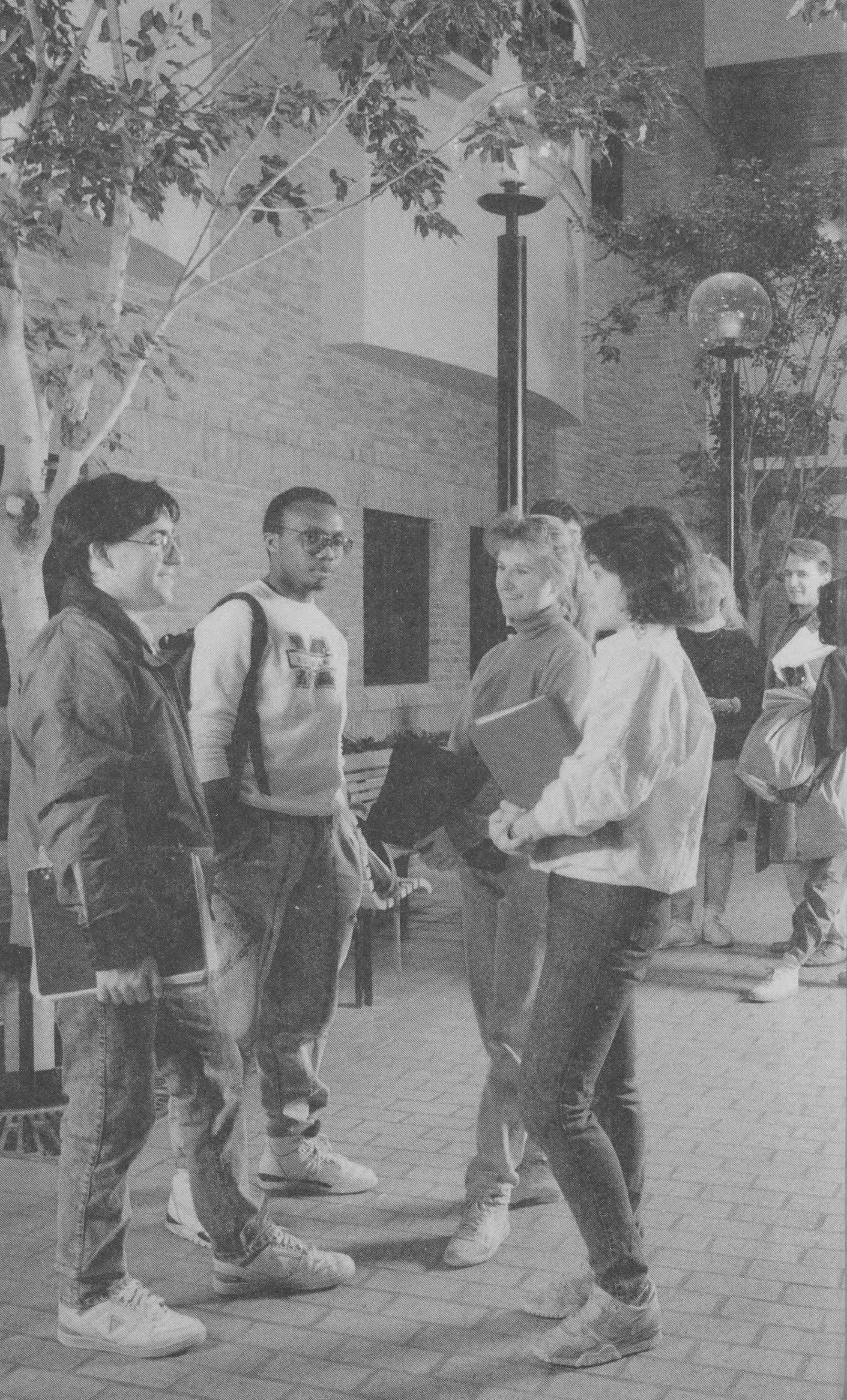
Today, the College of Engineering at the University of Michigan is consistently ranked among the top engineering schools in the world. Most of its degree programs are rated in the top ten nationwide. About 900 bachelor's degrees and 700 master's and doctorate degrees are awarded annually. And the opportunities for study have expanded so that students may choose from about 950 engineering courses.

There were 305 teaching faculty, 62 research faculty, 4,800 undergraduate students and 1,759 graduate students in the College of Engineering in Fall 1993, and they took advantage of the College's diverse research facilities.

The College of Engineering expended about $68 million dollars in research grants for 1992-93 — approximately 20% of total University research funds.

Each of the following research units operates with a budget of more than half a million dollars:

- Artificial Intelligence Laboratory
- Automotive/Combustion Laboratory, Walter E. Lay
- Biomechanics Research Laboratory
- Cellular Biotechnology Laboratory
- Chassis Durability Simulation and Design Center
- Communications and Signal Processing Laboratory
- Computer Aided Marine Design Laboratory
- Coordinate Measuring Machine Laboratory
- Design Laboratory
- Dimensional Measurement and Control in Manufacturing Laboratory
- Environmental and Water Resources Laboratory
- Ergonomics, Center for
- Fluid Mechanics Laboratory
- Gas Dynamics Laboratory
- Hazardous Substance Research Center
- High Frequency Microelectronics, Center for
- Laboratory for Advanced Scientific Computation
- Marine Hydrodynamics Laboratory
- Materials Research Laboratory
- Nuclear Engineering Measurements Laboratory
- Optical Coordinate Measuring Machine Laboratory
- Optical Science Laboratory
- Plasma Laboratory
- Precision Machining Laboratory
- Radiation Imaging Laboratory
- Radiation Laboratory
- Ship Hydrodynamics Laboratory
- Solid-State Electronics Laboratory
- Space Physics Research Laboratory
- Space Terahertz Technology, Center for
- Special Projects Division
- Structures Laboratory
- Ultrafast Optical Science, Center for
- S.M. Wu Manufacturing Research Laboratories



Our society is increasingly dependent on a scientific and technological base not only for its prosperity but for its very survival. Throughout the modern era, the need has been great for men and women who, as scientists, can discover the truths of nature, or, as engineers, can apply those truths "for the benefit of humankind." Never has the need been greater than it is today.

Engineers as well as scientists make their contributions to the storehouse of knowledge. It should be stressed, however, that engineers are occupied primarily with solving real-life problems. Engineering is a profession that began as a practical art, and although it has become less of an art and more of a science, its main concern is still "the benefit of humankind."

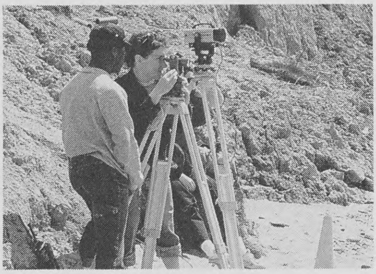
By bringing to bear on each problem a proper combination of knowledge, experience, and judgment, engineers seek the best or most economical solution. Every day of every year, they find more and more ways to make our way of life easier, safer, cleaner, and more comfortable—for more and more people. They invent methods for doing something never done before. Unhappy with what exists, they are always seeking ways to improve, to do things better and more efficiently. In the various processes of inventing, designing, manufacturing, and constructing, engineers are concerned continually with the use of humanpower, and the effects of their creativity on people and their total welfare. They also find ways of coping with the problems that derive from their earlier successes—such problems as air and water pollution, mass transportation, the noises of supersonic travel, or the need for better forms of information storage and retrieval.

In our time, the engineering approach to problems has taken on particular importance because social and technological problems have become so closely interrelated. The problem of air pollution, to cite but one example, cannot be solved in terms of the underlying physical causes alone. We must know why it looms as such a major problem; what social, political, legal, and ethical conflicts it arouses; and how the alternative technological solutions would affect both individual and group interests or welfare. Positions in modern engineering demand a sensitivity to such problems across the full range of our social and economic concerns. The College of Engineering is dedicated to

These Engineering students will soon join the ranks of the 52,000 other University of Michigan engineers who make things happen.

educating young men and women for such technological leadership.

To an increasing number of young people today, the words "environment" and "ecology" suggest a wide range of opportunities that lie ahead in solving the problems and meeting the needs of contemporary society. The solution to these problems certainly involves the contributions of the engineers who design, build, and operate our machines, plants, and processes.

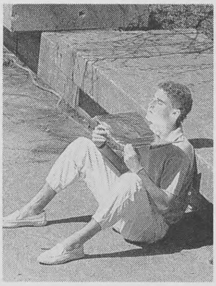


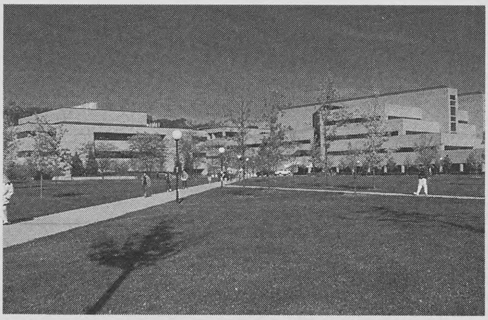
Students in the College of Engineering have the opportunity to elect courses that will broaden their knowledge of the environment and ecology. Those who do will be particularly well qualified to utilize their technical knowledge in developing definitive solutions to environmental problems.

The College's enduring educational objective is that of preparing its students for positions of responsibility that are commensurate with their abilities and interests. But the means by which the College carries out this objective must be continually revised in the light of conditions that are continually changing in education and throughout the whole of society. Students enrolled in the College soon discover that its programs have been planned to prepare them for any one of a broad range of possibilities. According to their aptitudes and desires, students may go on to become practicing engineers, researchers, administrators, or teachers. Moreover, the knowledge and discipline gained from undergraduate engineering study are proving to be excellent preparation for other careers, particularly in business, law, and medicine. Many graduates of the College remain after they have received an undergraduate degree to earn a master's or doctorate degree. Another opportunity for continued growth and development beyond the undergraduate degree is that of registration as a professional engineer. After a certain length of experience (usually four years), new engineers can take qualifying examinations offered by the state in which they seek registration.

At Michigan, students have an opportunity to associate with distinguished teachers who have not only solid academic grounding but also broad professional involvement, the result of continuing research and consultation on actual engineering projects. The College believes that such professional involvement is necessary if its faculty is to retain maximum efficiency both in the classroom and the laboratory. The benefits of such involvement are passed on to students through formal classroom exposure and through informal exposure as well. Often, teaching is most effective when a teacher can work together with students in fundamental scientific investigations, or on improved ways of applying scientific knowledge to the problems of industry and public well-being. Graduate and undergraduate students in the College have an opportunity to participate in such activities in well-equipped engineering laboratories and at a number of field locations.

The College's program for undergraduate study consists typically of a four-year program leading to a bachelor's degree. There are 12 programs that lead to the degree Bachelor of Science in Engineering, and one that leads to the degree Bachelor of Science; these are identified throughout this catalog 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. For further information, refer to the later section on Undergraduate Programs.





A view of North Campus, home of the College of Engineering

Career Choices

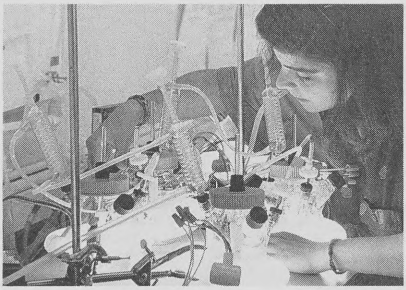
In choosing engineering as a career, the main criteria are usually an interest in and successful completion of high school mathematics and science courses; a desire and ability to investigate the "why" as well as the "how" of things; and an interest in the creative development of devices or systems that 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 signs or interests will fit everyone, but they can be used as a rough guide.

More and more women are enrolling in engineering. Women who like science and mathematics will find engineering 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.

Officers and academic counselors within 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 interest and abilities. A student with questions in this regard may benefit from a leaflet titled "Engineering"—available by writing to the office of the Assistant Dean, College of Engineering, 2419 EECS Building, Ann Arbor, Michigan 48109-2116.

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.

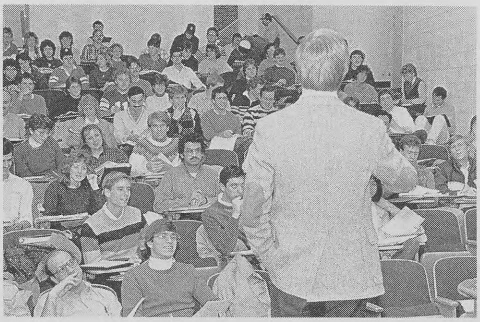


In Michigan, the State Board of Registration for Professional Engineers provides an opportunity for students during their senior year to take the first half of a 16-hour, two-part examination as the first step toward registration, provided the degree is awarded within six months after the examination, and the degree program is one that has been accredited at the College by the Accreditation Board for Engineering and Technology (ABET). The accredited degree programs are listed below. This first part is a general coverage of the fundamentals common to all 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.

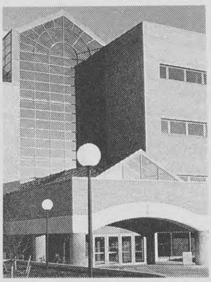
Accreditation

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, 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:



The Electrical Engineering and Computer Science (EECS) Building

North Campus Engineering Buildings

Advanced Technology Laboratories (ATL)
Aerospace Wind Tunnel Laboratories
George Granger Brown Laboratory (G.G. Brown)
G.G. Brown Connector Building
Chrysler Center
Mortimer E. Cooley Building
Dow Building
Electrical Engineering and Computer Science Building (EECS)
Environmental and Water Resources Engineering Building (EWRE)
François-Xavier Bagnoud Building (FXB) for Aerospace research and teaching
Industrial and Operations Engineering Building (IOE)
Institute of Science and Technology Building (IST)
Walter E. Lay Automotive Laboratory
Naval Architecture and Marine Engineering Building
Phoenix Memorial Laboratory with the Ford Nuclear Reactor
Space Research Building
Technical Information Design and Analysis Laboratory (TIDAL)
University of Michigan Transportation Research Institute (UMTRI)

Central Campus Engineering Building

West Engineering Building
- Naval Architecture and Marine Engineering Towing Tanks

Laboratories and other facilities are described within the sections on Undergraduate Degree Programs, pages 89-160.

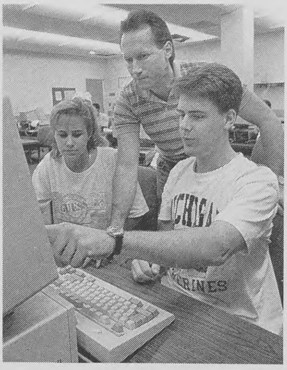
CAEN

The Computer Aided Engineering Network (CAEN) provides the College of Engineering with one of the world's premiere computing environments for engineering-related research and education. Dedicated to the concept of distributed computing since CAEN's inception in 1983, CAEN now maintains a fully integrated, multivendor 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 1,100 engineering class workstations and over 1,200 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 more than 20 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, DEC, Hewlett-Packard, IBM, NeXT, Silicon Graphics, Stellar, Sun Microsystems, and Texas Instruments. The College also houses the Center for Parallel Computing, which contains a 32-node Kendall Square Research Parallel System, an 8-node IBM RS/6000 cluster, and several new systems which will be added in 1993. Access to these parallel systems is available to anyone in the College with a legitimate need for their resources. 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.

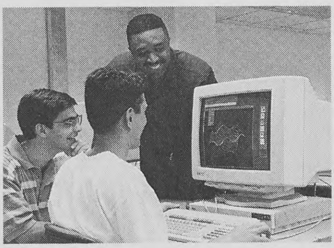


An Integrated Network

The CAEN network allows users to sit at any workstation, from an IBM PC 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 the Andrew File System—are actively supported. Together they enable CAEN to provide more than 250 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, Apple EtherTalk and LocalTalk, IBM Token Ring, and several high-speed FDDI fiber optic backbone networks.

CAEN's computing environment is fully integrated with other University of Michigan organizations, including the Computing Center's UMnet (a part of the State of Michigan's regional MichNet Computer Network) and the Electrical Engineering and Computer Science Department's Departmental Computing Organization (DCO). Michigan's gateways to the Internet (including NSFNET and CICNet) and BITNET extend this connectivity across the country and around the world.



CAEN Open Laboratories

As of fall 1993, CAEN will operate 22 open lab facilities. These labs contain Apollo, Apple, IBM, Sun, Hewlett-Packard and DEC 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 premiere 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 newsletter articles describe software that is available on the network. Short courses on various packages are announced via 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. Most of CAEN's open labs are also available 24 hours a day via electronic card-key access, using the standard University photo I.D.

Information and User Services

CAEN's Information and User Services has developed 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 Tutorials* and *CAEN Technical* notes provide topical instruction and information on using software, equipment, and services available to CAEN users; the monthly *CAEN Newsletter* offers technical articles on CAEN systems as well as regular information on changes and updates to the network and services; and classroom instruction ranging from single-session seminars to regular courses for credit are offered on a variety of topics.

The *CAEN Newsletter* is available for pickup at most CAEN labs. All other CAEN publications, including the *CAEN Handbook* and technical notes are available at the main CAEN office, 229 Chrysler Center. Most CAEN informational material, including the newsletter 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 Dow Library for on-site use. Copies for purchase of many manuals are available at various bookstores and copy centers. CAEN consultants are located in several of the larger labs, including the Dow Mezzanine, North Campus Commons, and the Undergraduate Library. Consultants are also located at the CAEN central hotline office in 231 Chrysler Center for both walk-in and phone consultation (763-5041). Hours vary at each location and change over the course of the year based on demand.

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, backup operations, lab counseling and user services, systems programming, and more. Postings for these positions—including details on how to apply for them—appear regularly in the *CAEN Newsletter* and as bulletins in the labs.

U-M Computing Center

The Computing Center is a research and service facility for the students, faculty, and research staff. Computing services are provided through an IBM ES9000-720 running under an operating system called the Michigan Terminal System (MTS). MTS permits both conversational and batch processing from microcomputers, workstations and terminals. Active support is provided for micro-computer services and computer network development. For questions concerning Computer Center facilities and services, call the Computing Center Consultants, 764-HELP, weekdays 8 a.m.-midnight.

Engineering Library

The Engineering Library, located in the Dow Building on North Campus, is one of more than 25 divisional libraries in the University Library System. Its collection of approximately 450,000 volumes covers all fields of engineering. The Library subscribes to almost 3,000 serial titles, including popular and scholarly engineering journals, maintains a large collection of technical reports, 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 in order to assist the student, faculty, and researchers in making 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 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 are required for entrance to many campus facilities, especially certain laboratories and libraries. Student ID cards are issued by the Housing Office in Room 100, Student Activities Building (SAB) or the Entree Plus office, Room 1300, on the main floor of North Campus Commons.

Health

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

The University Health Service (UHS) offers outpatient services and health education programs. Located at 207 Fletcher on the central campus, 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 by enrolling in its prepaid health care plan.

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. There is a Treatment Center for minor emergency care. For current building hours and services, call the UHS INFO HOTLINE, 764-8320. 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, Audiology, Musculo-skeletal 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 accessible to handicapped persons via its South entrance.

Scholarships

Numerous University of Michigan scholarships, fellowships, and prizes as well as loan funds, are available to qualified Engineering students. In keeping with the University's practice and policy, financial assistance is available to qualified students regardless of sex, race, color, or creed.

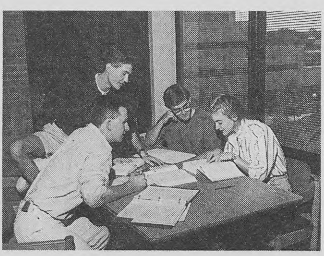
Scholarships are established by gift or endowment. The University and the College of Engineering are fortunate that many of their alumni, along with industry, and various organizations, have contributed support through annual gifts and endowment funds, which earn annual income to be used for scholarship awards.

There is no direct obligation to repay a scholarship, but as recipients recognize their moral obligations to return gifts to the College scholarship fund, according to their abilities, other worthy students will benefit.

Below is a brief description of the broad range of undergraduate scholarships available to Engineering students.

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 their 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 students submitted 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 Coordinator of Recruiting in Room 2417 EECS Building or call (313) 763-5050. The Transfer Student Award is for one term only. For further information on scholarships, contact the Financial Aid Officer in the College of Engineering, 2420 EECS Building, or call (313) 764-8477.

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's Office of Financial Aid.* Within the various scholarship funds are other criteria to be met. It is the task of the Engineering Scholarship Office and the Engineering Scholarship Committee to match qualified students to 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 the 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's Financial Aid Office, 2011 Student Activities Building.*** (See "Deadlines" on the next page.)

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 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, 2420 EECS Building. There is also a rack with applications next to 2417 EECS.

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 receive 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 you reach a point where your total awards equal more than the student budget, as established by the University of Michigan, you will not qualify for an engineering award.

Deadlines

Applications for Winter Term are accepted from September 15th to October 15th. Applications for Spring and/or Summer Terms; Fall only or Fall and Winter Terms, are accepted during the period of January 15th to March 15th.

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 15th.

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.

Graduate Students

Financial aid for graduate students is normally awarded through individual departments. Graduate students are encouraged to contact the graduate offices for more information.

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 numerous arrangements with overseas institutions at which our students can also study. These agreements give an opportunity for our students to experience the educational, social, political, and professional climate of an outstanding foreign institution for a prescribed period of time. Those students who choose to 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 see self-confident, imaginative people. Those who desire placement in educational programs at overseas locations should contact the Office of the Associate Dean for Graduate Education and Research, 2306 EECS, (313) 763-2174, which will provide the needed source for the desired information.

The programs in which the College participates are educationally oriented. Students wishing only to work in overseas locations are advised to contact the University's International Center for further information.

Cooperative Education

The Co-op Program is made possible through the cooperation of corporations, government agencies, and the University, whose goal it is to provide students with the opportunity for relevant employment experience. Co-op Education helps students apply theory and practice in a working situation and supports their efforts to plan their careers more effectively.

Engineering students who apply for Co-op Education are enrolled in a wide range of engineering degree programs, including: Aerospace; Atmospheric, Oceanic and Space Sciences; Chemical; Civil; Computer; Electrical; Interdisciplinary; Industrial; Materials Science; Mechanical; Naval Architecture and Marine; Nuclear; Engineering Physics.

Advantages

Among the many advantages to students participating in the program are the following: the opportunity to gain experience and expertise in a chosen field of study; progressively challenging responsibilities; growth in self-confidence; and greater personal financial independence. Students who have participated in cooperative education usually find that they are offered higher starting salaries than their classmates who have not had prior relevant work experience.

How the program works

Employers send letters to the Cooperative Education Office describing their hiring needs. The Co-op Office makes arrangements for interviews to be held with students whether on campus or at an employer location. On-campus interviews are conducted from October through November, and again from mid-January to March.

The Co-op Program Office works to match qualified applicants with employer needs. However, final selection for work assignments is made by the employer. Once a match has been made and both parties accept the terms of employment, a student will alternate a term of attendance at the University with a term of work.

> ***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 their employer company. The employer will rate their performance at the end of the work term and send a report to the Cooperative Education Office. Upon returning to the University, students are asked to submit an evaluation of their work experience to the Co-op Office.

How to sign up

Student participation in the Co-op Program is voluntary. Students may submit an application, resume, and transcript during the second term of their sophomore year. At that time, students are asked to select the corporations with which they desire to interview. To learn more about eligibility requirements, and for more information on the program, write or call: Cooperative Education Program, College of Engineering, 2423 EECS Building, The University of Michigan, Ann Arbor, Michigan 48109-2116, (313) 763-5086.

Placement

The College of Engineering considers the proper placement of its graduates to be very important, and it is recognized 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, 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 three 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 be informed that placement services for them are very limited. Almost all 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's Career Planning and Placement Office conducts lectures, discussion groups, and seminars each fall and winter on a number of career planning and job search topics; included are 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.

Minority Engineering Program Office (MEPO)

The Minority Engineering Program Office (MEPO) of the College of Engineering was founded in 1969. Its primary function is to provide a support system for minority students beginning in the seventh grade and continuing through graduate school.

At the pre-college level, MEPO offers students in grades 7 through 12 a chance to actively explore and prepare for engineering and other technical career fields. MEPO hosts a Summer Engineering Academy each year with a program that addresses pre-college students' academic and personal development needs. The Office also maintains a formal relationship with the Detroit Area Pre-College Engineering Program, Inc. (DAPCEP), which sponsors tutoring activities, academic enrichment and engineering exposure sessions, and hands-on projects for Detroit Public School students; and sponsors the Engineering Industrial Support Program (EISP), which sponsors similar activities for the Ann Arbor/Washtenaw County area.

At the college level, orientation/professional development workshops, career advising, academic advising services, and scholarship assistance is available through MEPO.

The Engineering Learning Resource Center (ELRC), located in the Electrical Engineering and Computer Science Building, is maintained by MEPO. The Center provides a study room with reference books, study materials, and microcomputers, and is available to students daily. Tutoring and study group assistance is also coordinated through ELRC. In addition, MEPO provides support to the student-based organization, the Society of Minority Engineering Students (SMES).

At the graduate level, MEPO has supported the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. (GEM) since its inception in 1976. GEM is involved in encouraging promising minority students to pursue graduate degrees in engineering.

The Minority Engineering Program Office (MEPO) is located at 2316 EECS Building, (313) 764-6497.

Women in Engineering Program

The Women in Engineering Program at the University of Michigan was established in 1991 in response to a growing concern for the quality of the undergraduate and graduate experience for women students, a national concern about the future pool of engineers in the face of changing demographics, and the need for the College of Engineering to more effectively utilize existing resources for women in the sciences. Serving approximately 22% of the undergraduate and 12% of the graduate engineering population, the Women in Engineering Program strives to:

- Increase the pool of qualified women pursuing engineering
- cooperatively create an environment which values the contributions of all
- provide students with resources and services to ensure their success
- work to prepare students for graduate programs and engineering careers

Several of the programs created to meet these goals include the Marian Sarah Parker Scholars Program, recruitment activities such as Expanding Your Horizons and Girls Are SMART (Science, Math and Related Technologies), a resource center, and walk-in advising. Students are welcome to the Women in Engineering office at any time to explore career and academic options including financial assistance, career guidance, and personal goal setting. The Marian Sarah Parker Scholars Program is designed to help junior-year women, who are interested in graduate school, develop the tools they need to make the process of getting an advanced degree successful, including an opportunity to work as a research intern with a College of Engineering faculty member.

The Women in Engineering office acts as an advocate for women students. Gender discrimination and sexual harassment, unfortunately, still occur. Women should know how to fight against it and what steps to take if it occurs. Educating the general student body, teaching assistants, faculty, and staff is an important component to combatting gender discrimination.

The Women in Engineering Program is located in the Student Services area of the College, 2421 EECS Building, (313) 763-5462. Input is always welcome for ways to improve the climate for the growing number of women pursuing a degree in engineering. Feel free to stop by anytime!

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, musical 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—campus-wide as well as those within the College. Used to advantage, college activities can provide a basis for many friendships and memorable times, as well as an opportunity for self-development.

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

College Student Government and Judiciary

Engineering Council. The University of Michigan Engineering Council 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 Engineering Council 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 Discipline Committee in the case of alleged violations of the Honor Code or College rules on conduct.

Honor Societies

The criteria for election to one of the honor societies are 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.

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, engineering leadership honor society
Eta Kappa Nu, national electrical engineering honor society
Golden Key, national honor society
Mortar Board, national senior honor society
Phi Beta Kappa
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, 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 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
Institute of Management Sciences/Operations Research Society of America (IMS/ORSA), student chapter
Michigan Materials Society (MMS), student chapter
Michigan Student Society of Professional Engineers (MSSPE)
National Society of Black Engineers (NSBE), student chapter
Society of Automotive Engineers (SAE), student chapter
Society of Hispanic Professional Engineers (SHPE), student chapter
Society of Manufacturing Engineers (SME), student chapter
Society of Minority Engineering Students (SMES)
Society of Women Engineers (SWE), student chapter

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 has continued to assist 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 different 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 763-5027.

Residence Regulations

Residence Regulations of the University of Michigan

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/her attendance as a student, unless and until he/she demonstrates that his/her previous domicile has been abandoned and a Michigan domicile established.

2. No student shall be eligible for classification as a resident unless he/she shall be domiciled in Michigan and has resided in Michigan continuously for not less than one year immediately preceding the first day of classes of the term for which classification 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 is defined as one whose domicile is elsewhere. A student shall not be considered domiciled in Michigan unless he/she is in continuous, physical presence in this State and intends to make Michigan his/her 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 necessarily conclusive, have probative value in support of a claim for resident classification:

   a. Continuous presence in Michigan for 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 commitment 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 para graph b, above, by taking the following steps within 20

calendar days after notice of such decision was served upon him/her, either in person, by mail, or by posting in a conspicuous place at 500 South State Street:

i. Provide the Residency Appeal Committee with 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. *The decision of the Residency Appeal Committee shall be the final recourse within the University.*

d. Reclassification, whether pursuant to paragraph b or c above, shall be effective for the term in which the applica tion therefore 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 LS&A Building, The University of Michigan, Ann Arbor, MI 48109-1382.

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

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 applicable federal and state laws prohibiting discrimination, including Title IX of the Education Amendments of 1972 and Section 504 of the Rehabilitation Act of 1973. It is the policy of the University of Michigan that no person, on the basis of race, sex, color, religion, national origin or ancestry, age, marital status, handicap, or Vietnam-era veteran status, shall be discriminated against in employment, educational programs and activities, or admissions. Inquiries or complaints may be addressed to the University's Director of Affirmative Action, Title IX/Section 504 Compliance, 6015 Fleming Administration Building, Ann Arbor, MI 48109-1340, (313) 763-0235. T.D.D. (313) 747-1388.

Admission as a Freshman

Freshmen 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 whom 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.

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. 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 so that they arrive in 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 freshmen 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 without deficiency:

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*

Deficiency: It is possible to be admitted with a deficiency. An applicant who has a deficiency is advised to consult the Director of Admissions concerning the particular program. Courses elected at the University to remove a deficiency will not count toward degree.

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 along 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. This brief essay may include your activities, interests, accomplishments and talents.

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.

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 Deans, 2419 EECS Building, College of Engineering, The University of Michigan, Ann Arbor, MI 48109-2116.

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 list below.)

1. *Engineering.* A Pascal advance placement test is normally given at the beginning of each term to students enrolled in Engr. 104. Students who pass this test should then drop Engr. 104 and take

Engr. 105 instead. After they pass Engr. 105, they will be awarded two hours of credit for the Pascal advance placement test, which will be noted as "Engr. 104, 2 hours" on their record, in addition to the one hour of credit for Engr. 105.

2. *Mathematics.* Placement Examinations for Math. 115 and 116 are usually offered in the first week of the fall term. Information as to the time and date will be available from Math. 115 and 116 instructors; the Mathematics Department Office, 3217 Angell Hall, 764-0337; and the Freshmen Counseling Office, 2419 EECS Building, North Campus, 764-5158. Students who have taken calculus in high school and have not taken the Advanced Placement examination for some reason but want credit for Math. 115 and/or 116, must take the Mathematics Department Placement Examination. **Members of the Mathematics Department DO NOT have the authority to exempt students from the Math. 115 or 116 degree requirements.**

   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.

3. *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 100-level courses cannot be used to satisfy the Humanities requirement; however, such 100-level courses can be used as free electives. Credit for 200-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.

4. *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 240 can be earned through this program.

Admission of Transfer Students

An applicant desiring to transfer from an approved college in the United States with advanced credit should write to Transfer Admissions, 2417 EECS Building, College of Engineering, The University of Michigan, Ann Arbor, MI 48109-2116, for an application form and instructions. The applicant will be required to arrange for an official transcript of both secondary school and college work, together with evidence of honorable dismissal from the previous college attended. This applies also to students planning to transfer from another unit in the University. Applicants are subject to departmental requirements for admission to a particular program, which means being a part of any quota the department may have and meeting the departmental GPA requirement.

Applications for admission should be submitted before March 1 for the following spring half term, summer half term, and fall term, and prior to October 1 for the winter term, for equal consideration. Applications will be accepted prior to any term if there is space available.

For admission without deficiencies, the applicant must satisfy the requirements for admission from high school as stated under Admission as a Freshman. The official college transcript must list the subjects studied, the number of credit hours and grades earned in each subject, and the basis upon which grades are assigned. Results of any aptitude tests that were taken in high school or college are helpful but not required.

The history of an applicant must demonstrate the ability of the applicant to meet the requirements of the College of Engineering for graduation. An overall scholastic average satisfactory for good standing at the previous institution may not in itself be sufficient. The grades earned in subjects related to the program elected by the applicant will be taken into account in judging ability to succeed. As a minimum requirement, the scholastic record as interpreted by the College of Engineering must be such that the applicant would be considered a better than average student if the work had been taken at this College.

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 the student can qualify under provision 1(f) of Requirements for Bachelor's Degree.

A student transferring at the junior level has the opportunity to attain a commission in the 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 the campus to make the necessary arrangements for basic training during the summer. See section on Military Officer Education Program for details.

Attention of prospective transfer students is called to the section on Planning the Student's Program.

Program with Basic Courses Taken in Another Institution

Basic pre-engineering courses in mathematics, chemistry, physics, English composition or literature and a computer course in either FORTRAN or Pascal as per the requested program requirements, are offered by many liberal arts colleges. Generally, such courses are offered as a complete two-year program designed to meet the requirements for study at the professional level in many engineering colleges (e.g., a mathematics sequence requiring four semesters or six quarters). In many institutions a student is able to satisfy the requirements of economics, and some elective courses in humanities and social sciences; the student may also be able to elect, engineering materials and engineering mechanics if equivalent material is covered.

A student in another college or university who desires to transfer to the College of Engineering should examine carefully the program that the individual plans to elect at this College 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 in the program the student wishes to elect. Other questions of general nature and those relating to admission requirements should be addressed to the Office of the Assistant Deans, 2419 EECS Building.

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 of 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, 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 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 Ann Arbor campus. Class standing is determined by the number of hours transferred. (See under Class Standing.)

Grades earned while enrolled in another college are not recorded and the student's grade-point average is determined solely by the grades earned while enrolled in this College. 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 question regarding the adjustment of credit, the student should consult the Office of the Assistant Deans.

Prescribed Program

If an applicant meets our admission standards, and is acceptable to the Program Advisor in the program of the student's choice, the Program Advisor will prescribe a program that meets the requirements for a degree in that program. 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 here (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.

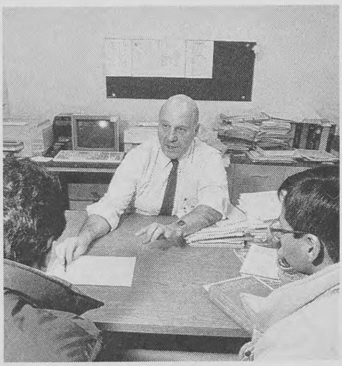
Admitting Graduates of Other Colleges

A graduate of an approved college may 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 enrollment and a minimum of 30 hours credit, 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 whose native language is other than English are required to complete basic college subjects, i.e., English, mathematics, chemistry, physics, and a computer course in FORTRAN (PASCAL for Computer Engineering only) language, before applying to the Assistant Dean for admission to the College of Engineering; they must 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 maximum and passing grades.

Foreign students must be prepared to finance their entire education while enrolled in the College of Engineering. It is estimated that a foreign student enrolled as a freshman would require approximately $81,500 to complete four years of study; a junior, $42,100; and a senior, $21,050. 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 the foreign student must maintain the same scholastic standards. In order that the student may know 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 Assistant Dean's office.

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 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. In order 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 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.

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 foreign students.

International Center

The International Center is housed in a wing of the Michigan Union building, with its entrance on East Madison Street. Services are provided here for both United States citizens anticipating travel abroad, and to foreign students coming into the United States.

For United States citizens planning to travel abroad, there are complete informational services, and experienced advisors to help individuals plan for trips abroad for the purpose of recreation, education, or employment. There is an extensive library of materials available 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, and 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 which provide tours, home hospitality, speaking engagements, and assistance for wives 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)

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

Requests for admission as a special student and supporting evidence of official college transcripts should be addressed to the Office of the Assistant Dean for Admissions and Instruction. Admission and approval of courses are subject to the approval of the program advisor of the program in which the courses will be taken. 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 the Assistant Dean 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 the Assistant Dean for Advising and Career Planning 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.

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 on effecting a transfer and, if necessary, 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 which are guided through the various steps of orientation: these include testing, student's identification card, consultation with academic advisors, selection of courses, registration, assessment of fees, 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 schedule. At the same time, parents are invited to attend a program particularly arranged for them.

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

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 the educational goal. 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 people who are qualified to help.

A student who experiences in the first term any difficulty 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 Deans, 2419 EECS Building.

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 at 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 of the undergraduate degree programs (described in this *Bulletin* beginning on page 89) 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 counseling 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

In addition to academic advising, the University provides specialized services to meet the various needs of students. A counseling service is available in the Counseling Center, Institute for Human Adjustment for those needing more specialized assistance to clarify their educational and vocational objectives. For those students experiencing personal difficulties requiring the assistance of specially qualified counselors, help is available at the Counseling Center or Counseling Services in the Michigan Union.

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.

The churches in Ann Arbor 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 55.) Descriptions are included at the beginning of the Departmental Undergraduate Degree sections.

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 during the winter term 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. 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 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.

Opportunity to Attain Two Bachelor's Degrees

Students with interests 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. Also available is an opportunity to obtain an additional bachelor's degree in the College of Literature, Science, and the Arts. (See under Requirements for Additional Bachelor's Degrees.)

Combined Degree Program

For Simultaneous Bachelor's Degree from the College of Literature, Science, and the Arts

Program Advisors: Assistant Dean Gene Smith, 2419 EECS
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 modern 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.

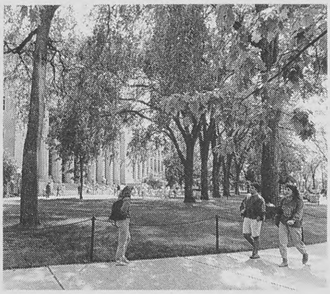
Candidates for a Bachelor of Science in Engineering (B.S.E.) or Bachelor of Science (B.S.) in the College of Engineering, combined with a Bachelor of General Studies (B.G.S.) in LS&A must: (a) satisfy the requirements of one of the degree programs in the College of Engineering; (b) take a minimum of 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 Bulletins of the two colleges. If unusual difficulties or special problems arise, students should consult the Combined Degree Program Advisors listed above. These Program Advisors will work with the students and their faculty advisors in attempting to find a solution.

Regulations

The following regulations for administering 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 Assistant Dean's office in the College of Engineering to apply for admission and to establish counseling 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 which 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 Engineering or Music. They lead to concurrent bachelor's degrees from both units, and are intended primarily for students who enrolled as freshmen in either unit.

The variety of courses which can be elected by students in the joint program makes it impractical to list specific requirements. 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 Bulletins of the College of Engineering and the School of Music.

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 1) complete one of the degree programs in the

College of Engineering, 2) complete one of the degree programs in the School of Music (usually 90 credits), and 3) 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 enroll as freshmen in either the College of Engineering or the School of Music. Formal application to begin the dual degrees should be made after the student has completed 30 credit hours of appropriate course work. Music students must have an overall Grade Point Average equal to or higher than the current minimum required by the particular engineering degree sought. Engineering students must have an overall GPA of at least 2.7 and meet the audition requirements for the particular music degree sought. Applicants must choose a field of specialization in both Engineering and Music. Admissions must be approved by the administration of both units and also by the Academic or Program Advisor in the field of specialization.

Planning the Student's Program

Students vary in their abilities and interests, 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 previous preparation and ability, exercising care not to include any courses which the student is judged to be unable to handle successfully.

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 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. However, Chemistry 125 will be required by most programs; thus, with few exceptions, *the common requirements amount to 56 hours.*

To be scheduled during first four terms as shown below.

Hours Credit	
16	1. Mathematics 115, 116, 215, and 216
4	2. English 124 or 125 or equivalent
3	3. Engineering 103 or 104
3*	4. Chemistry 130
8	5. Physics 140 and 141, and 240 and 241

Additional 18 hours (minimum)

3	6. Senior Technical Communication *(to be scheduled during senior year)*
17**	7. Humanities and Social Sciences *(May be scheduled any term—see Elective Studies)*

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

**Two programs require more than the minimum of 17. For complete information on the requirements of the respective programs, see the individual departmental 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 plan the courses for the first term. A student with an admission deficiency is required to remove it during the first year.

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 be in the student's file. It is the student's responsibility to make certain that all evidence is brought to the attention of the advising office before classes start in order that the advisor may make considered adjustment in the elections for the first term.

First Year

On the assumption that a student has no admission deficiency and no advanced placement credit, the individual will be expected during the first year to complete courses that include the following:

1. Mathematics 115 and 116
2. Chemistry 130 and 125, or, for some, 130, 210, and 211
3. English 124 or 125 or equivalent
4. Physics 140 and 141
5. Engineering 103 or 104
6. The Counselor will provide information on a number of courses that the student may elect to make up 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; for the remainder of the second-year elections, the student should refer to the description of the program selected. 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. Those 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.

Third Term

Hours Credit	Group I
4	* Mathematics 215
4	* Physics 240 with Lab. 241
5 or 4	+ Mech. Eng. 110, 210, or 211
3	+ Mat. Sci. & Eng. 250
4	* Humanities or Social Science
	Group II
5	Chemistry 215 and 216
2	Aero. Eng. 200
4	Chem. Eng. (Mat. Sci.& Eng.) 230
3	CEE 232
3	EECS 250
3	A.O. & S.S. 304
3	Nav. Arch. 270

Fourth Term

Hours Credit	Group I
4 or 3	+ Mathematics 216 or 286
3	+ Mech. Eng. 240
3	+ Mech. Eng. 231 or 235
4	* Humanities or Social Science
	Group II
3	Physics 242
3	CEE 312
4	EECS 216
3	I. O. E. 300, 310, or 333
3	Mech. Eng. 251
3	Mech. Eng. 252
3	Nav. Arch. 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 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 three (3) credit hours of mathematics. Students should consult with their program advisor to determine how these three 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	4	Math 185 or other honors courses
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 14 degree programs offered by the College of Engineering. The complete College requirement is described under *Elective Studies*.

Introductory Composition Requirement

During the time of Orientation to the University and the College of Engineering, all freshmen will write an essay to be evaluated by the ECB (English Composition Board). According to the quality of their performance in this essay, 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 English 125 and 167, 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 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: 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 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: (1) Advanced Placement Examination, (2) Foreign Language Placement Examination after arriving at the University. Humanities credit will be granted for all foreign languages that are elected and successfully completed at the University of Michigan or any other college or university. First year foreign language courses taken for Humanities credit cannot be elected as pass/fail courses. 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 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 (100- and 200-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, 497, 498 or 499. (See page 395.)

Engineering

Three credit hours of digital computing or equivalent are required in each program. This requirement may be met by electing Engineering 103, Digital Computing, for three credit hours, in which FORTRAN-77 is the programming language used. Alternately, Engineering 104, which uses Pascal as the programming language, may be elected.

Engineering 103 or 104 is intended to help the student feel comfortable at interacting with a computer, and to give him or her a general awareness of the organization and capabilities of digital computers. The course meets twice weekly, a lecture being followed immediately by a laboratory in which the students use IBM PS/2 personal computers both stand-alone and for communicating with the large mainframe IBM machine at The University of Michigan's Computer Center.

Chemistry

The minimum requirement in chemistry for most undergraduate degree programs is five 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 five hours of chemistry would normally elect Chem 130 (3 hrs.) and 125 (2 hr. laboratory) during the freshman year. Students expecting to enter a degree program requiring additional chemistry would normally elect Chem 130 (3 hrs.), 210 (4 hrs.), and 211 (1 hr. 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 orientation or by receiving advanced placement credit for Chem 130. These students will be given the option to take Chem 210 and 211 for an advanced 5 hour chemistry sequence. The courses must be taken concurrently. Students who receive advanced placement credit for Chem 130 and 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 (3) with laboratory, Physics 141 (1). This course assumes knowledge of calculus.

A second course, Physics 240 (3), with laboratory, is required by all programs and is normally scheduled in the third term. A third course, Physics 242 (3), is required for programs in Aerospace Engineering, Electrical Engineering, Engineering Physics, and Nuclear Engineering.

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 this College 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. 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) which focuses the student's H/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) can not 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 (six credit hours)
   — at least two courses in humanities, totaling at least six 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 or HU.
d. Advanced placement foreign language credit at the second year level or higher.

2. Sequence of humanities or social science courses — a sequence of at least two courses in either the humanities or the social sciences, or both, totaling at least six credit hours, must be taken from the same department or division (for example, History), one of which must be a 300- or 400-level 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 (1).
   b. Any course designated as Social Sciences (SS) in the *LS&A Bulletin.*
   c. Eng. 451: Technology & Society (Social Sciences Credit).

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 three credit hours of performance courses in the School 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 and augment the student's preparation for continued or professional interests 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 77 for further information on P/F elections.)

Fee Regulations, Expenses, Indebtedness

A non-refundable fee of $30 will be required of each applicant for admission to the University.

The fees for one full term for the 1992-93 academic year were as follows:

	Michigan Resident	Non-resident
Lower Division	$572 for first hour + $148 for each additional hour	$885 for first hour + $549 for each additional hour
12-18 credit hours	$2,177	$7,015
Over 18 credit hours add	$148 per credit hour	$549 per credit hour
Upper Division *(55 or more credit hours)*	$615 for first hour + $180 for each additional hour	$1,050 for first hour + $610 for each additional hour
12-18 credit hours	$2,585	$7,750
Over 18 credit hours add	$180 per credit hour	$610 per credit hour

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

The following guideline was used for the total expenses for upper division students for 1992-93:

Michigan resident (two terms, academic year)	$17,280
Non-Michigan U.S. citizen (two terms, academic year)	$23,888
Foreign (three terms, calendar year)	$35,832

Fees are subject to change at any time by the Regents of the University.

Detailed information relating to fees, deposits, payments, and refunds may be obtained in the Assistant Dean's Office and/or may be found in the first few pages of the 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 Assistant Dean's Office.

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

A transfer student is classified in this manner in terms of the tentative adjustment of credit applicable to the elected program. On a prescribed program the student will be a senior when there are 35 hours or less to complete.

Withdrawal

A student withdrawing after registration shall pay a disenrollment fee according to the rules in effect at the time of withdrawal as published in the *Time Schedule* for each term.

Indebtedness to the University

Proper observance of financial obligation is deemed an essential of good conduct, and students who are guilty of laxness in this regard to a degree incompatible with the general standards of conduct shall be liable to disciplinary action by proper University authorities. 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 the life and conduct of the student while enrolled at the University.

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

The student is expected to develop his or her relationships with integrity; to respect the rights and properties of others; to comply with University regulations and public laws; and to live with high standards of personal and social conduct.

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 should discharge all duties with the high 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 (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 Canons of Ethics for Engineers developed and adopted by national professional engineering societies. The following statement relating to ethical conduct is part of a revision of the Canons approved 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, a number of 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, home work, and laboratory reports. Although the instructor is available for questions, the examination is not 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 764-8470, which 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, available at the Records Office, which explains the principles and operation of the Honor Code.

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 that they benefit from studying together and discussing home assignments and laboratory experiments. When any material is turned in for inspection and grading, the students should clearly understand 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, maturity, and devotion to recognized standards of conduct that contribute to the dignity of the profession. The reasons for good attendance should be obvious, and students may expect unexcused absences to reflect in their final grade.

All students are required to account to their instructors for their absences. An instructor may report to the 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 the 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 the Assistant Dean.

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's 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. Staff in SSD 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

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

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

See Honor Code for procedures pertaining to examinations.

Election of Studies

Term. A term is a period of enrollment extending over approximately four months, including examinations. Term requirements are equivalent to those of the conventional semester. Schedule, by months, of the University's year-round calendar 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" or "semester hours credit."

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.

Classification and Registration

As needed, the Assistant Dean's Office will prepare instructions to program advisors and students relating to election of courses, classification (including assignment to sections), and registration (official enrollment).

All students are required to have and use a Student Identification number for registration and records purposes.

Completion of both the classification and registration procedures is required before a student attends any classes or uses any University facilities. Late registration is subject to a $15 fee and the fee increases by $10 at the end of each month that the registration is late, so that as much as an additional $40 may be added to the original $15 fee. The fee must be paid in advance by the late registrant.

Unless a student is classified and 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 Assistant Dean's Office and pay the usual disenrollment fee as stated in the current *Time Schedule.*

Change of Classification

After a term has begun, adding or dropping a course can be made official only through use of an "election change request" form, and upon authorized approvals.

A course may be added during the first few weeks of a term with the expressed permission of the instructor with whom arrangements must be made for the necessary make-up work. In most cases, this consideration puts a practical time limit of the first two weeks of a term (or the first week of a half term) for adding courses. Thereafter the program advisor (or the Assistant Dean for Admissions and Instruction) also must approve any addition.

A change in classification from credit to audit must be made during the first six weeks of a term (the first three weeks of a half term). No change to audit status will be allowed after this period.

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.

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. A tentative program established at this time will be helpful as a guide to the student through the completion of the degree requirements. 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 Records Office in the EECS Building.

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.

Elections Considerations

At any time, a student's elections must take into account the preparation (including deficiencies and prerequisites), demonstrated ability and performance, the need for repeating courses, interests and career plans, extracurricular activities or part-time employment, and recommendations of the Committee on Scholastic Standing, when applicable.

Any student who fails to maintain a satisfactory proficiency in English in any work in the College of Engineering shall be reported to the Assistant Dean. After consultation with the program advisor, the student may be required to elect such further work as may be deemed necessary.

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 in Room 2420 EECS Building.

Dropping a Course

The College expects students to finalize their academic schedules during the first three weeks (first two weeks of a half term). During this time changes may be made in academic schedules for educational reasons with approval of the student's academic or program advisor. Courses dropped during this period do not appear on the academic record. Fees are determined by the schedule in effect at the end of the third week of a full term and at the end of the second week of a half term.

Students will be permitted to drop courses of less than a full term's duration (mini-course) up to the mid-point of the course without it being recorded on the transcript.

Students dropping a class from the fourth week through the ninth week (three to four and one-half weeks for the half terms), must obtain permission from the program advisor. A "W" will appear on the transcript.

From the ninth week to the end of the term (four and one-half to the end of half terms), 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 in the Records Office, 2420 EECS Bldg.

The grade for any course dropped without the permission of the program advisor or 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 requests dropping all courses, the program advisor will refer the student to the Assistant Dean's Office to effect a total withdrawal from the College.

A Change of Election Fee of $10.00 is charged to all students who drop/add, change credit hours, or change modifiers after the end of the third week in a full term, or the second week in a half term. The fee will be assessed for each student session, regardless of the number of changes made at that session.

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 the 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.

The Assistant Dean may be consulted for procedures to effect a transfer.

Withdrawing

In order to disenroll after having registered (including early registration), the student must report to the Assistant Dean's Office, 2417 EECS Bldg., 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 the 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 may specify the conditions for readmission.

Disenrollment fees vary from a minimum of $50.00 for first three weeks of a term to full assessed fees for the term after the sixth week.

Honorable Dismissal

Honorable dismissal will be granted to a student who wishes to transfer to another college when the record of the student is void of any College of Engineering or University action regarding misconduct.

Readmission

A student who is non-enrolled for more than 12 months must apply for readmission through the Assistant Dean's 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 Office of the Assistant Deans.

A student whose further 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 Health Service for clearance.

Grades and Scholastic Standing

Academic Record

Each student's "Academic Record" is the cumulative record maintained by the Engineering Records Office in the Office of the Registrar, of courses elected, grades, averages, and other matters relating to the progress of the student. A copy is given to the student's program advisor at the end of each term. Other copies are released by the Transcript Office, 555B LS&A Building, 764-8280, only when requested by the student except as restricted under Indebtedness to the University.

An individual may obtain an official copy of the academic record at any time upon payment of $4.00 per official copy.

A student is provided with an official copy (free) of the academic record at the time of graduation.

Grade Reports

Unless withheld for infringement of rules, each term's grades are reported to the student.

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 (twice as many grade points as hours computed); each course which is graded with A+ through E, or ED is included in the computations.

Averages

The term grade point average 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 on the basis of:

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 do not affect 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), by the hours attempted (Michigan Term Hours).

Grades associated with transfer credit are not 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 '86).

A course elected under pass/fail option does not affect a student's average.

Pass/Fail Option

A student who completed 30 hours of credit or more, including advanced credit, and is in good scholastic standing may elect courses on a pass/fail basis only as follows:

Elective courses in Humanities and Social Sciences or courses to be used as Free Electives. The 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 which is offered only on a pass/fail basis would not be counted in the above totals. The Introductory English Composition, Senior Technical Communication, and first year foreign language courses taken for Humanities credit cannot be elected as pass/fail courses. Courses elected pass/fail which exceed the limitations stated above cannot be applied in any way to the degree Passed courses, however, will appear in the cumulative totals.

The following regulations will apply:

1. The decision to elect a course on pass/fail basis must be made within the first six weeks of the term (or first three weeks of a half term). The student must abide by the decision to take a course for pass/fail once it has been made.

2. The Assistant Dean may approve for a freshman the election of a course offered only on a pass/fail basis.

3. Instructors are not notified of pass/fail elections; they will report grades as usual, A+ through E. The Records 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).

4. To be eligible for the Dean's Honor List a minimum of 12 credit hours (six for a half term) must be elected for grades.

5. To be eligible for Recognition on Diploma a minimum of 45 hours of credit must be completed with grades.

6. If a student has taken a course for pass/fail and subsequently changes the degree program of study such that 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 course on the basis that the instructor will report the grade as pass/fail for each student enrolled, and that the grade will be treated on the same basis 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 a required one 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 might be: design, survey-type, individual directed research, laboratory, or undergraduate seminars.

c. It 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 degrees of scholastic deficiency identify a student's unsatisfactory performance: *Probation and Enrollment Withheld.*

Scholastic standing is determined by observing both the term and cumulative grade points. When a student has less than twice as many grade points as hours computed, the individual is deficient in the number of grade points required to make the total equal to twice the hours computed. (Example: Term—15 hours computed with 29 grade points, student deficient 1 grade point. Cumulative—80 hours computed with 150 grade points, student deficient 10 grade points.)

Scholastic standing will be determined as follows:

Rule 1. Probation: When a student has a deficiency of 0.001 to 9.999 grade points on either the term or cumulative record, the student will be placed on probation. The College Recorder will enter the notation "Probation" on the Academic Record. A student on probation may continue enrollment but must consult with the counselor (if freshman) or program advisor to initiate any adjustments in elections which 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 shall be put on enrollment withheld.

Rule 3. Enrollment Withheld: When a student has a deficiency of 10 grade points or more on either term or cumulative record, enrollment will be withheld. The College Recorder will enter the notation "Enrollment Withheld" on the Academic Record.

Rule 4. When a student's enrollment is withheld as a result of grades earned during the previous term, the following procedure will be employed: a student may appear before 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 be extended the privilege of presenting a petition complete with evidence of the associated circumstances for the unsatisfactory performance to the Committee on Scholastic Standing for consideration for an interview 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 should be given, the Committee may reinstate the student on probation.

For an interview, you must first petition the Committee for reinstatement in writing. Petition forms may be picked up in person or obtained by calling or writing the Dean's Office, 2309 EECS Building (313/763-3170). Appointments for interviews should be made through the same office.

The petition must be received 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 what 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 grade point deficiency on term or cumulative.
c. Reinstated on Probation—10 or more grade point deficiency but reinstated on grounds of extenuating circumstances surrounding poor record.

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 (for freshmen) 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 and before continuing enrollment in order to make any changes in elections that may be necessary.

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.

E Grades

Neither credit nor grade points are allowed 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 vital 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 and without enrolling in the class again. 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 regardless of whether or not the student is enrolled. The student should plan to complete the work as soon as possible; however, in order that credit may be allowed, 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 Engineering Recorders in the Office of the Registrar when the work is completed.

Other Irregularities

Irregularities associated with failure to submit change in classification to the Records Office, 2420 Electrical Engineering and Computer Science Building, 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 allowed 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's Office 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) 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 honor points will be granted.

A student repeating a course in which a C- through D-was previously earned will receive honor points 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 (six for a half term) and earn 3.50 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 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 Registrar's Office, and recipients of this honor are invited to attend the annual Honors Convocation. *The criteria for awarding Class Honors are currently under review and are subject to change.*

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 Registrar's Office, and recipients of this honor are invited to attend the annual Honors Convocation.

Branstrom Award

Students in the top 5 percent of the freshman class are eligible for this honor, administered by the Office of the Registrar, if they have earned at least 14 *graded* credits at Michigan. A book with an inscribed nameplate is presented to each student, and 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 Women in Science 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-long 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 and several employers of engineers give special recognition or awards to students with high scholastic achievement, with records of service to the College and its student organizations, or with evidence of extraordinary potential for professional leadership. Information on qualification requirements can be picked up in the Dean's office.

Society Recognition

Distinguished scholarship and services to the College are also recognized by election to any of a number of honor societies that are included with the list of organizations 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 which have been completed with grades while enrolled in this College (or as directed by the Executive Committee) will be recommended for a degree (and for each degree, if more than one) 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 may be noted from the sample schedules appearing with the several program descriptions. A student who is admitted with advanced preparation, with demonstrated levels of attainment, or with ability to achieve at high levels may materially 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.

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 Horace H. Rackham School of Graduate Studies.

Requirements for a Bachelor's Degree

As a basic principle, the quality and level of attainment reached by the student are considered to be of greater significance in determining the requirements and standards for graduation than the completion of a specified number of credit hours.

In order 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 done 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 which 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 those courses in which the program advisors judge 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 for 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 department, or in courses designated by the program in the case of interdisciplinary programs.
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 used to satisfy each of the two programs must satisfy the cumulative grade point average requirement of 2.00 or more.
2. To obtain an additional bachelor's degree in the College of Literature, Science, and the Arts (LS&A), refer to program requirements under Combined Programs with LS&A.

Diploma and Commencement

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

The application must be submitted to the student's department office, at the beginning of the term in which the student is reasonably certain of completing the work for the degree.

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

All students who are entitled to receive diplomas are expected to be present at the Commencement exercises appropriate to the date of graduation. 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 for a number of the degree programs includes a schedule that is an example of one leading to graduation in eight terms; this 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 electing Military Officer Education Program or a freshman admitted with advanced placement.

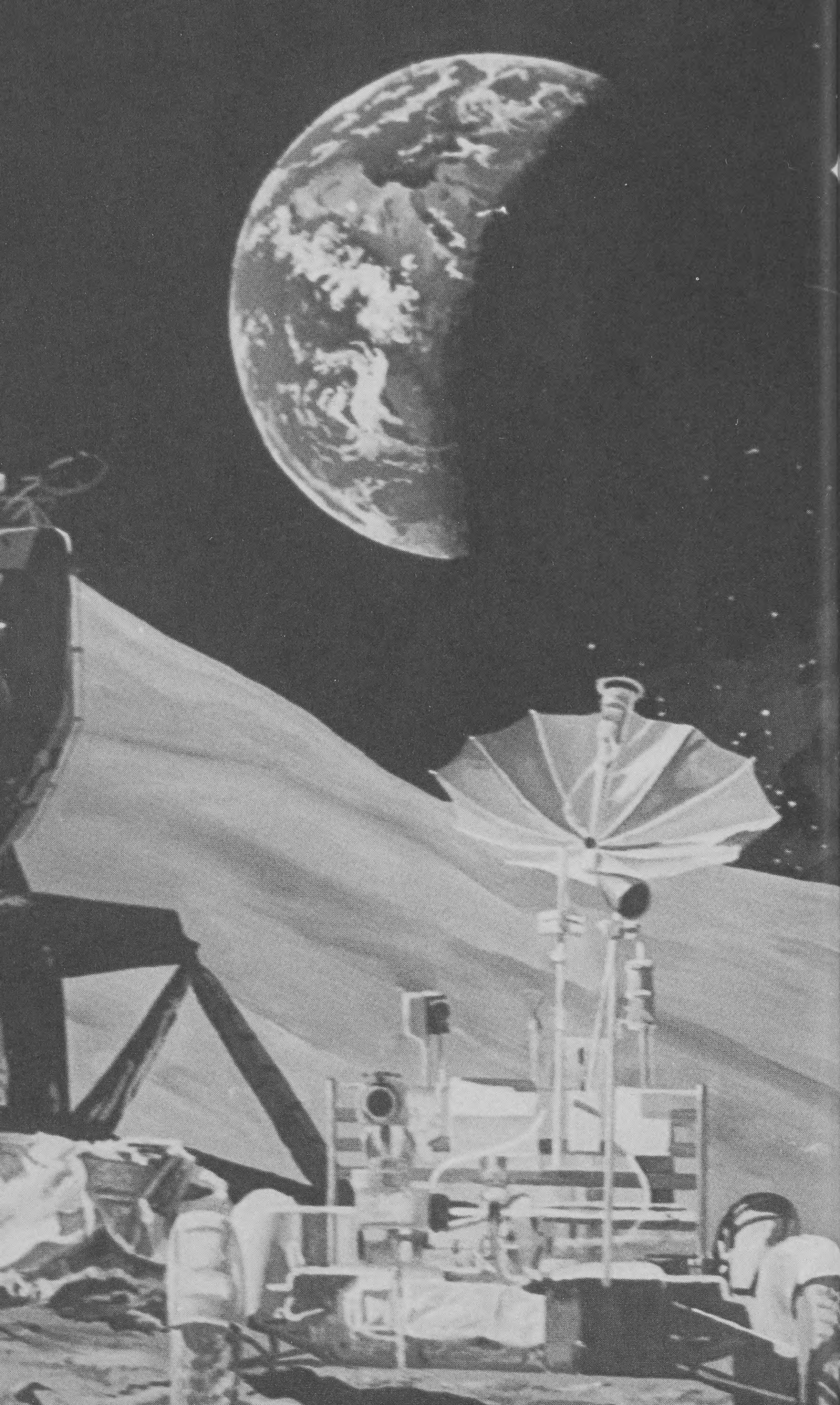
A transfer student attending a community or liberal arts college and pursuing a pre-engineering degree program may not be able to follow a similar schedule because of a lack of certain offerings. If this is the case, the student should elect humanities and social sciences subjects in place of the professional courses listed in the schedule during terms three and four.

Even though a student is unable to maintain the pace of the schedule printed, it will be desirable to follow the order in which the courses are scheduled to satisfy prerequisites.

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.

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 administered on a College-wide basis. See Contents at front of this *Bulletin* for listing.



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 light-weight 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 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, spacecraft and other vehicular systems and subsystems. Courses in gas dynamics treat fluid and gas flow around bodies and through

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A portion of a mural in the Aerospace Building, "A History of Aerospace Engineering at Michigan," by Brian Myers, 1978. This section depicts the *Apollo XV* mission with three U-M astronauts.

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, light-weight 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 aero-physical 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 ABET.

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.

Combined Degrees

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.

Several Engineering students participated in **Aero Design '93**—an international airplane design competition for college students. Shown here with one of the entries are (from left) team leader and Aerospace Engineering senior John Rose, Aerospace Engineering senior Jason Evink, and Mechanical Engineering senior Nadine Messih. Students got plenty of hands-on experience as they competed against 88 other schools in this year's competition, sponsored by the Society of Automotive Engineers. (At the time of publication, race results were not yet in, but the team expected a good solid finish.)

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. Many students find that it is necessary to extend their schedule to 8-1/2 or nine terms.*

Required Programs

	Hours	1	2	3	4	5	6	7	8
		Sample Schedule by term							
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, 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	-	-	-	-	-	-	-
Chemistry 125*	2	-	2	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences (See page 60)	17	-	4	-	-	3	3	3	4
Advanced Sciences (3 hrs.)									
Physics 242	3	-	-	-	3	-	-	-	-
Related Technical Subjects (20 hrs.)									
Mech. Eng. 110, Statics	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mech.	3	-	-	3	-	-	-	-	-
Mech. Eng. 240, Intro. to Dynamics	3	-	-	-	3	-	-	-	-
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	3	-	-	-	-	-
Mech. Eng. 235, Eng. Thermodynamics	3	-	-	-	3	-	-	-	-
EECS 314, Cct. Analy. & Electronics	3	-	-	-	-	3	-	-	-
Engineering 303 or Math. 371, Comp. Meth.	3	-	-	-	3	-	-	-	-
Program Subjects (33 hrs.)									
Aero. Eng. 200, Gen. Aero. and Astro.	2	-	-	2	-	-	-	-	-
Aero. Eng. 301, Laboratory I	2	-	-	-	-	2	-	-	-
Aero. Eng. 302, Laboratory II	2	-	-	-	-	-	2	-	-
Aero. Eng. 314, Structural Mech. I	3	-	-	-	-	3	-	-	-
Aero. Eng. 320, Intro to Gas Dyn. I	3	-	-	-	-	3	-	-	-
Aero. Eng. 330, Intro to Gas Dyn. II	3	-	-	-	-	-	3	-	-
Aero. Eng. 340, Mechanics of Flight	3	-	-	-	-	-	3	-	-
Aero. Eng. 350, Aero. Eng. Analy.	3	-	-	-	-	3	-	-	-
Aero. Eng. 414, Structural Mech. II	3	-	-	-	-	-	3	-	-
Aero. Eng. 420, Aerodynamics I	3	-	-	-	-	-	3	-	-
Aero. Eng. 430, Aerospace Propulsion	3	-	-	-	-	-	-	3	-
Aero. Eng. 471, Automatic Control Sys.	3	-	-	-	-	-	-	3	-
Design and Technical Electives (10 hrs.)	10	-	-	-	-	-	-	4	6

These must include one of the following design courses:

Aero. Eng. 481, Airplane Design, or Aero. Eng. 483, Aerospace System Design
Aero. Eng. 484, Computer Aided Design

Technical electives are to be chosen from advanced courses in Aero. Eng. and related areas, with approval of program adviser.

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

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

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 basic 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 atmosphere ranging from the sea floor to the altitude of orbiting satellites. This knowledge is necessary to understand and manage global change caused by natural and man-made modifications of our environment.

The applied aspects of the disciplines treated in AOSS cover a wide range of activities and interests. The applied atmospheric scientists will be called upon to solve meteorological problems in connection with air pollution, industrial plant location and processes, the design of structures and the wind loading of them. Many important decisions on transportation, whether by land, water, or air, depend critically on meteorological factors. The applied oceanographer is concerned with 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

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Many diverse career opportunities are available for atmospheric, oceanic, and space scientists in industry, private consulting firms, government, higher education, and research.

system. The B.S. degree in AOSS will prepare graduates for employment in the National Weather Service, private weather forecasting companies, air and water quality management firms, or NASA.

It is recognized that the undergraduate program cannot, in the time available, adequately treat all areas of importance. Graduate work, therefore, is strongly encouraged.

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 of ten required courses 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. A total of 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. The technical electives are to be at the 300 level or above. Some examples of electives are shown below:

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

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

Preparation for a non-technical profession, such as law, business, or medicine: AOSS 412(3), 479(3), Statistics 412(3), Nat Res 310(4), Engin 451(3), Econ 400(4), Pol Sci 412(3), Phil 356(4), Geo Sci 123(2).

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).

Facilities

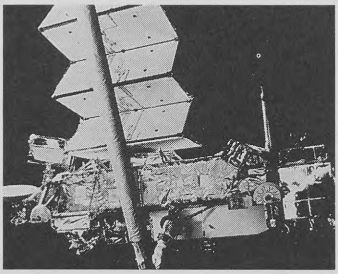
Laboratories include Air Pollution Meteorology, Meteorological Instrumentation, and a Synoptic Meteorology Laboratory where current weather data including satellite information are received over a satellite link. The Department also operates a Radiation Measurement Analysis Facility, which includes comprehensive 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.

Requirements

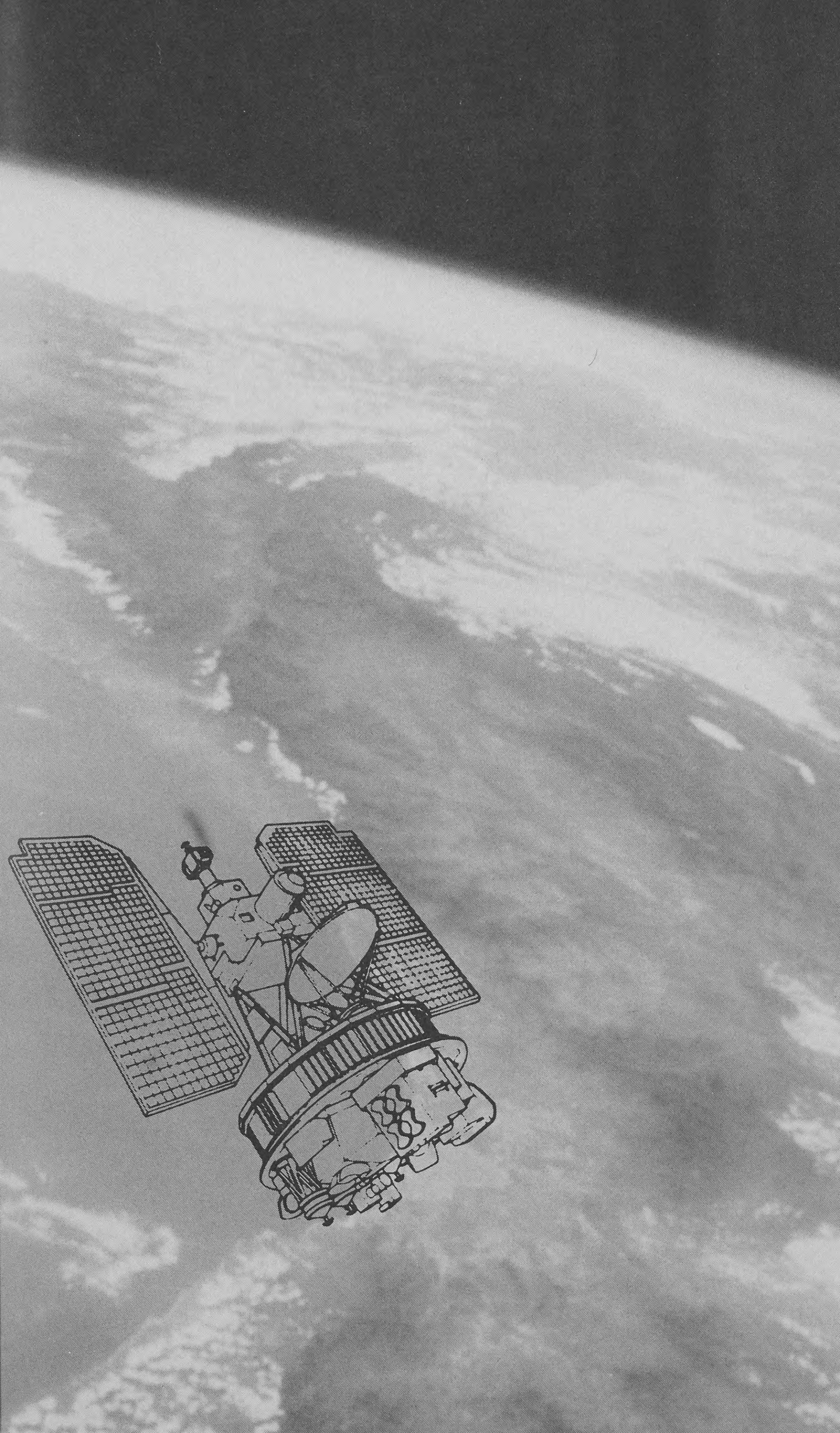
Candidates for the B.S. degrees must complete the 120 credit hour program listed on the following page.

The sample schedule is an example of one leading to graduation in 8 terms. Many students find that it is necessary to extend their schedule to 8-1/2 or nine terms.



Required Programs

	Hours	*Sample Schedule by term* 1	2	3	4	5	6	7	8
Subjects required by all programs (58 hrs.)									
(See under "Minimum Common Requirements," page 55, 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 135, or 210 and 211	5	3	2	-	-	-	-	-	
Physics 140 with Lab. 141	4	-	4	-	-	-	-	-	-
Physics 240 with Lab. 241	4	-	-	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Soc. Sci.	19	-	6	4	6	3	-	-	-
AOSS Core Courses									
304 Atmos. & Ocean. Environment	3	-	-	3	-	-	-	-	-
305 Intro. to Atmos. & Ocean. Dynamics	3	-	-	-	3	-	-	-	-
335 Space Science & 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 Proceses	3	-	-	-	-	-	3	-	-
462 Instrumentation for Atmos. Interactions	3	-	-	-	-	-	-	-	3
475 Earth-Ocean-Atmos. Interactions	3	-	-	-	-	-	-	-	3
Technical Electives	16	-	-	-	-	3	3	4	6
Free Electives	16	-	-	-	-	6	3	4	3
Total	**120**	**14**	**16**	**15**	**16**	**15**	**12**	**14**	**18**



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 in the last decade of the nineteenth century. The Michigan Student Chapter of the American Institute of Chemical Engineers was the first established by that professional society.

Chemical Engineering, of 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, such as pure research, development, process design, plant operation, marketing, sales, and corporate or government administration.

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

The program allows seven hours of free 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, computers, nuclear energy, biochemical processes, solar energy, and natural resource usage.

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Miranda Rivers (BSE Chem E, Dec '93) works with a Total Internal Reflection Microscope.

This program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology

Facilities

The facilities located in the Dow Building include biochemical engineering, catalysis, energy logistics, ecosystem simulation, electrochemical, heat transfer, light scattering and spectroscopy, petroleum research, polymer physics, process dynamics, real time computing, and surface science laboratories; and in the George Granger Brown Laboratory, 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 fourteen additional hours in the field of process, physical, and mechanical metallurgy. Those who choose the materials option will take at least fourteen additional hours in physical metallurgy, physical ceramics, and polymers.

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. Transfer students may find that it is necessary to extend their schedule to 8-1/2 or nine 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

	Hours	1	2	3	4	5	6	7	8
		Sample Schedule by term							
Subjects required by all programs (54 hrs.)									
(See under "Minimum Common Requirements," page 55, 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	8	-	4	-	4	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Human. and Social Sciences (See page 60) (to include a course in economics)	17	3	3	3	-	4	4	-	-
Advanced Science (21 hrs.) (Note A)									
Chem. 210 & 211, Struct. & Reactiv. I & Lab.	5	-	5	-	-	-	-	-	-
Chem. 215 & 216, Struct. & Reactiv. II & Lab.	5	-	-	5	-	-	-	-	-
Chem. 302, Inorganic Chem.	3	-	-	-	-	3	-	-	-
Chem. 468, Physical Chemistry	4	-	-	-	-	-	4	-	-
Chem. 469, Physical Chemistry	4	-	-	-	-	-	-	4	-
Related Technical Subjects (10 hrs.)									
EECS 314, Cct. Analy. and Electronics	3	-	-	-	-	-	-	3	-
EECS 315, Cct. Analy. and Electronics Lab.	1	-	-	-	-	-	-	1	-
Elective Courses in Engineering ***(Note B)***	6	-	-	-	-	3	-	-	3
Program Subjects (36 hrs.)									
Chem. Eng. 230, Thermo. I	4	-	-	4	-	-	-	-	-
Chem. Eng. 330, Thermo. II	4	-	-	-	4	-	-	-	-
Chem. Eng. 341, Fluid Mechanics	3	-	-	-	3	-	-	-	-
Chem. Eng. 342, Heat and Mass Transfer	3	-	-	-	-	3	-	-	-
Chem. Eng. 343, Separation Processes	3	-	-	-	-	3	-	-	-
Chem. Eng. 344, Reaction Eng. and Design	3	-	-	-	-	-	3	-	-
Chem. Eng. 360, Chem. Eng. Lab I	3	-	-	-	-	-	3	-	-
Chem. Eng. 460, Chem. Eng. Lab II	3	-	-	-	-	-	-	-	3
Chem. Eng. 466, Process Control and Dynamics	3	-	-	-	-	-	-	3	-
Chem. Eng. 486, Chem. Proc. Sim. & Design I.	3	-	-	-	-	-	-	3	-
Chem. Eng. 487, Chem. Proc. Sim. & Design II.	4	-	-	-	-	-	-	-	4
Free Electives (7 hrs.)	7	-	-	-	-	-	3	1	3
Total	**128**	**17**	**16**	**16**	**15**	**16**	**17**	**15**	**16**

Note A. An advanced natural science course may be substituted for Chem. 468 or Chem. 469.
Note B. The courses are to be at the 200 or higher level.

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 engineers will be even more important and the challenges more exciting. Civil 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, 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 civil engineering. In all of these areas, civil 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.

Construction Engineering and Management

Planning, estimating, scheduling, and managing the construction of engineered facilities using modern construction methods, materials, and equipment. Business and legal principles of construction contracting.

Environmental Engineering

Municipal and industrial water distribution and waste collection, water quality and

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

Shown here are a few members of the 1992 Concrete Canoe Team (clockwise from bottom left): project advisor, Professor Iris Tommelein; Kevin Schmidt, engineering technician; Adam Larky, graduate student; Cathy Jo Cavanaugh, undergraduate student. (Photo, courtesy of *Ann Arbor News*.)

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.

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, polymer, and ceramics), micromechanics of composite materials, durability of materials, and innovative materials/structures.

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.

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 Department has its departmental offices in the G. G. Brown Building.

The George Granger Brown 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.

Requirements

Candidates for the Bachelor of Science degree in Engineering (Civil Engineering)—B.S.E. (C.E.)—must complete the program listed on the next page. *The sample schedule is an example of one leading to graduation in eight terms. Many students find that it is necessary to extend their schedule to 8-1/2 or nine 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

	Hours	1	2	3	4	5	6	7	8
		Sample Schedule by term							
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, 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	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences *(**Note A**)*	17	-	3	3	-	4	4	3	-
Advanced Electives									
Advanced Mathematics *(**Note B**)*	3	-	-	-	-	3	-	-	-
Advanced Sciences *(**Note C**)*	3	-	-	-	-	-	-	3	-
Engineering Sciences (20 hrs.)									
Mech. Eng. 110, Statics	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mechanics	3	-	-	3	-	-	-	-	-
Mech. Eng. 240, Introduction to Dynamics	3	-	-	-	3	-	-	-	-
CEE 280, Intro. to Environ. Engin.	3	-	-	-	3	-	-	-	-
Mech. Eng. 235, Engineering Thermodynamics *(**Note D**)*	3	-	-	-	3	-	-	-	-
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	3	-	-	-	-	-
CEE 325, Fluid Mech.	3	-	-	-	-	3	-	-	-
Program Subjects (17 hrs.)									
CEE 303, Computational Methods	3	-	-	-	3	-	-	-	-
CEE 312, Theory of Structures	3	-	-	-	-	3	-	-	-
CEE 315, Design of Structures	3	-	-	-	-	-	3	-	-
CEE 400, Contracts and Engr. Legal Rel.	2	-	-	-	-	-	-	-	2
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, Environmental Chemodynamics
CEE 485, Water Supply & Waste-water Eng.

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

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

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). Students electing Chem. 210 are advised to elect Chem. 211 (1).

Note D. Chem. Eng. 230 (3) may be substituted for Mech. Eng. 235 (3).

Note E. Upper Division 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 regarding the electives required for the completion of the program. A student must elect one set of two courses which will provide the required minimum of 3 units of design. Groupings of courses which meet the technical concentration requirements are available in the following areas:

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

Electrical Engineering and Computer Science

Modern electrical engineering is itself a broad and diverse field, but 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 the program students work with modern laboratory equipment and are exposed to the most recent analytical techniques and technological developments in the field. Association with outstanding faculty, most of whom are actively engaged in research or professional consulting, serves to acquaint students with the opportunities and rewards available to practicing electrical or computer engineers and scientists. If further specialization and a high degree of competence in a particular area is desired, students are encouraged to seek an advanced degree. The advanced degrees available are described under Graduate Studies.

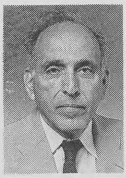
Facilities

The facilities of the Electrical Engineering and Computer Science Department include instructional laboratories in Electrical Engineering and Computer Science and the

Researchers at work in the Solid State Electronics Laboratory.

following laboratories devoted primarily to research: communications and signal processing, bioelectrical science, systems engineering, radiation, solid-state electronics, optical science, vehicular electronics, advanced computer architecture, computer vision and cognitive science, artificial intelligence 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
Keki Irani
Program Office
3415 EECS Building
(313) 763-2305

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 ABET.

Advising

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

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. Many students find it necessary to extend their schedule to 8-1/2 or nine terms.*

Required Programs

	Hours	Sample Schedule by term 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, for alternatives)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125 , Intro. Comp. (see pg. 61)	4	4	-	-	-	-	-	-	-
Engineering 104, Computing	3	3	-	-	-	-	-	-	-
*Chemistry 130 and 125	5	3	2	-	-	-	-	-	-
Physics 140, with Lab. 141; 240 with Lab 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences (See page 60)	17	3	7	-	4	3	-	-	-
Program Subjects (50 hrs.)									
EECS 216, Circuit Analysis	4	-	-	-	4	-	-	-	-
EECS 270, Intro. to Logic Design	4	-	-	-	4	-	-	-	-
EECS 280, Prog. & Intro. Data Structures	4	-	-	4	-	-	-	-	-
EECS 300, Math. Meth. Sys. Analysis	3	-	-	-	-	3	-	-	-
EECS 303, Discrete Structures	4	-	-	4	-	-	-	-	-
EECS 317, Digital Electronics	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 381, Systems Programming	4	-	-	-	-	-	4	-	-
EECS 401, Probabilistic Methods or Math/Stat 425	3	-	-	-	-	-	3		
EECS 400 or Math 419, Lin. Spcs. & Matrix Theo.	3	-	-	-	-	3	-	-	
EECS 360 or 476 or 477 or 478, Sys Comput. Sci.	3	-	-	-	-	-	-	3	-
EECS 482, Oper.Sys, or EECS 483, Compil. Const.	4	-	-	-	-	-	-	4	-
Technical Electives (13 hrs.) (Note A)	13	-	-	-	-	-	4	3	6
Free Electives (9 hrs.)	9	-	-	-	-	-	-	3	6
Total	**128**	**17**	**17**	**16**	**16**	**17**	**17**	**13**	**15**

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

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 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 4th credit is earned from the group requirement EECS 360, 476, 477, 478, the free electives will be reduced to (8). No more than 4 hours of EECS 499, Directed Study, may be taken to fulfill the technical elective requirement.

Engineering Sciences (not in CSE) Technical Electives (3 hrs.). Courses can be selected with the approval of the counselor from EECS, IOE, ME, NE, AERO, and AO & SS.
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
EECS 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 so that students, with the assistance and approval of the program advisor, may design an academic program to achieve a variety of objectives. Furthermore, students may emphasize the applied and experimental aspects of electrical engineering or may concentrate on subjects requiring an analytical or theoretical treatment.

Students are expected to pursue a coherent course of study, and ten possible areas of concentration are listed 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 ABET.

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Assoc. Professor
E.L. McMahon
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Program Office
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Student Advisor
Barb Toma
Program Office
3415 EECS Building
(313) 747-1762

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. Students may find that it is necessary to extend their schedule to 8-1/2 or nine terms.*

Required Programs

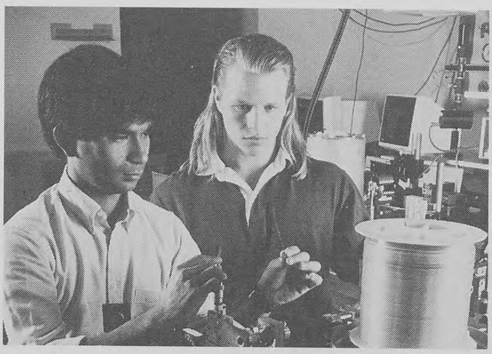
	Hours	1	2	3	4	5	6	7	8
		Sample Schedule by term							
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, for alternatives)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125 Intro. Composition	4	4	-	-	-	-	-	-	-
Engineering 103 or 104, Computing	3	3	-	-	-	-	-	-	-
Chemistry 130 (3 hours) and Chem. 125 (2 hours) OR Chem. 210 (4 hours) and Chem. 211 (1 hr.)	5	3	2	-	-	-	-	-	-
Physics 140 with Lab. 141; Phys 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences (See page 60)	17	3	7	-	3	-	4	-	-
Related Technical Courses (9 hrs.)									
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	3	-	-	-	-	-
Physics 242, General Physics III	3	-	-	-	3	-	-	-	-
Group Requirements (3 hrs.)									
One of the following courses: ME 231, ME 240, Physics 401, or Physics 406	3	-	-	-	3	-	-	-	-
Program and Laboratory Course Requirement (36 hrs.)									
I. Core Courses (34 hrs)									
EECS 216, Circuit Analysis	4	-	-	-	4	-	-	-	-
EECS 270, Intro. to Logic Design	4	-	-	4	-	-	-	-	-
EECS 300, Math Methods in Sys. Analy.	3	-	-	-	-	3	-	-	-
EECS 316, Circuits and Systems	3	-	-	-	-	-	3	-	-
EECS 317, Solid State Devices & Digital Electronics	3	-	-	-	-	3	-	-	-
EECS 318, Analog Electronics	4	-	-	-	-	-	-	4	-
EECS 320, Intro to Semiconductor Device Theory	3	-	-	-	-	3	-	-	-
EECS 331, Electromag. Fields I	4	-	-	-	-	4	-	-	-
EECS 332, Electromag. Fields II	3	-	-	-	-	-	3	-	-
EECS 401, Probabilistic Methods in Engineering	3	-	-	-	-	-	3	-	-
II. Laboratory Requirement (2 hrs)	2	-	-	-	-	-	-	2	-
One of the following courses: EECS 359, 373, 423, 425, 431, 437, 452, 458, 467									
Technical Electives (21 hrs.)	21	-	-	-	-	-	3	6	12
Technical Electives (See next page)									
Free Electives (6 hours)	6	-	-	-	-	3	-	3	-
Total	**128**	**17**	**17**	**15**	**17**	**16**	**16**	**15**	**15**

Technical Electives Description

1. **Technical** electives must include at least 12 hours of EECS courses and at least 3 hours of non-EECS courses.
2. Non-EECS technical electives are from Physical or Biological Sciences, Mathematics, other Engineering Departments, and certain courses in Business and Economics, as approved by the Program Advisor.
3. Technical electives must be 300 level or higher except for EECS 280, EECS 283, and EECS 284.
4. **Technical** electives must be chosen to satisfy the balance of 16 hours of Engineering Design; at least three of these hours must come from no more than two courses, each of which has at least 50% Engineering Design content.
5. No more than 4 hours of Independent Study courses are permitted.

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

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



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, 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.

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)

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Professor
Tony C. Woo
242 Industrial
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Professor Don B. Chaffin, the G. Lawton and Louise G. Johnson Professor of Engineering and director of the Center for Ergonomics, explains musculoskeletal biomechanics to one of his classes.

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 & 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 I.&O.E. courses. A solid foundation in the five areas of interest described above is obtained through 12 credits of departmental I.&O.E. 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 six credits of I.&O.E. technical electives, nine credits of non-I.&O.E. technical electives, and eight credits of free electives. The goal of the non-I.&O.E. 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 I.&O.E. program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering Technology.

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, 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.

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.

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. Many students find that it is necessary to extend their schedule to 8-1/2 or nine terms.*

Required Programs

	Hours	Sample Schedule by term 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, for alternatives)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 125, Intro. Comp.	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
*Chemistry 130	3	3	-	-	-	-	-	-	-
Chemistry 125	2	-	2	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication 498	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	3	3	-	3	4	-	-	4
Related Technical Subjects (13 hrs.)									
Mech. Eng. 211, Intro to Solid Mech.	4	-	-	-	4	-	-	-	-
Mech. Eng. 235, Thermodynamics I	3	-	-	-	-	3	-	-	-
Mat. Sci. 250, Prin. of Engr. Materials	3	-	-	-	3	-	-	-	-
EECS 314, Circuit Analysis and Electronics	3	-	-	-	-	-	-	3	-
Program Subjects (36 hrs.)									
I.&O.E. 301, Indust. & Oper. Mgmt	3	-	-	3	-	-	-	-	-
I.&O.E. 310, Intro. to Optim. Methods	3	-	-	-	-	3	-	-	-
I.&O.E. 315, Stochastic Industrial Proc.	3	-	-	-	3	-	-	-	-
I.&O.E. 333,Ergonomics	3	-	-	3	-	-	-	-	-
I.&O.E. 334, Ergonomics Lab	1	-	-	1	-	-	-	-	-
I.&O.E. 365, Engineering Statistics	4	-	-	-	-	4	-	-	-
I.&O.E. 373, Data Processing	4	-	-	-	-	-	4	-	-
I.&O.E. Senior Design Course (See Note)	3	-	-	-	-	-	-	-	3
I.&O.E. Electives (12 hrs., see Note next page)	12	-	-	-	-	3	3	6	-
Technical Electives (15 hrs.)									
(6 hrs. must be I.&O.E.)	6	-	-	-	-	-	-	3	3
(9 hrs. must be non-I.&O.E.)	9	-	-	-	-	-	6	-	3
Free Electives (8 hrs.)	8	-	3	-	-	-	2	3	-
Total	**128**	**17**	**16**	**15**	**17**	**17**	**15**	**15**	**16**

*Chem. 210 (4 hours) and Chem. 211 (1 hour) may be substituted for Chem. 130 and Chem. 125.

Note on Departmental I.&O.E. Electives:

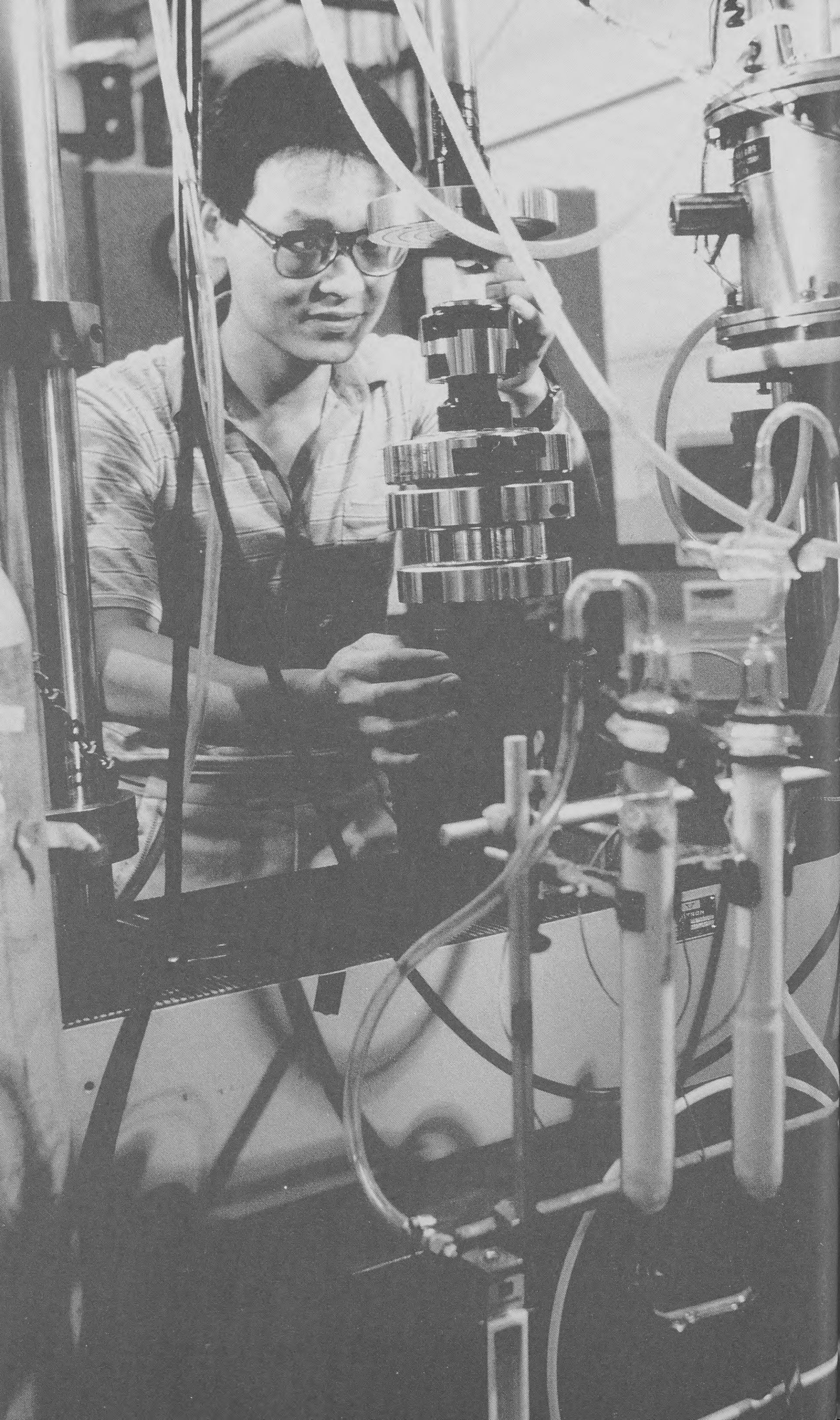
Within the 12-hour elective requirement, the student must elect one course from four of the following six I.&O.E. core groups shown below:

1.	I.&O.E.	441	(Production and Inventory Control)
	I.&O.E.	447	(Facility Planning)
	I.&O.E.	449	(Material Handling Systems)
2.	I.&O.E.	465	(Experimental Design)
	I.&O.E.	466	(Statistical Quality Control)
3.	I.&O.E.	473	(Information Processing Systems)
	I.&O.E.	474	(Simulation)
	I.&O.E.	478	(Interactive Computer Graphics)
	I.&O.E.	484	(Database Management Systems)
4.	I.&O.E.	436	(Human Factors in Computer Systems)
	I.&O.E.	439	(Safety Management)
	I.&O.E.	463	(Work Measurement and Prediction)
5.	I.&O.E.	416	(Queuing Systems)
	I.&O.E.	460	(Decision Analysis)
6.	I.&O.E.	421	(Work Organizations)
	I.&O.E.	425	(Manufacturing Strategies)
	I.&O.E.	451	(Engineering Economy)
	I.&O.E.	452	(Capital Budgeting and Financial Engineering)

Note on I.&O.E. Senior Design Requirement:

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

1. I.&O.E. 424 (Practicum in Production and Service Systems)
2. I.&O.E. 482 (Practicum in Hospital Systems)
3. I.&O.E. 499 (Senior Design Projects)
4. Other I.&O.E. 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 five most promising technical fields of the '90s.

Materials scientists and engineers specialize in the development, production, and utilization 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 naming of the Stone Age, the Bronze Age, and the Iron Age for the most advanced materials available then 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 the very high temperatures encountered in jet and rocket engines; strong, light alloys for aerospace applications; specialized glasses and ceramics having high thermal, mechanical, and chemical stability; and a host of polymeric materials which are replacing 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 than in the past. It is already widely recognized that we are facing a crucial energy shortage and there is growing public concern about waste disposal problems. It is less widely appreciated, but equally important, that the supplies of copper, lead, zinc, nickel, tin, manganese, chromium, and a number of other important materials are as limited as those of petroleum and natural gas.

New processes that will consume less energy and reduce pollution must be

Program Advisor
Professor John W. Halloran
2168 Dow Building
(313) 763-1051

The Structural Ceramics Laboratory.

developed for producing all types of materials. To conserve our dwindling natural resources and to protect our natural environment, methods 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. Materials scientists and engineers of the future will continue to be at the forefront of all of these important and challenging activities.

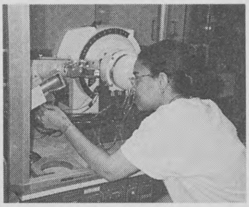
In addition to these newly developing fields, materials scientists and engineers are in constant demand for a number of more traditional, but equally important and rewarding activities. These include: the production of basic materials from ores and minerals; the processing of basic materials into forms suitable for use in various manufacturing processes; managing manufacturing processes that critically involve the manipulation of materials properties; modifying existing types of materials and the development of new types of 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; plus various kinds of supervisory, research, teaching, and management activities. The tremendous range of opportunities open to materials scientists and engineers will be more evident if it is recognized that all of these types of activities apply equally for metals, polymers, ceramics and electronic materials, and for applications ranging 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 an M.S. or Ph.D. 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 a firm interest in materials can take a special course (MSE 150) in their second term, thereby getting 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 and thermodynamics, and transport phenomena, while two senior design courses ensure a high level of professional competence.

Two laboratory courses give our students a working knowledge of practical things, such as operating a furnace, running a rolling mill, the use of various kinds of testing equipment, preparation of specimens for microscopic examination, use of optical and electron microscopes and x-ray diffraction equipment, and the measurement and evaluation of the important properties of different types of materials.

To give students an opportunity to tailor their courses to meet individual interests, the program provides six credits of free electives, ten credits of electives in engineering, science and technical subjects, and six credits of electives in advanced program subjects, plus allowing a selection 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 in most engi-neering activities. They are also urged to select other humanities and social sciences courses in such a way as 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.

Combined Degrees

Materials are critically involved in most fields of engineering; therefore, it is particularly 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. Students interested in such double degree programs should consult with the program advisors in both programs as early as possible to work out optimum combinations of courses.

Facilities

The facilities for the program in materials science and engineering are housed primarily in the 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.

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. Many students find that it is necessary to extend their schedules to 8–1/2 or nine terms.*

Required Programs

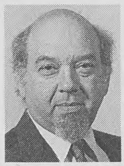
	Hours	1	2	3	4	5	6	7	8
		Sample Schedule by term							
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, for alternatives)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125 or equivalent, Intro. Comp.	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 130 and 125 or 210 and 211	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Science, including Economics (See page 60)	17	-	3	3	3	-	4	-	4
Free Electives (6 hrs.)	6	-	3	-	3	-	-	-	-
Science and Technical Subjects (29 hrs.)									
*A 200-level course in Chemistry or Physics	3	-	3	-	-	-	-	-	-
Chemistry 365, Prin. of Physical Chem.	4	-	-	-	-	-	4	-	-
Mech. Eng. 211, Intro. to Solid Mechanics	4	-	-	-	4	-	-	-	-
Mat. Sci. & Eng. 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
(*Organic chemistry is a recommended elective for those with special interests in polymers. Physics 242 is recommended for those with special interest in electronic materials.)									
Program Subjects (37 hrs.)									
Mat. Sci. & Eng. 350, Prin. of Eng. Mat. II	3	-	-	-	-	3	-	-	-
Mat. Sci. & Eng. 356, Mat. Lab. I	2	-	-	-	-	2	-	-	-
Mat. Sci. & Eng. 430, Thermodynmics of Matls	3	-	-	-	-	-	-	3	-
Mat. Sci. & Eng. 435, Transport Phenomena	3	-	-	-	-	-	3	-	-
Mat. Sci. & Eng. 456, Matls. Lab. II	2	-	-	-	-	-	2	-	-
Mat. Sci. & Eng. 480, Matls.Engr. Design	3	-	-	-	-	-	-	3	-
Mat. Sci. & Eng. 489, Matls. Process Design	3	-	-	-	-	-	-	-	3
Elect 2 of the following 3 courses:	6	-	-	-	-	3	-	3	-
Mat. Sci. & Eng. 400., Elec.,Mag. & Opt. Prop. of Matls. (3)									
Mat. Sci. & Eng. 420, Mech. Behavior of Materials (3)									
Mat. Sci. & Eng. 460, X-ray Methods & Crystallography (3)									
Elect 2 of the following 3 courses:	6	-	-	-	-	-	3	-	3
Mat. Sci & Eng. 412 Polymeric Matls. (3)									
Mat. Sci. & Eng. 440, Ceramic Matls. (3)									
Mat. Sci. & Eng. 470, Physical Metallurgy (3)									
Electives in Program Subjects	6	-	-	-	-	-	-	3	3
Total	**128**	**16**	**17**	**15**	**17**	**16**	**16**	**15**	**16**

Mechanical Engineering

The scope of activities 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.

They 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 prefer a career along technical and professional lines.

Because a mechanical engineer might work in any one of these fields, an academic program has been planned that offers a challenging and basic education.



Program Advisor
Professor Alan S. Wineman
116 Auto Lab
(313) 936-0411

Student Advisor
Susan J. Gow
2206 G.G. Brown
(313) 763-4277

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.

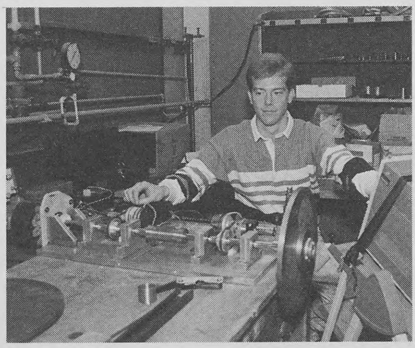
A basic science program in physics, chemistry, and mathematics, an engineering science program in thermodynamics, fluid mechanics, heat transfer, solid mechanics, dynamics, materials, and electronics integrated with laboratory experiences in measurement, and studies in design and manufacturing, will prepare the student equally well for any of the fields of application. The program includes a number of both technical and non-technical electives that permit the student to undertake further studies in an area of

Student performs heat transfer through oscillation in the MEAM Laboratory.

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.

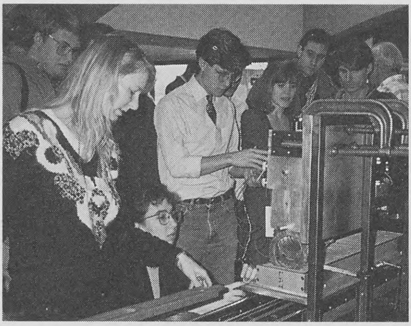


Facilities

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

The George Granger Brown Laboratory 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 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.



On Senior Mechanical Design Day, students and visitors examine products designed by Mechanical Engineering and Applied Mechanics students. Many of these products were commissioned by Ann Arbor-area industry.

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. Many students find it necessary to extend their schedule to 8-1/2 or nine terms.*

Required Programs

	Hours	1	2	3	4	5	6	7	8
		Sample Schedule by term							
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, 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	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; 240 with Lab 240 +	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Sciences **	17	-	3	-	4	4	3	3	-
(to include one course in micro- or macro-economics) (see page 273)									
Advanced Mathematics (3 hrs.) (Note 1)									
Elective	3	-	-	-	-	3	-	-	-
Related Technical Subjects (15 hrs.)									
Mat. Sci. & Eng. 250, Princ. of Eng. Materials +	3	-	3	-	-	-	-	-	-
M.E. 101, Intro to CAD	2	-	2	-	-	-	-	-	-
M.E. 211, Intro. to Solid Mechanics +	4	-	-	4	-	-	-	-	-
M.E. 240, Intro. to Dynamics +	3	-	-	-	3	-	-	-	-
EECS 314, Cct. Analy. & Electronics	3	-	-	-	-	3	-	-	-
Program Subjects (32 hrs.)									
M.E. 235, Thermodynamics +	3	-	-	3	-	-	-	-	-
M.E. 281, Mech. Behav. of Engineering Materials +	4	-	-	-	4	-	-	-	-
M.E. 320, Fluid Mech. I +	3	-	-	-	-	3	-	-	-
M.E. 350, Mech. Design I +	4	-	-	-	-	-	4	-	-
M.E. 360, Dynamics of Mech. Sys.+	4	-	-	-	-	-	4	-	-
M.E. 370, Heat Transfer	3	-	-	-	-	-	3	-	-
M.E. 395, Thermal-Fluids Lab	3	-	-	-	-	-	-	3	-
M.E. 450, Mech. Design II	4	-	-	-	-	-	-	-	4
M.E. 461, Automatic Control	4	-	-	-	-	-	-	-	4
Technical Electives (15 hrs.)									
(see opposite page for courses within specific areas of interest)	15	-	-	-	-	-	3	6	6
Free Electives (7 hrs.)									
(hours may also come from excess Hum./S.S. and/or AP credits)	7	-	-	-	3	4	-	-	-
Total	**128**	**16**	**16**	**15**	**18**	**17**	**17**	**15**	**14**

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.

Technical Electives

Program Advisor: *Alan Wineman*

The pertinent technical subjects are listed by area of interest. The course list provided below is to allow students to focus on a specific area within ME, although it is not mandatory.

Energy and Power: *Professor M. Kaviany, Area Advisor*
M.E. 336, 420, 424, 432, 435, 436, 437, 438, 439, 458, 474, 478, 490, 491

Materials and Manufacturing: *Professor J. Holmes, Area Advisor*
M.E. 305, 311, 381, 401, 451, 452, 465, 467, 482, 487, 490, 491

Systems/Design: *Professor J. Stein, Area Advisor*
M.E. 305, 311, 381, 412, 441, 442, 443, 451, 452, 454 , 458, 465, 467, 490, 491

Industrial Design: *Professor A. Samuels, Area Advisor, School of Art*
Art 391-396

Total: 15

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 (the 15 hours of technical electives) begin at the 300 level. Students will elect 5 courses from those noted above. The information is provided by areas of interest to encourage greater knowledge in a specific concentration. A maximum of 6 hours of courses from related departments may be substituted with departmental approval. Students should consult with the Student Advisor in the Academic Services Office, Room 2206 G.G. Brown, prior to their final semester, to ensure that 16 hours of design credit will be completed.

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 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 arrangements, hydrostatic stability, structures, resistance and propulsion, and seakeeping. Other areas of concern are the economic aspects of ship design and

Program Advisor
Associate Professor
G. A. Meadows
214 Naval Architecture and Marine Engineering Building
(313) 764-5235

This drawing depicts an overall view of the curriculum possibilities in naval architecture, marine engineering, and ocean engineering. (Drawing, courtesy of: E. Paul Oberlander/ Woods Hole Oceanographic Institution).

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 the areas of marine dynamics, the student studies the vibrations of marine structures and engines as well as the rigid body responses of the vessel to wind and waves. 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 may earn an additional B.S.E. degree in Aerospace Engineering, Mechanical Engineering, or in combined programs with these two 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.

The department operates the Marine Hydrodynamics Laboratory (MHL) located on Main 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 utilizing the model basin. The MHL also hires students on a part time basis to help with the 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 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. 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).

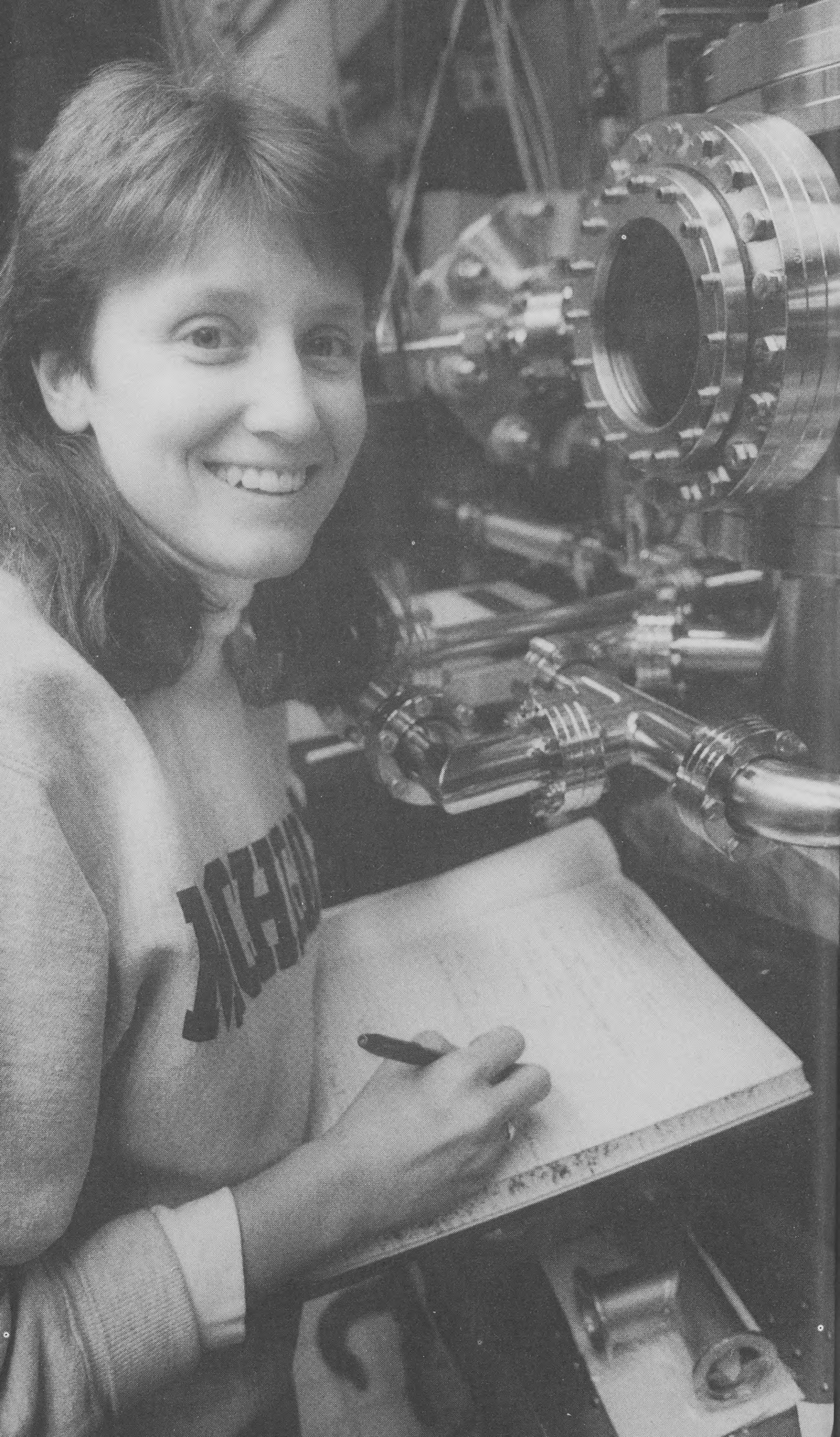
Requirements

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. Many students find that it is necessary to extend their schedule to 8-1/2 or nine terms.

Required Programs

	Hours	1	2	3	4	5	6	7	8
		Sample Schedule by term							
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, 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	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences (See page 60)	17	-	4	-	3	-	-	6	4
Advanced Mathematics (3 hrs.)									
Mathematics 350	3	-	-	-	-	3	-	-	-
Related Technical Subjects (23 hrs.)									
Mat. Sci. & Eng. 250, Prin. of Eng. Materials	3	-	-	3	-	-	-	-	-
Mech. Eng. 101, Intro. to CAD	2	-	2	-	-	-	-	-	-
Mech. Eng. 110, Statics	2	-	2	-	-	-	-	-	-
Mech. Eng. 210, Intro. to Solid Mechanics	3	-	-	3	-	-	-	-	-
Mech. Eng. 240, Intro. to Dynamics	3	-	-	-	3	-	-	-	-
Mech. Eng. 235, Thermodynamics I	3	-	-	-	3	-	-	-	-
Mech. Eng. 325, (CEE 325), Fluid Mech.	3	-	-	-	-	3	-	-	-
EECS 314, Cct. Analy. and Electronics	3	-	-	-	-	-	3	-	-
EECS 315, Cct. Analy. and Electronics Lab.	1	-	-	-	-	-	1	-	-
Program Subjects (33 hrs.)									
Nav. Arch. 270, Marine Design	3	-	-	3	-	-	-	-	-
Nav. Arch. 302, Static Stability of Marine Vehicles	3	-	-	-	3	-	-	-	-
Nav. Arch. 310, Marine Structures I	4	-	-	-	-	4	-	-	-
Nav. Arch. 320, Marine Hydrodynamics I	4	-	-	-	-	-	4	-	-
Nav. Arch. 330, Marine Power Systems I	4	-	-	-	-	4	-	-	-
Nav. Arch. 340, Marine Dynamics I	4	-	-	-	-	-	4	-	-
Nav. Arch. 381, Probal. Meth. in Marine Sys.	3	-	-	-	-	-	3	-	-
Nav. Arch. 385, Ship Produc. & Ship Man.	2	-	-	-	-	2	-	-	-
Nav. Arch. 470, Ship Design or Nav. Arch. 471, Offshore Eng. Design	3	-	-	-	-	-	-	3	-
Nav. Arch. 475, Design Project	3	-	-	-	-	-	-	-	3
Technical Electives (9 hrs.)									
These must include at least two of the second courses in the four areas of concentration—Nav. Arch. 410, Marine Struc. II; Nav. Arch. 420, Mar. Hydro II or Nav. Arch. 425 Phys. of the Ocean; Nav. Arch. 430, Mar. Power Systems II; or Nav. Arch. 440, Mar. Dynamics II	6	-	-	-	-	-	-	3	3
Another Technical Elective	3	-	-	-	-	-	-	-	3
Free Electives (4 hrs.)	4	-	-	-	-	-	-	4	-
Total	**128**	**16**	**16**	**17**	**16**	**16**	**15**	**16**	**16**



Nuclear Engineering

Nuclear Engineering applies the basic sciences to the design and development of nuclear energy sources, to the beneficial application of nuclear radiation, and to the protection of people from medical and industrial radiation sources. Primary sources of nuclear energy are fission and fusion reactions and radioactive decay. Engineers involved in these activities require a broad background combining knowledge of basic principles from physics, chemistry, and other basic sciences, together with expertise in the engineering sciences and engineering design. Specific topics range from microscopic phenomena involving nuclear and atomic interactions through large scale engineering systems such as nuclear power plants. The Department of Nuclear Engineering has teaching and research programs in:

Nuclear reactor engineering including reactor theory, reactor design applications, nuclear power plant analysis, and reactor safety analysis;

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Radiation measurement including radiation detection, radiation damage, and radiation imaging for medical and industrial applications;

Materials studies using neutrons and ion beams;

Plasma physics applications to thermonuclear fusion, plasma processing and electron beams;

Radiation transport theory and applications;

Fluid flow and heat transfer phenomena related to reactor performance problems.

Nuclear engineers have many opportunities to apply their knowledge to topics that are at the forefront of technology.

Melisa Buie (BS Math '85, Troy State; MS Physics '88, Auburn Univ), Nuclear Engineering doctoral pre-candidate at Michigan.

From studies of the safety of second generation fission reactors through the development of future fusion energy devices, the field offers an exceptional set of interesting problems in research, design, and technical development.

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

Facilities

Special facilities available to nuclear engineering students include the following:

Ford Nuclear Reactor

2 megawatt open pool research reactor with pneumatic tube system
Neutron depth profiling facility
Single, double, and triple axis crystal neutron spectrometers
Hot laboratories and two hot caves with master slave manipulators
10,000 curie Cobalt-60 gamma ray irradiator
Real-time neutron imaging facility and neutron radiography ports
Helium profile spectrometer
Prompt gamma spectrometer
Extensive state-of-the-art neutron activation facilities

Michigan Ion Beam Laboratory

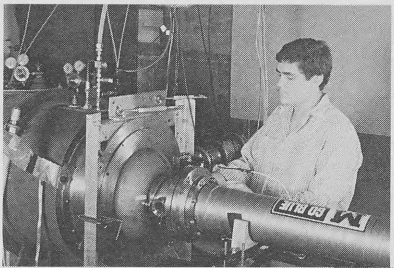
1.7 MV Tandem ion accelerator
200 kV and 400 kV ion implanter
Dual source vacuum evaporator
Ion beam assisted deposition system vacuum furnace

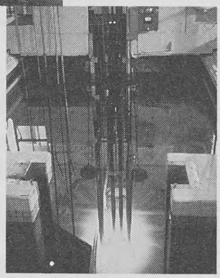
Nuclear Data Laboratory

150 kV Cockcroft-Walton accelerator used as nanosecond-pulsed 14 MeV neutron generator
Radiation spectroscopy equipment and fast neutron time-of-flight facility

Intense Energy Beam Interaction Laboratory

Michigan Electron Long Beam Accelerator (MELBA)
Intense relativistic electron-beam accelerators
TEA CO_2, excimer, and ruby lasers
Duopigatron based ion-neutral beam accelerator
Holographic interferometry diagnostic
X-ray scintillator photomultiplier systems
z-pinch experiment
Laser-guided discharge experiment





Magnetic Mirror Laboratory

Michigan mirror machine (EECS)
High power microwave heating system
Super heterodyne microwave diagnostic
Microwave Interferometer ECR configuration at 2.45 GH_2 Gridded Energy Analyzer
UV-visible Spectrometer

Radiation Detection

Measuring equipment including three PC-based analysis systems
Radiation solid state laboratory
Neutron activation analysis laboratory

Computation

IBM ES/9000 Model 720 vector supercomputer (U-M mainframe)
Access to the U-M KSR-1 32-node parallel supercomputer
Fifteen UNIX workstations
Access from all computers to San Diego, Illinois, and Cornell Supercomputer Centers
MacIntosh personal computers
Six Apple LaserWriters
Part of Computer-Aided Engineering Network (CAEN)

Radiation Imaging Laboratory

Compton scatter radiation imaging camera
Environmental chamber
Raster scanning radiation imaging camera

Glow Discharge Laboratory

Microwave resonant cavity
GEC RF reference cell
High resolution spectrograph
Fabry-Perot interferometer

High Temperature Corrosion Laboratory

Recirculating autoclave systems for PWR and LWR conditions
Static autoclaves
Constant extension rate machines
Corrosion measurement systems

Materials Preparation Laboratory

Furnaces
Polishing tables
Jet electropolisher
Metallograph

Metastable Materials Laboratory

X-ray diffractometers
Differential scanning calorimeter
Ball mill

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. Many students find that it is necessary to extend their schedule to 8-1/2 or nine terms.*

Required Programs

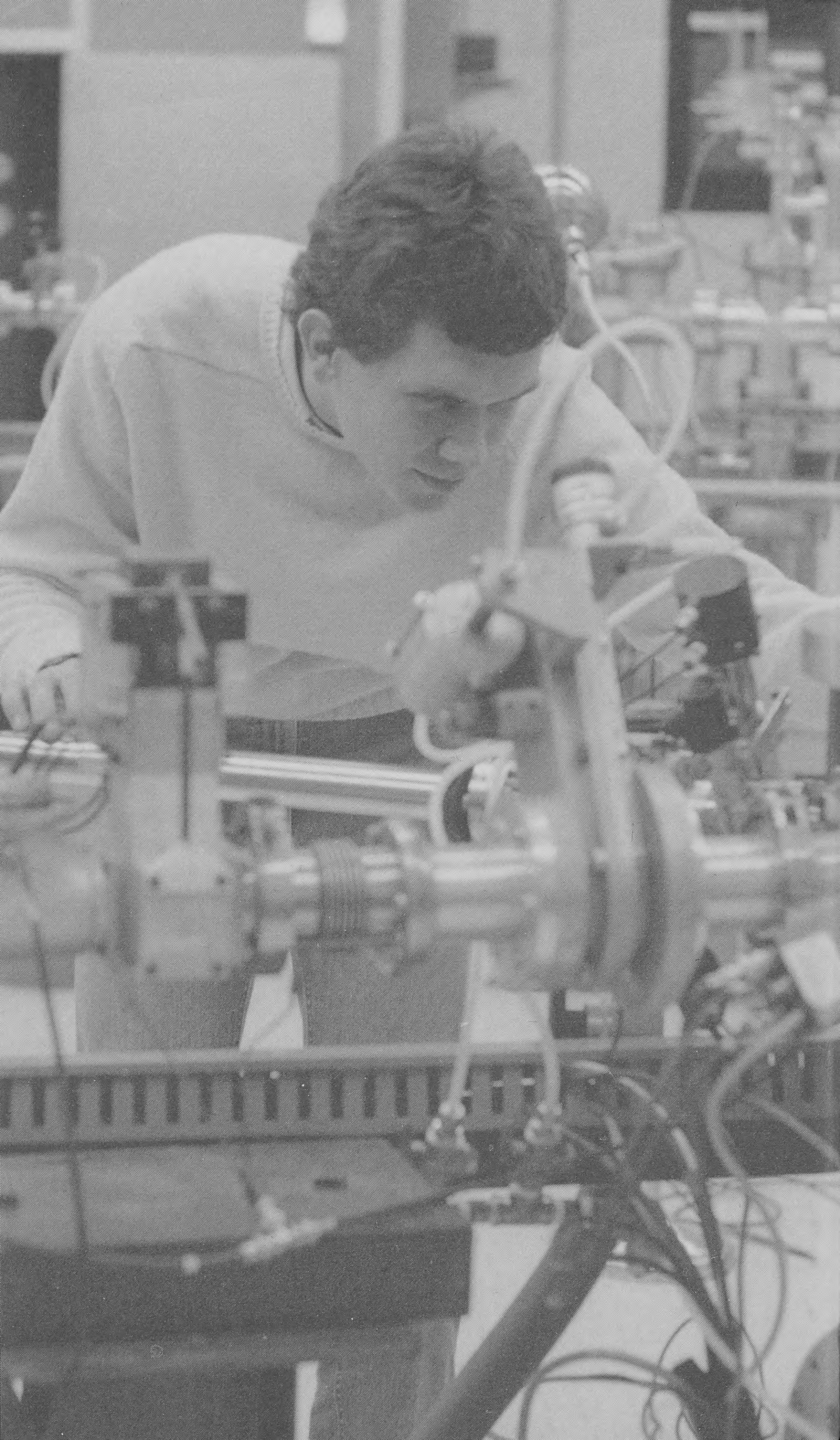
	Hours	Sample Schedule by term 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, for alternatives)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
English 124 or 125 or equivalent, Intro. Comp.	4	4	-	-	-	-	-	-	-
Engineering 103, Computing	3	3	-	-	-	-	-	-	-
Chemistry 130 and 125 or 210 and 211	5	5	-	-	-	-	-	-	-
Physics 140 with Lab. 141; 240 with Lab. 241	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	-	6	3	3	-	3	2	-
Advanced Mathematics and Science (10 hrs.)									
Phys. 242, Gen. Phys. III	3	-	-	-	3	-	-	-	-
Math. 450, Adv. Math. for Eng. I	4	-	-	-	-	4	-	-	-
Math. Elective*	3	-	-	-	-	-	3	-	-
Related Technical Subjects (20 hrs.)									
Mat. Sci. & Eng. 250, Princ. of Eng. Materials	3	-	-	-	-	3	-	-	-
Mech. Eng. 211, Intro. to Solid Mech.**	4	-	-	4	-	-	-	-	-
Mech. Eng. 235, Engr. Thermodyn.	3	-	-	-	3	-	-	-	-
Mech. Eng. 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 (26 hrs.)									
Nuc. Eng. 311, Elements of Nuc. Eng. I	3	-	-	-	-	3	-	-	-
Nuc. Eng. 312, Elements of Nuc. Eng. II	3	-	-	-	-	-	3	-	-
Nuc. Eng. 315, Nuc. Instr. Lab	4	-	-	-	-	-	4	-	-
Nuc. Eng. 441, Fiss. Reactors and Power Plants I	4	-	-	-	-	-	-	4	-
Nuc. Eng. Elective	9	-	-	-	-	-	-	3	6
Nuc. Eng. Laboratory (above Nuc. Eng. 315)	3	-	-	-	-	-	-	-	3
Technical Electives (9 hrs.) ***	9	-	-	-	3	-	-	3	3
Free Electives (7 hrs.)	7	-	-	-	-	-	3	4	-
Total	**128**	**16**	**17**	**15**	**16**	**17**	**16**	**16**	**15**

Notes:

* Math Electives must be 300 level or higher. Suggested courses are: Math 300, 371, 404 , 454, 471, EECS 300, Engr. 303, 371, CEE 303.

** ME110 and ME 210 may be substituted for ME 211.

***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.



Engineering Physics

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Physics has traditionally been an 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 programs as well as a traditional physics or applied physics program.

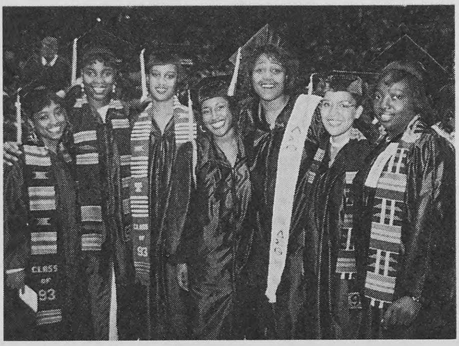
Engineering Physics meets these needs by providing a thorough curriculum in basic and advanced engineering courses combined with sufficient physics and mathematics to be equivalent to a traditional degree in physics. A unique feature of the curriculum is the elective sequence of engineering courses that 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

A student, hard at work, in the Michigan Ion Beam Laboratory, administered by the Department of Nuclear Engineering.

fusion, computational methods, optics, and radiological science, 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.

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. Many students find that it is necessary to extend their schedule to 8-1/2 or nine terms.*



Required Programs

	Hours	1	2	3	4	5	6	7	8
		Sample Schedule by term							
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, for alternatives)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engl. 124 or 125 or equivalent, 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	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	3	-
Humanities and Social Sciences	17	3	3	4	3	-	4	-	-
Technical Electives (9 hrs.)									
Mathematics	6	-	-	-	-	3	-	3	-
Engineering or Science	3	-	-	-	-	3	-	-	-
Related Technical Subjects (37 hrs.)									
Mat. Sci. & Eng. 250, Princ. of Eng. Materials	3	-	3	-	-	-	-	-	-
Mech. Eng. 211, Intro. to Solid Mech. (See Note)	4	-	-	4	-	-	-	-	-
Mech. Eng. 320, Fluid Mech.	3	-	-	-	-	3	-	-	-
Mech. Eng. 370, Heat Transfer	3	-	-	-	-	-	-	-	3
EECS 314, Cct. Analy. & Electr.	3	-	-	-	3	-	-	-	-
Laboratory Elective (400 level)	3	-	-	-	-	-	3	-	-
Engineering Elective*	18	-	-	-	-	4	4	6	4
Program Subjects (23 hrs.)									
Phys. 242, Gen. Phys. III	3	-	-	-	3	-	-	-	-
Phys. 401, Int. Mech.	3	-	-	-	-	3	-	-	-
Phys. 405, Int. Elect. and Mag.	3	-	-	-	-	-	3	-	-
Phys. 406, Stat. and Thermal Phys.	3	-	-	-	-	-	3	-	-
Phys. 453, Quantum Mechanics	3	-	-	-	-	-	-	3	-
Phys. 463, Solid State Phys.	3	-	-	-	-	-	-	-	3
Physics Lab Elective	2	-	-	-	-	-	-	-	2
Phys. Elective	3	-	-	-	-	-	-	-	3
Free Electives (3 hrs.)	3	-	-	-	3	-	-	-	-
Total	**128**	**17**	**16**	**16**	**16**	**16**	**17**	**15**	**15**

Note: ME 110 and ME 210 can be substituted for ME 211.

*The engineering electives are to be chosen in consultation with the faculty advisor to form a coherent sequence that clearly defines professional goals for the student. Sample elective sequences for a number of different subject areas are available from the faculty advisors. 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.

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.

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.

The program also 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 instead.

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 adminis-

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tration, 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 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 engineering.

This program does not meet the requirement of the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology for a 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.

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. Many students find that it is necessary to extend their schedule to 8-1/2 or nine terms.*

Required Programs

	Hours	Sample Schedule by term 1	2	3	4	5	6	7	8
Subjects required by all programs (56 hrs.)									
(See under "Minimum Common Requirements," page 55, for alternatives)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engl. 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	8	-	4	4	-	-	-	-	-
Senior Technical Communication	3	-	-	-	-	-	-	-	3
Humanities and Social Sciences	17	-	2	3	3	3	3	3	-
Engineering Sciences* (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**

*See guidelines for Engineering Science courses, page 157.
**See guidelines for Engineering Concentration courses, page 157.
The combined hours for Engineering Science and Engineering Concentration courses must total at least 40 hours.
***See guidelines for Program Option courses below.

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.

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 on the next two pages. (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 in order to design and market their products to 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 dual 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 163 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 216 (4) or EECS 314 (3) & 315 (1), EECS 331 (4).
Materials	Mat. Sci. & Eng. 150 (4) or Mat. Sci. & Eng. 250 (3), Mech. Eng. 280 (3), Mech. Eng. 281 or 282 (3).
Mechanics	Mech. Eng. 110 (2), Mech. Eng. 210 (3), Mech. Eng. 211 (4), Mech. Eng. 240 (3), Aero. Eng. 314 (3), Mech. 320 (3) or Mech. Eng. 325 (3).
Nuclear	Nuc. Eng. 311 (3), Nuc. Eng. 312 (3).
Systems	I.&O.E. 310 (3) or CEE 405 (3), I.&O.E. 315 (3), I.&O.E. 373 (4).
Thermodynamics	Mech. Eng. 231 (4) or Mech. Eng. 235 (3) or Chem. Eng. 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 course selections 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


LABORATORY
FILM

Graduate Studies

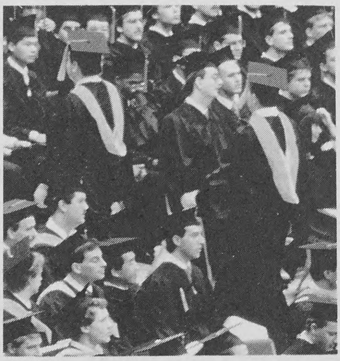
The undergraduate program in engineering offers only limited opportunities for advanced or special studies. Many students find continued study for at least one additional year a decided advantage. It offers an attractive opportunity to pursue their special interests and to acquire a more thorough preparation 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.

All students who are candidates for graduate degrees are enrolled in the Horace H. Rackham School of Graduate Studies. Its *Bulletin* should be consulted for complete information.

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.



Master's Degrees

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.

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.

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.

It is required that a student take at least two graduate-level cognate courses for a minimum of two hours of credit each, 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 degrees offered are designated in the headings to the several descriptions that follow.

Master of Engineering

The College of Engineering offers the Master of Engineering degree as an alternative 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 will be designed with preparation for a career in the practice of engineering in industry as the primary goal. These will be 12-month programs organized around a team project experience which will be undertaken in close association with industry. The initial M. Eng. degree will be in the field of Manufacturing and will begin in the 1993-1994 academic year.

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

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. A candidate for the M.S.E. degree will include in his or her 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 four credit hours of non-technical studies and up to six 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 James Barber, 2006 G.G. Brown, (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, Applied Mech. 407, ME/AM 441, and ME/AM 520 or their equivalent; and at least six hours from graduate courses concerned with advanced mathematics. A master's thesis, subject to departmental approval, may be substituted in place of six of the twelve 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; M.S. in Oceanic Science

Advisors: Professor Sushil Atreya and Professor Stanley Jacobs

Candidates for the M.S. in atmospheric and space or oceanic sciences must present the substantial equivalent of a bachelor's degree in engineering, physics, mathematics, or some other scientific area. 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 hours is required, including 15 hours of atmospheric, oceanic and space sciences, and six hours of mathematics, or three hours of mathematics and three hours of physical sciences. A Master's thesis or research essay is required.

Thesis or Research Essay: A student will select a research topic in conjunction with an appropriate faculty member who will guide the student in preparation of both the research and the thesis or research essay. Satisfactory completion of the thesis or research essay will count for six credit hours of the total 30 required for the master's degree. A student must sign up for a 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.

M.S. in Bioengineering

Executive Committee: Professors James Ashton-Miller (MEAM), Spencer Bement (EECS), Charles Cain (EECS), John Faulkner (Physiology), Steven Goldstein (Surgery), Janice Jenkins (EECS), Alfred Nuttall (OTO), and Leslie Rogers (Nuclear Medicine)

The Bioengineering Program at The University of Michigan is a graduate program in the School of Graduate Studies granting the M.S. and Ph.D. degrees in Bioengineering. The Program is jointly supported by the College of Engineering and the Medical School.

The program is interdisciplinary. A student may plan a widely diversified educational program to advance the student's personal goals under the guidance and counsel of faculty associated with the Program. Research opportunities are as diversified as the range of activities conducted by the University units supporting the program.

Entrance requirements for the Bioengineering Program: 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 as anatomy, experimental psychology, microbiology, physiology, pharmacology, etc.

Those students with a Bachelor of Science or Bachelor of Arts degree and majors in related bioengineering areas such as experimental psychology, physiology, zoology, microbiology, and biochemistry, must complete the above requirements plus the following:

Two terms of college physics

Mathematics through differential equations

One course in basic electronic circuits

Two courses of either mechanics, fluid mechanics, or thermodynamics

Students may enter the Bioengineering Program 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 Bioengineering.

The requirements for degrees follow.

In order to obtain the master's degree in bioengineering, 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 5 curriculum options available:

Bioelectrical option
Biotechnology option
Biomechanics option
Rehabilitation option

Please see department program booklet for further details. A grade of B or better must be attained in each course used toward the master's degree.

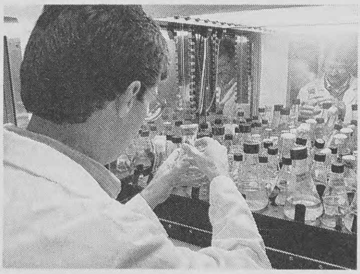
Directed Research and Thesis Research Opportunities

The University of Michigan Bioengineering Program 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 Bioengineering students 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 the above 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 biocompatibility 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 utilization of the techniques of systems analysis and optimization theory 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 devoted to a large extent to medical imaging problems. This machine is part of a network which 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 Chem. Eng. prefix) of which up to six credit hours of research are accepted (Chem. Eng. 695); and at least two courses outside the chemical engineering program. The required courses are Chem. Eng. 595 (research survey), Chem. Eng. 527 (fluid flow), Chem. Eng. 528 (chemical reaction engineering), and Chem. Eng. 542 (intermediate transport phenomena). 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 Linda M. Abriola, Robert I. Carr, Donald H. Gray, Victor C. Li, James K. Wight (Chair), Steven J. Wright
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 two 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), engineering properties of soil (CEE 445), hydraulics (CEE 421), and contracts and engineering legal relationships (CEE 400).

M.S.E. in Construction Engineering and Management

Advisor: Professor Robert I. Carr, 2340 G.G. Brown Building

A student interested in Construction Engineering and Management (CE&M) may elect to pursue a M.S.E. degree in either Civil Engineering or CE&M. The M.S.E. in CE&M is described below.

Regular admission to the M.S.E. (CE&M) program is open to applicants who hold a bachelor's degree from a recognized program of engineering. Applicants with bachelor's degrees in architecture or other non-engineering programs (but not engineering technology programs or their equivalent), may be granted conditional admission if they have taken a year of calculus and a year of physics.

The basic requirements to receive the M.S.E. (CE&M) are 30 hours of graduate credit courses, which include 9 hours of CE&M core courses; 9 hours of CE&M electives; 3 hours of mathematics, probability, statistics, or 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.

In addition to the normal M.S.E. requirements, students without a degree in engineering must complete structural analysis (CEE 312), structural design (CEE 315), civil engineering materials (CEE 351), construction contracting (CEE 431), construction engineering (CEE 432), and soil mechanics (CEE 445), or approved equivalents at another university. Students with architecture degrees will normally have the equivalent of structural analysis and structural design.

Joint M.B.A./M.S.E. in Construction Engineering and Management

Advisor: Professor Robert I. Carr, 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.S.E. (CE&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 CE&M program. This combined degree program is not open to students who have earned either the M.B.A. or M.S.E. (CE&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 MBA core.
2. 15 elective hours in business administration, including an acceptable Statistics and Management Science elective.
3. 9 hours of construction engineering core courses.
4. 9 hours of graduate-level construction engineering courses.
5. 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.
6. 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 CE 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 CE&M should see a counselor in the Business School to arrange an appropriate plan of study.

Dual M. Arch./M.S.E. in Construction Engineering and Management

Advisor: Professor Robert I. Carr, 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 semester hour M.Arch degree with the one-year, 30 semester hour M.S.E. 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 a year of calculus, a year of physics, and a minimum B average in science and mathematics courses. In addition to the normal M.S.E. requirements, students must complete civil engineering materials (CEE 351), construction contracting (CEE 431), construction engineering (CEE 432), and soil mechanics (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/Master of Architecture and one to the Horace Rackham School of Graduate Studies for the M.S.E./Construction Engineering and Management Program. Admission to the M.Arch program is normally limited to the fall term, but winter admission may be considered in special cases. The recommended procedure is to apply to each program for the same term, but one 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. 36 hours in 500/600 level architecture courses.
2. 9 hours of construction engineering core courses.
3. 9 hours of graduate-level construction engineering courses.
4. 3 hours in advanced mathematics, probability, statistics, or mathematical programming.
5. Any additional cognate/elective courses needed to fulfill the 75 hours and general requirements of each degree.

M.S.E. in Public Works Administration

Advisor: Professor Eugene Glysson

The program in municipal engineering and public works administration is available to those students who meet the requirements for admission to master's degree work in Civil

Engineering. The requirement for this degree is the successful completion of at least 30 hours of graduate work of which at least 15 must be in civil engineering courses related to public works engineering. The remainder of the program will be selected from such areas as: urban planning, theory of management, system analysis, and political science, in conference with the advisor so as to best complement the student's ultimate objective.

M.S.E. in Environmental Engineering

Advisor: Professor Steven Wright (Environmental and Water Resources Engineering)

A student interested in Environmental and Water Resources Engineering may elect to pursue a 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 degree M.S.E. 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.E. and M.S. in Computer Science and Engineering
Requirements for all Divisions of Electrical Engineering and Computer Science

1. A student must satisfy both the general master's degree requirements of the Rackham School of Graduate Studies, as specified in Section 7:1 of the *Rackham Bulletin*, and the College of Engineering regulations as specified in the College of Engineering *Bulletin*. The Rackham cognate requirement (at least

two graduate level courses for a minimum of two credit hours each) must be satisfied. In addition, the student must satisfy the requirements listed below.
2. 30 credit hours of graduate level courses must be completed.
3. At least 24 credit hours in technical coursework must be earned.
4. At least 12 credit hours of CSE coursework at the 500 level or higher must be earned. 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.
5. A maximum of six (6) credit hours of individual study, research, and seminar courses (EECS 599 and similar courses) will be accepted toward the master's degree.
6. The course grade must be B- or better for the credit hours received in any course to be counted towards any master's requirement (including the 30 total credit hours).
7. The Grade Point Average in EECS coursework must be at least 5.0, based on Rackham's 9.0 scale. (In addition, Rackham requires the overall GPA among all courses applied to the master's degree to be at least 5.0.)
8. Courses of 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 requirement.

Degree-Specific Requirements to Computer Science and Engineering

The Computer Science and Engineering masters degree program requires students to complete "kernel" course requirements, mandated electives, and free electives, for the total of 30 credits. A research-oriented directed study or Master's Thesis is also required. The purpose of the kernel is to give the student training in the major areas of computer science and engineering. Students who enter without an undergraduate engineering degree receive a M.S. degree. Students who enter with an engineering degree have a choice of either the M.S. or M.S.E. degrees.

Computer Science and Engineering kernel requirements:

1. *Software:* EECS 482, Computer Operating Systems (Prerequisite: EECS 370 and 381) or EECS 483, Compiler Construction (Prerequisite: EECS 370 and EECS 381)

2. *Hardware:* EECS 478, Switching and Sequential Systems (Prerequisite EECS 303 and 270, and senior or graduate standing) or EECS 470, Computer Architecture

(Prerequisite: EECS 370)

3. *Theory:* EECS 574, Theoretical Computer Science I (Prerequisite: EECS 476) or EECS 586, Analysis of Algorithms (Prerequisite: EECS 380)
4. *Intelligent Systems:* EECS 492, Introduction to Artificial Intelligence (Prerequisite: EECS 380)

Courses taken at another university or department that are equivalent in level and content may fulfill one or more of these requirements. Such "equivalency" is granted by the graduate chairman. Moreover, equivalency does not fulfill any other degree requirements—in particular credit hour requirements.

Computer Science and Engineering directed study requirement:
A research-oriented directed study of at least three credit hours must be completed. (It is possible to replace this directed study with a Master's Thesis.)

Computer Science and Engineering mathematical cognate requirement:
One of the two cognate courses required by the Rackham graduate school must be a mathematics course. A list of courses is maintained by the CSE division from which this course must be selected.

M.S.E. and M.S. in Electrical Engineering (Systems)

Program Chair: Professor Wayne Stark, EE Systems, CICE

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, 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. The program is administered by the Systems Science and Engineering Division of the Electrical Engineering and Computer Science Department (EECS).

The M.S.E. and M.S. degree programs are identical except for admissions 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 three (3) credit hours must be in mathematics. 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 and electrodynamics, electro-optics, or solid state. At least nine (9) credit hours must be earned from the kernel of the major area, with at least six (6) of these at the 500 level or higher. At least six (6) credit hours must be earned from the kernel of the minor area, with at least three (3) of these at the 500 level or higher and satisfactory completion of the EECS Introductory Seminar course in the first fall term. Course grades must be B- or better in order to be counted towards any requirements. A master's thesis is optional. Up to six (6) credit hours may be transferred if the department grants approval. The student must also satisfy the regulations of the School of Graduate Studies and the College of Engineering.

M.S.E. and M.S. in Electrical Engineering

Program Chair: Professor Ronald Lomax

The Graduate Program in Electrical Engineering covers topics such as circuits, electronics, electrodynamics, electromagnetics, energy conversion, electro-optics, and solid state materials, devices and integrated circuits. The program is administered by the Electrical Science and Engineering Division of the Electrical Engineering and Computer Science Department (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 three (3) credit hours must be in mathematics. EECS 590, "EECS Introductory Seminar," must be taken in the first fall term of graduate studies. The student must also choose a major and minor area, and satisfy a requirement in each. The major area must be circuits and electronics, electromagnetics and electrodynamics, electro-optics, or solid state. The minor area must be different from the major and must be chosen from either the previous list or bioelectrical sciences, 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 nine (9) credit hours must be earned from the kernel of the major area, with at least six (6) of these at the 500 level or higher. At least six (6) credit hours must be earned from the kernel of the minor area, with at least three (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 master's thesis is optional. Up to six (6) credit hours may be transferred if the department grants approval. The student must also satisfy the regulations of the School of Graduate Studies and the College of Engineering.

M.S.E. and M.S. in Industrial and Operations Engineering

Advisor: Graduate Program Office, 3062 H.H. Dow 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 (independent study courses, IOE 590, do not count towards this requirement); no more than four credit hours of independent study. At least two courses (four 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, Room 240 IOE Building.

B.S.E and M.S.E. in Industrial and Operations Engineering

Advisor: Professor James C. Bean, 272 IOE Building

The Engineering Global Leadership Honors Program is a five-year, 158-hour program leading to B.S.E. IOE. and M.S.E. IOE 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 240 IOE Building.

Joint M.B.A./M.S. (IOE) Degree Program

Advisor: Professor Jeffrey K. Liker, 210 IOE Building

The School of Business Administration and the 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. (IOE) degree. The program is arranged so that all requirements for the degree are completed in two and one-half years of enrollment with 65 credit hours necessary.

Students interested in the M.B.A./M.S. (IOE) 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. However 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 commencing either program. This joint program is not open to students who have earned either the M.B.A. or M.S. (IOE) 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 nine 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, SPH

This 60 credit hour interdepartmental master's degree program is administered jointly by the Industrial & Operations Engineering Department in the College of Engineering and the Health Services Management and the 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 Frank E. Filisko, 2046 Dow

Students select an option of study in this interdisciplinary Program from the Departments of Applied Mechanics, Chemistry, Chemical Engineering, Materials Science and Engineering, Nuclear Engineering, or Physics. Course requirements will depend upon 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 thirty credits of graduate work with not more than six credits and not less than four 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.Eng. in Manufacturing

Advisor: Professor A. Galip Ulsoy, Room 2266, 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), and who have industrial experience in manufacturing. A total of 30 credit hours is required, of which at least 24 credit hours must be graded (not pass/fail), and at least 18 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 industrial experience in manufacturing engineering. Students with outstanding qualifications who do not have two years of industrial experience can be considered for admission if they have relevant summer internship or co-op experience of at least four months. Prerequisites for admission include: (i) at least two years of college engineering mathematics (including probability and statistics), (ii) a course in manufacturing processes.

Admitted students will follow a program tailored, in consultation with the program advisor, to their individual background and to meet their individual needs. The student must satisfy a course distribution requirement as follows:

(1) Engineering Core (9 credits)
(2) Management and System Core (9 credits)
(3) Discipline Electives (6 credits)
(4) Seminar and Project/Internship (6 credits, pass/fail)

All students in the M. Eng. in Manufacturing program, however, must take the course sequence MFG 501 Manufacturing Seminar, MFG 502 Manufacturing Seminar/Project, and MFG 503 Manufacturing Project. Lists of acceptable courses in each distribution area are available, and substitutions require the approval of the program advisor.

M.S.E. in Materials Science and Engineering

Advisor: Professor David J. Srolovitz, 2210 H.H. Dow Building

A total of 30 graduate level credit hours of departmental and cognate subjects must be completed for this degree. Of the 30 hours at least 21 hours must be formal course work which includes Mat. Sci. Eng. 590 (1 credit hour) and a minimum of 2 cognate courses. 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 Mat. Sci. Eng. 690 and submit a Master's thesis for approval by the department. For others, a research report may be substituted for the thesis for up to 6 hours of graduate credit under Mat. Sci. Eng. 690.

A booklet describing the graduate program in more detail is available from the secretary in the Graduate Program Office, 3062D H.H. Dow Building.

M.S.E. in Mechanical Engineering

Graduate Chair: Professor J.R. Barber, 2206 G.G. Brown, (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 six credit hours of research or nine 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.E. and M.S. in Naval Architecture and Marine Engineering

Advisor: Professor Michael M. Bernitsas, 204 Naval Architecture and Marine Engineering Building

The applicant should have a bachelor's degree in Naval Architecture and Marine Engineering or its equivalent. Applicants with bachelor's degrees in other engineering disciplines will have to take extra courses beyond the 30 credit-hour minimum.

A minimum of 30 credit hours is required for the degree, of which at least 15 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 two credit hours each must be taken outside the department.

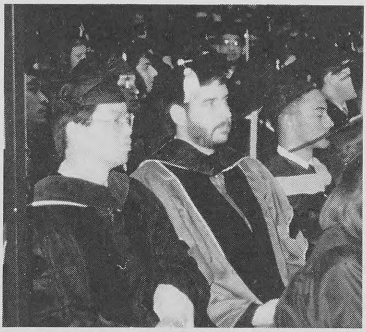
Students will specialize in one or more of the following areas: ship hydrodynamics, ship strength and vibration, marine engineering, ocean engineering (coastal or offshore), marine systems, ship production, or computer-aided marine design.

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, "Graduate Programs in 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.B.A./M.S.E. (NA&ME) Degree Program

Advisor: Professor A. N. Perakis, 218 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 NA&ME background and the specialty area of the NA&ME masters 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 NA&ME 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. 32-credit M.B.A. core
2. 12 elective hours in business administration
3. 15 hours of graduate level NA&ME courses
4. 5 hours of mathematics, some of which could be part of (1), (2), (3)
5. 10 hours acceptable to NA&ME advisors, some of which could be part of (1), (2), (3).

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

Advisor: Professor Terry Kammash

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 (Elec. Eng. and Comp. Sci. 313, 314, or 315, Physics 455, or equivalent), a course in fluid mechanics (Mech. Eng. 325, or equivalent), a course in electromagnetic fields (Physics 405 or equivalent), and a course in digital computer programming (Eng. 103, Elec. Eng. and Comp. Sci. 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 two courses outside the department. At least four of the nuclear engineering courses, excluding Nuc. Eng. 599 and 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 two to six credit hours of graduate course work, with the Nuc. Eng. 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, 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 courses, substitution of other courses will be arranged by the program advisor.

M.S. in Technical Information Design and Management

Advisory Committee: Consult program office, 111 TIDAL, (313) 764-1426

The University of Michigan's M.S. program in Technical Information Design and Management is a 30-credit 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. The program is a technically based program 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 computer requirements: two advanced communications courses; one programming course in Pascal, LISP, C, FORTRAN, or COBOL; a second advanced computer 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 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 practicum. The program is structured to address 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.

Professional Degrees

The following programs lead to professional degrees:

Aerospace Engineer - Aerospace E.
Applied Mechanics Engineer - App. M.E.
Chemical Engineer- Ch.E.
Civil Engineer- C.E.
Electrical Engineer - E.E.
Industrial and Operations Engineer - IOE
Marine Engineer - Mar.E.
Mechanical Engineer - M.E.
Metallurgical Engineer - Met.E.
Naval Architect - Nav. Arch.
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 six 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 nine hours in mathematics beyond the Bachelor of Science in Engineering mathematics requirements of the department cited in the degree.

Doctoral Degrees

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 some 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 nontechnical courses are left to individual departments or programs, and to the Graduate School. A prospective doctoral student should consult the program advisor regarding specific details.

A pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School office 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 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 are 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, 1049 Randall Laboratory, The University of Michigan, Ann Arbor, MI 48109-1120 or telephone on (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 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 1st.

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: In order 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, Phy 510 and Phy 520 — must be passed with a grade B or better. 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 four credit hour supervised research project, and the results of a two-part Qualifying Examination. The first part of the Qualifying Examination consists of a written 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
	CM&E I (AP 560)	QM II (AP 541)
	QM I (AP 540)	CM&E II (AP 561)
	Stat Mech. (Phy. 510)	Supv. Research (AP 715)
	Graduate Seminar (AP 514)	
Second Year:		
	Computational/Math Methods+	Elective Course*
	Solid State (Phy 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 (M 556)	
	or Numerical Methods for Scientific Computing I (M 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 Applied Mechanics and Nuclear Engineering; thus making the Program a truly cooperative and interdisciplinary endeavor. The faculty believe that the approach taken permits the students to eventually make a more significant contribution to macromolecular science. It also allows the students to develop the self-confidence needed to adapt to the changes inherent in modern research and development.

Admission: The Macromolecular Science 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. 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 must 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. A two-part comprehensive written examination in macromolecular science is to be passed before the end of the student's second year. Students are approved for candidacy after they have completed the basic prescribed courses satisfactorily (see below), passed the comprehensive exam, formed a Dissertation Committee and 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 students have demonstrated satisfactory progress in courses and have selected a Research Supervisor. The interdisciplinary nature of the Program allows for a wide range of research possibilities.

Representative Course Programs: It is recommended that in all the options an introductory course such as MMS 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 or 5 courses from Chemistry and 12 hours or 5 courses from MMS.

For an Organic option, these courses must include: MMS 890, MMS 535, MMS 536, MMS 538, Chem 540, Chem 541, Chem 542.

For a Physical option, these courses must include: MMS 890, MMS 536, Chem 570, Chem 575, Chem 580, Chem 672, Chem 804.

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 or 5 courses from ChE and 12 hours or 5 courses from Macromolecular Science. These courses must include: MMS 890, MMS 536, ChE 528, graduate courses in transport phenomena, numerical methods or mathematical modeling and polymer processing.

Materials Science and Engineering Option:

A minimum of 30 hours of course work from Materials Science and Engineering and Macromolecular Science courses. This must include a minimum of 2 hours or 5 courses from MSE and 12 hours or 5 courses from MMS.

These courses must include: MMS 890, MMS 536, 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 or 5 courses from Physics and 12 hours or 5 courses from MMS. These courses must include: MMS 890, MMS 536, Phys 505, Phys 506, Phys 507, Phys 510, Phys 518 and an advanced course in physical properties of polymers.

Additional Options:

Additional options in Mechanical Engineering and Applied Mechanics and in Nuclear Engineering are available. An individualized option may be proposed by students. 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, 2200 Bonisteel Blvd., Ann Arbor, MI 48109-2099, or telephone (313) 763-2316.

Military Officer Education Programs

Military Officer Education Programs

The University, 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 $100 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 $100 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 Christensen
Captains Gaul, Nelson and Campbell

Students who enroll as cadets in the Air Force Officer Education Program, 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, 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 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 must be made by January 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 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), plus an approved course in English Composition (scholarship students only).

Advanced course sequence (third and fourth years): Aerospace Studies 310, 311, 410, 411 (12 hours), plus an approved course in mathematical reasoning.

Scholarship students must, in addition, successfully complete one academic year (6 semester hours) of a major Indo-European or Asian language prior to commissioning.

This sequence of courses attempts to develop an understanding of the global mission and organization of the United States Air Force, of the historical development of air power and its support of national objectives, of concepts of leadership, management responsibilities and skills, of national defense policy, and of the role of the military officer in our society.

Flying Activities

Cadets who are physically and mentally qualified to become Air Force pilots receive dual and solo flight instruction under the supervision of an Air Force instructor pilot. The training is usually given between a cadet's junior and senior years at an Air Force pilot training base.

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)
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, and employment in relief missions and civic action programs in the late 1960s.

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 analysis will be made of management principles 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 socialization 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 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
Chair: Lieutenant Colonel Sonntag;
Assistant Chairs: Major Young, Captain Neal, Captain Rauch, and Captain Lapham

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, 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 in order 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 at a level determined by the chairman and based on an evaluation of prior service or training.

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 $100/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 5% (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 $100/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 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, Army orientation, 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 120 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 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.
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.

102.
Armed Forces and Society

Prerequisite: none.
(1 credit)

Armed Forces and Society is an introductory course in military institutions. The course will explore the evolution from feudal to modern military systems, the origin of military professionalism, the social characteristics of the officer corps and the enlisted soldier, and the sociology of combat. The course will also explore contemporary issues in the recruitment, organization, and training of the American armed services. Although the course will focus on American military institutions, the course method will be comparative. Students will compare the American military system with those of other countries to gain insight on how national culture influences the development of military systems. The course grade will be determined by two examinations and a short research paper.

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. The importance of these principles will be illustrated through an examination of some of the campaigns of Napoleon. 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 map reading, terrain analysis and platoon level operations in offensive, defensive and patrolling operations. Cadets will be required to present formal and informal briefings on the various topics covered in the course. 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 Combined 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 the Air-Land Battle doctrine of the U.S. Army. The course emphasizes the missions, organization and capabilities of the elements of a company-sized combined arms team. Instruction includes practical exercises involving company team offensive and defensive operations. Students will be evaluated through quizzes, examinations, oral presentations and two writing assignments.

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 Uniformed 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: Capt. Clark, USN
CDR Ringle; Lieutenant Commander Stevens; Lieutenants Perrone, Reynolds and Maynard; Captain Widhalm, 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 and in subspecialties such as nuclear propulsion or intelligence. Marine Corps officers may choose aviation, infantry, armor, or artillery specialties. After graduation, all commissioned officers receive additional training in their chosen specialties.

Four-Year and Two-Year Programs

The four-year program includes eight terms of course work. A military obligation is incurred at the beginning of the sophomore year for scholarship students.

The two-year program includes six weeks of training at the Naval Science Institute in Newport, Rhode Island during the summer before a student's junior year. This is followed by enrollment in the same junior and senior level courses taken by four-year program students. A military obligation is incurred by two-year program students upon enrolling in junior level classes.

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. Each year 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 between 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 upon the program in which they are enrolled, graduates have a three or four year active duty service obligation. Those who are selected for postgraduate 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. (2 credits)

This course focuses on the role of seapower 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. (Nav. Arch. 102)
Naval Ship Systems

Prerequisite: none. II. (3 credits)

Propulsion systems, auxiliary power systems, interior communications, and ship control. Elements of ship design to achieve safe operations, and ship stability characteristics.

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 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 with a brief description of each. *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 boldface type.

[Course number] refers to past course numbers.

(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 and above	Graduate level courses

**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 adviser.*

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

In general, the prerequisites listed for a course designate specific subject materials and/or skills 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 (DIVISION 235)

Department Office
302 Aerospace
Engineering Building
(313) 764-3310

N. Harris McClamroch, Ph.D., *Professor and Chair*

Professor

William J. Anderson, Ph.D.
Joe G. Eisley, Ph.D.
Gerard M. Faeth, Ph.D,
Arthur B. Modine Professor of Aerospace Engineering
Elmer G. Gilbert, Ph.D.
Donald T. Greenwood, Ph.D.
Paul B. Hays, Ph.D.,
Dwight F. Benton Professor of Engineering
Arthur F. Messiter, Jr., Ph.D.
Philip L. Roe, B.A.
Martin Sichel, Ph.D.
John E. Taylor, Ph.D.
Bram van Leer, Ph.D.
Nguyen X. Vinh, Ph.D.

Adjunct Professor

Jack R. Lousma, Eng. Degree

Professor Emeritus

Thomas C. Adamson, Jr., Ph.D.
Frederick L. Bartman, Ph.D.
Frederick J. Beutler, Ph.D.
Harm Buning, M.S.E.
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 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.
James F. Driscoll, Ph.D.
Pierre T. Kabamba, Ph.D.
C. William Kauffman, Ph.D.
Kenneth G. Powell, Sc.D.
Nicolas Triantafyllidis, Ph.D.

Assistant Professor

Vincent T. Coppola, Ph.D.
Alec D. Gallimore, Ph.D.
Anthony M. Waas, Ph.D.
Peter D. Washabaugh, Ph.D.

Lecturer

Donald M. Geister, M.S.E.

See page 205 for statement on course equivalence.

200.
General Aeronautics and Astronautics
Prerequisite: Physics 140, preceded or accompanied by Eng. 103. I and II. (2 credits)
Introduction to aerospace engineering. Elementary problems designed to orient the student in the program of aerospace engineering, together with a discussion of the current state of aerospace developments and the role of the engineer. Recitations and demonstrations.

301.
Laboratory I
Prerequisite: preceded or accompanied by EECS 314. I and II. (2 credits)
Comprehensive series of lectures and experiments designated to introduce the student to basic principles of electronics, circuit analysis, transducers, modern laboratory instrumentation, experimental methods, and data analysis. Experiments involve simple measurement and instrumentation problems.

302.
Laboratory II
Prerequisite: Aero. Eng. 301; preceded or accompanied by Aero. Eng. 330. I and II. (2 credits)
Continuation of the material in Aero. Eng. 301.

314.
Structural Mechanics I
Prerequisite: Mech. Eng. 210; preceded or accompanied by Aero. Eng. 350. I and 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

Prerequisite: Mech. Eng. 235; preceded or accompanied by Aero. Eng. 350. I and 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. Eng. 320 or introductory course in fluid mechanics. I and 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

Prerequisite: Aero. Eng. 200, Mech. Eng. 240. I and II. (3 credits)

Mechanics of a particle applied to the analysis of vehicle flight paths. Rigid body mechanics applied to translational and rotational vehicle motion. Analysis of vehicle motion and static and dynamic stability using perturbation theory.

350. (Math. 350)
Aerospace Engineering Analysis

Prerequisite: Math. 216 or 316 or the equivalent. I and 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.

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) (Nav. Arch. 411)
Finite Element Applications

Prerequisite: Eng. 103, Mech. Eng. 211 or Mech Eng. 210. 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. Eng. 314. I and 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

Prerequisite: Mech. Eng. 210, Math. 450 or Aero Eng. 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

Prerequisite: Aero. Eng. 320; preceded or accompanied by Aero. Eng. 330. I and 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 Eng. 320. I and II. (3 credits)

Fundamentals of propulsion: performance parameters, thermodynamic cycles, introduction to combustion. Performance analysis of various flight propulsion systems: turbojets, turbofans, ramjets, rockets, propellers.

440.
Vehicle Systems Performance

Prerequisite: junior standing. (3 credits)

Role of performance in systems analysis; mathematical modeling; identification of constraints, performance parameters, and performance indices. The aircraft performance problem: flight envelope, aerodynamic approximations, available propulsion systems; takeoff, landing, climb, and range performance. Modern performance optimization techniques. Applications to automobile, high-speed train, and space vehicle performance analysis.

443.
Spaceflight Dynamics

Prerequisite: ME/AM 240; Aero. Eng. 340 recommended. II. (3 credits)

Particle dynamics with applications to space station dynamics and tethered bodies. Orbital mechanics and earth satellite operations. Orbital decay. Rigid body dynamics and satellite attitude control. Dual-spin satellites. Gyroscopic instruments.

447.
Flight Testing

Prerequisite: Aero. Eng. 340. (2 credits)

Theory and practice of obtaining flight-test data on performance and stability of airplanes from actual flight tests. No laboratory fee will be charged, but a deposit covering student insurance and operating expense of the airplane will be required.

452. (EECS 401)
Probabilistic Methods in Engineering

Prerequisite: EECS 300 or Math. 448. I and II. (3 credits) C.I.C.E. students may not receive graduate credit for both EECS 401 and 501.

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. (A.O. & S.S. 464)
Upper Atmospheric Science

Prerequisite: senior or graduate standing in a physical science or engineering. I. (3 credits)

An introduction to physical processes in the upper atmosphere; density, temperature, composition, and winds; atmospheric radiation transfer processes and heat balance; the ionosphere; rocket and satellite measurement techniques.

471.
Automatic Control Systems

Prerequisite: Aero. Eng. 340. I, II and 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.
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 layouts and preliminary structural design. Subsonic and supersonic designs. Emphasis on design techniques and systems approach. Lectures and laboratory.

482.
Design of Rocket- and Air-Borne Remote Sensing Probes

Prerequisite: senior standing. (4 credits)

Design techniques and projects for geophysical, environmental, and earth resources surveys. Aircraft, sounding rocket, and balloon instruments and payloads as well as vehicle characteristics, and performance are considered. Student projects bring together in a unified concept components for sensing (remote and in situ), telemetering, tracking, performance, safety, and data processing.

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

Prerequisite: Aero. Eng. 414 and 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.

490.
Directed Study

(To be arranged)

Individual study of specialized aspects of aerospace engineering. Primarily for undergraduates.

510.
Finite Elements in Mechanical and Structural Analysis I

Prerequisite: Aero. Eng. 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

Prerequisites: Aero Eng. 510 or Appl. Mech. 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.

514.
Foundations of Solid Mechanics

Prerequisite: Aero. Eng. 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 non-linear shell theories from 3-D considerations.

515.
Mechanics of Composite and Microstructured Media

Prerequisite: Aero. Eng. 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

Prerequisites: Aero Eng. 414 or Appl. Mech. 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. (Appl. Mech. 518)
Theory of Elastic Stability I

Prerequisite: Appl. Mech. 511. 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 Eng. 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 techniques. Flow visualization, two- and three-dimensional velocity field measurement. Digital image analysis, contrast enhancement, pattern recognition. Lecture and laboratory.

522.
Viscous Flow

Prerequisite: Aero. Eng. 330 and 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.
Computational Fluid Dynamics I

Prerequisite: One graduate math course or permission of instructor; some computer programming experience; preceded or accompanied by Aero. Eng. 520. I. (3 credits)

Mathematical and physical fundamentals of computational fluid dynamics, with computer applications to model equations. Classification of partial differential equations, finite-difference approximations to linear convection and diffusion equations, truncation error, stability, monotonicity, nonlinear conservation laws, weak solutions, finite-volume approximations.

524.
Aerodynamics II

Prerequisites: Aero. Eng. 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. Eng. 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 fluctuating structure of free and wall-bounded turbulent flows.

530.
Turbojet Propulsion

Prerequisite: Aero Eng. 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

Prerequisites: 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. Eng. 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. Eng. 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: Mech. Eng. 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. Eng. 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.

542.
Astrodynamics I
Prerequisite: Aero. Eng. 340. I. (3 credits)
The study of motion of aircraft in a vacuum and in the atmosphere with emphasis on preliminary mission planning. Analysis of trajectories in suborbital, orbital, lunar, and interplanetary operations. Aerodynamic forces and heating characteristics and their effect on the selection of flight paths during entry into planetary atmospheres.

543.
Structural Dynamics
Prerequisite: Aero. Eng. 414 or 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. Eng. 414 or 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. Eng. 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. Eng. 540 or Appl. Mech. 443 or Mech. Eng. 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 II
Prerequisite: Aero. Eng. 542. (3 credits)
Orbit determination. Systems of canonical equations. Perturbation theory with applications to the motion of an artificial satellite. Lunar and planetary theories.

550. (EECS 560)
Linear Systems Theory

Prerequisite: graduate standing. I and II. (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)
Non-Linear Dynamical Systems

Prerequisite: graduate standing. II. (3 credits)

Introduction to and analysis of phenomena which occur in non-linear dynamical systems. Topics include: equilibria, limit cycles, second order systems and phase plane analysis, bifurcations and chaos, Liapunov and input-output stability theory, asymptotic analysis including averaging theory and singular perturbations, numerical techniques.

552. (EECS 501)
Probability and Random Processes

Prerequisite: EECS 401 or graduate standing. I and 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 ruin, branching processes, Markov jump processes, uniformization, reversibility, and queueing applications.

565. (Appl. Mech. 565)
Optimal Structural Design

Prerequisite: Aero. Eng. 414 and 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: a course in feedback control. I. (3 credits)

Principles of space vehicle, homing and ballistic missiles guidance systems 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 determination and redundant measurements. Application of Kalman filtering to recursive navigation theory.

571. (EECS 561)
Digital Control Systems

Prerequisite: EECS 460/Aero. Eng. 471/Mech. Eng. 461. I. (3 credits)

Sampling and data reconstruction in computer control systems, z-transforms and state equations to describe discrete and mixed data systems. Analysis of digital feedback systems using root locus, Nyquist and Jury tests. Design of digital feedback systems using frequency domain techniques and state space techniques. Nonlinear digital feedback systems.

572. (EECS 566)
Non-linear Control Systems

Prerequisite: EECS 460/Aero. Eng. 471/Mech. Eng. 461 and EECS 562/Aero. Eng. 551. I. (3 credits)

Methods of analysis and design of non-linear control systems. Topics include: stabilizing controllers, absolute stability theory, describing function methods, input-output stability of feedback systems. Control techniques for non-linear systems: dither, vibrational control, variable structure systems and sliding mode control, linearization by nonlinear feedback.

573.
Real-Time Simulation of Dynamic Systems

Prerequisite: permission of instructor. II. (3 credits)

High-speed simulation of systems described by ordinary differential equations with emphasis on real-time applications and hardware-in-the-loop. Error analysis of numerical integration methods, use of multiple frame rates, treatment of discontinuous non-linearities, performance of D-A and A-D converters. Examples include control systems, flexible structures, and aerospace vehicles.

574.
Control of Aircraft, Missiles, and Space Vehicles

Prerequisite: a course in feedback control. I. (3 credits)

Analysis and synthesis of autopilots for aircraft. Design of thrust-vector control systems including effects of elastic structures and fuel sloshing. Altitude control systems for space vehicles; mechanization using jet thrusters and inertia wheels; gravity gradient moments.

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

Prerequisite: EECS 560/Aero. Eng. 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 condition. Application to a variety of specific optimal control problems from diverse disciplines. Introduction to computational methods in optimal control.

577. (EECS 505) (I.&O.E. 511) (Math. 562)
Continuous Optimization Methods

Prerequisite: Math 217, Math. 417 or Math. 419. I and 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

Prerequisite: EECS 501, 560. II. (3 credits)

Principles of estimation, linear filtering and detection. Estimation: linear and non-linear 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

Prerequisite: Aero. Eng. 471, Aero. Eng. 414, and Aero. Eng. 550. II. (3 credits)

Equations of motion of controlled elastic structures; modal and finite element formulations; shape control; active damping using feed-back; application to control of flexible aircraft and flexible space structures.

580. (EECS 565)
Linear Feedback Control Systems

Prerequisite: EECS 460/Aero. Eng. 471/Mech. Eng. 461 and EECS 560/Aero. Eng. 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.

590.
Directed Study

(To be arranged)

Individual study of specialized aspects of aerospace engineering. Primarily for graduates.

597. (A.O. & S.S. 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

Prerequisites: Aero. Eng. 511 or Mech. Eng. 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. Eng. 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. (CEE 615)
(ME/AM 649)
Random Vibrations

Prerequisites: CEE 513 or ME/AM 541 or Aero Eng. 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. (Appl. Mech. 618)
Theory of Elastic Stability II

Prerequisite: Aero. Eng. 518 or equivalent and graduate standing. II. (3 credits)

Koiter's theory for buckling, post-buckling, mode interaction and imperfection sensitivity behavior in non-linear 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. Eng. 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. Eng. 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

Prerequisite: Aero. Eng. 523 or equivalent, substantial computer-programming experience, and Aero. Eng. 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

Prerequisite: Aero. Eng. 520 and 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. Eng. 533. II. (3 credits)

Thermodynamics of gas mixtures, chemical kinetics, conservation equations for multicomponent reacting gas mixtures, deflagration and detonation waves. Nozzle flows and boundary layers with reaction and diffusion.

651. (EECS 600)
Function Space Methods in System Theory

Prerequisite: EECS 400. 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.

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.
Seminar in Flight Dynamics and Control Systems
(To be arranged)

880.
Seminar in Space Technology
Prerequisite: permission of instructor. (To be arranged)

990.
Dissertation/Pre-Candidate
I and II (2-8 credits); IIIa and 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 and II (8 credits); IIIa and 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
(313) 763-4277

Administered by the Department of Mechanical Engineering and Applied Mechanics

See page 205 for statement on course equivalence.

401. (ME 401)
Engineering Statistics for Manufacturing Systems
Prerequisites: 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.
Experimental Stress Analysis
Prerequisite: Mech. Eng. 211 and 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.

407.
Theory of Solid Continua
Prerequisite: Mech. Eng. 211, Mech. Eng. 320, 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.

412. (ME 412)
Advanced Strength of Materials
Prerequisite: Mech. Eng. 311. I. (3 credits)
Review of energy methods, Betti's reciprocal theorem; elastic, thermo-elastic 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.
Mechanics of Composite Materials
Prerequisite: Mech. Eng. 211 and 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

Prerequisites: Mech. Eng. 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 & Synthesis of Motion

Prerequisites: Mech. Eng. 240. II. (3 credits)

Particle and rigid body kinematics in 3D 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: Mech. Eng. 240. II. (3 credits)

Vector Kinematics in 3D, 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.
(Bioeng. 456) (ME 456)
Biomechanics

Prerequisite: Mech. Eng. 211 and Mech. Eng. 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. (Bioeng. 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.
P/F credit only.

501. (ME 501)
Analytical Methods in Mechanics I

Prerequisite: Mech. Eng. 211, Mech. Eng. 240 and 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) The Principles and Applications of Variational Methods

Prerequisite: ME/AM 443. (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

Prerequisite: ME/AM 501, Mech. Eng. 311, or Mech. Eng. 320, or Mech . Eng. 370. I and 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.

512. (ME 512) Theory of Elasticity

Prerequisite: Appl. Mech. 407 or ME/AM 412. 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. Asymmetric contact and crack problem. Asymmetric torsion.

514. (ME 514) Nonlinear Fracture Mechanics

Prerequisite: ME/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. (ME 515) Contact Mechanics

Prerequisite: Mech. Eng. 350 or ME/AM 412. I, alternate and even years. (3 credits)

Hertzian elastic contact; elastic-plastic behavior under repeat 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. (ME 517)(Macromolecular Science & Engineering 517) Theory of Linear Viscoelasticity I

Prerequisite: Appl. Mech. 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.

518. (Aero. Eng. 518)
Theory of Elastic Stability I

Prerequisite: Appl. Mech. 407. I. (3 credits)

Elastic and inelastic buckling of bars and frameworks; variational principles and numerical solutions; lateral buckling of beams. Instability of rings.

519.
Theory of Plasticity I

Prerequisite: Appl. Mech. 407. I. (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 and 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: ME/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.

524. (ME 524) (NAME 524)
Wave Motion in Fluids

Prerequisite: ME 320. I. (3 credits)

Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to a moving body; Kortweg-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.

525. (ME 525)
Computational Fluid Dynamics

Prerequisite: ME/AM 520. I. (3 credits)

Finite difference and finite volume methods for incompressible, viscous flows, in two and three diminutions, complex geometries and coordinate mapping, methods for stratified flows. Special methods for inviscid flows, panel methods for flow around bodies, vortex methods for unsteady flows and free surface flows. Visualization of flow fields.

527. (ME 527)
Multiphase Flow

Prerequisite: ME/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.

541. (ME 541)
Mechanical Vibrations

Prerequisite: ME/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. (ME 543)
Analytical and Computational Dynamics I
Prerequisite: ME/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 stimulation.

548. (ME 548)
Nonlinear Oscillations and Dynamic Stability of Mechanical Systems
Prerequisite: ME/AM 443. II. (3 credits)
Large-amplitude vibrations of mechanical systems; dynamic instability theory of rods, plates, and shells; methods of Liapunov; asymptotic approaches of Krylov, Bogoliubov, and Mitropolsky; perturbation methods; Floquet theory.

565 (Aero. Eng. 565)
Optimal Structural Design
Prerequisite: Aero. Eng. 435 or 414. 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, and III. (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: ME/AM 505 or CEE 510/Naval. Arch. 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. Eng. 618)
Theory of Elastic Stability II
Prerequisite: Aero. Eng. 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.

619.
Theory of Plasticity II
Prerequisite: Appl. Mech. 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 Fluids

Prerequisite: ME/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.
Hydrodynamic Stability

Prerequisite: ME/AM 520. I. (3 credits)

An introduction to the theory of hydrodynamic stability with applications to stability of thermal flows, rotating and curved flows, wall-bounded 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: ME/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. (ME 625)
Nonhomogenous Fluids.

Prerequisite: ME/AM 520. I and 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)
Pertubation Methods for Fluids.

Prerequisite: ME/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. (ME 627)
(NAME 524)
Wave Motion in Fluids

Prerequisite: ME/AM 520. II. (3 credits)

Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to a moving body; Korteweg-deVries equation; onoidal 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: ME/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. (ME 643)
Analytical and Computational Dynamics II

Prerequisite: ME/AM 543. II. (4 credits)

Kinematic and dynamical equation formulation for rigid and flexible mechanical multibody systems undergoing large overall motion and small elastic deformation. Energy principles, higher and lower pair joint parameterizations, sparse and dense equation formulation and solution techniques, numerical integration, generalized impulse and momentum, collisions, and computational elastodynamics. Course project.

648. (ME 648)
Nonlinear Oscillations and Stability of Mechanical Systems

Prerequisite: ME/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.
(ME 649) (CEE 615) (Aero. Eng. 615)
Random Vibrations

Prerequisite: CEE 513 or ME/AM 541 or Aero. Eng. 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.

699.
Advanced Special Topics in Applied Mechanics

Prerequisites: 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 ME/AM. 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 that discusses the future trends in his/her field.

990.
Dissertation/Pre-Candidate

I and II (2-8 credits); IIIa and 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 and II (8 credits); IIIa and 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
(313) 936-0653

**College of Literature, Science and the Arts*
***College of Engineering*

Professor Roy Clarke, *Director*

Professors Allen, Atzmon, Bhattacharya, Bilello, Dierker, Field, Gilgenbach, Gland, Haddad, Kopelman, Lau, Merlin, Mourou, Orr, Pang, Pavlidis, Rand, Ross, Sander, Singh, Srolovitz, Steel, Uher, Winful, Yalisove, Zorn.

See page 205 for statement on course equivalence.

514.
Applied Physics Seminar
Prerequisite: Graduate Studies I and II (1 or 2).
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 micro-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.

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)
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)
Lasers and Electro-Optics II
Prerequisite: AP 550 or EECS 538. 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. (Phys 540)
Advanced Condensed Matter
(3 credits)
A unified description of equilibrium condensed matter theory (using Greens functions); critical phenomena, Anderson localization and correlated electron theory.

609. (EECS 638) (Phys 609)
Quantum Theory of Light
Prerequisite: one graduate level course in quantum mechanics
(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) (Phys 611)
Nonlinear Optics
Prerequisite: EECS 530, 537, or 538 or permission of instructor.
(3 credits)
Variety of nonlinear optical phenomena, formalism of nonlinear optics - the nonlinear 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. (Phys 619)
Advanced Solid State

Prerequisites: Physics 520 (or 463), 511, and 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 (Raleigh, 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. (Phys 633)
Fluid Dynamics

(3 credits)

The course begins with a derivation of the hydrodynamical equations as prototypical phenomenological equations, based on general conservation laws and the second law of thermodynamics; Two dimensional ideal fluid flow, the Joukowsky theory of the airfoil, gravity waves and the theory of tides, solitary waves, incompressible viscous flow and the Stokes formula, Sommerfeld's theory of lubrication, the turbulent wake, Prandtl's theory of the boundary layer, shock waves, relativistic hydrodynamics, fluctuations in hydrodynamics, etc.

644. (Phys 644)
Advanced Atomic Physics

(3 credits)

Lase 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

Prerequisites: 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.

674. (Nucl 674)
High-Intensity Laser Plasma Interactions

Prerequisites: Nucl Eng 471, 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
2233 Space Research Building
(313) 764-3335

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.
Professor of Atmospheric, Oceanic and Space Sciences; Professor of Electrical Engineering and Computer Science; Dean of the College of Engineering

John R. Barker, Ph.D.
Atmospheric Science

John P Boyd, Ph.D.
Atmospheric Science

Thomas M. Donahue, Ph.D.
Edward H. White II Distinguished University Professor of Planetary Science

Tamas I. Gombosi, Ph.D.
Atmospheric Science

Paul B. Hays, Ph.D.
Dwight F. Benton Professor of Advanced Technology

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

Donald J. Portman, Ph.D.
Atmospheric Science

Perry J. Samson, Ph.D.
Atmospheric Science

John Vesecky, Ph.D.
Atmospheric Science

James C. G. Walker, Ph.D.
Atmospheric Science

Adjunct Professor

George R. Carignan
Adjunct Professor of Atmospheric Sciences, Associate Dean for Graduate Education and Research of the College of Engineering

Professor Emeritus

Frederick L.W. Bartman, Ph.D. *Atmospheric Science*

Albert Nelson Dingle, Sc.D.
Atmospheric Science

Gerald C. Gill, M.A.
Atmospheric Science

Associate Professor

Dennis G. Baker, Ph.D.
Atmospheric Science

Mary Anne Carroll, Ph.D.
Atmospheric Science

Guy A. Meadows, Ph.D.
Oceanic Science

Assistant Professor

John T. Clarke, Ph.D.
Atmospheric Science

Peter J. Sousounis, Ph.D.
Atmospheric Science

Lecturer

Lee H. Somers, Ph.D.
Oceanic Science

See page 205 for statement on course equivalence.

105. (Chem 105) Our Changing Atmosphere

Prerequisite: None. I and 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. Underwater Methods for Engineering and Sciences

Prerequisite: permission of instructor (to establish physical and swimming abilities). I and II. (3 credits)

Principles and practices of conducting engineering and research operations underwater include human performance, use of diving equipment; underwater safety; underwater engineering and research techniques. Preparation of students to organize and conduct their own under-water operations. Lecture and laboratory.

123. Life and the Global Environment

Prerequisites: None. II. (2 credits)

A hard look at the Gaia hypothesis. Do organisms cooperate to control the compositions of ocean and atmosphere? Can life prevent harmful changes in the global environment? Does the geologic record provide answers to these questions? What future change in the global environment can be expected?

171. Introduction to Global Change-Part I

Prerequisite: None. I. (3 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. Introduction to Global Change-Part II

Prerequisite: None. II. (3 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

I and 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

I and 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 204) Introduction to Planetary and Space Science

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.

Prerequisites: Sophomore standing in Engineering or Natural Science. I. (2).

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
Prerequisite: Physics 140, Math. 116, Chem. 130 or 210. I and II. (3 credits)
An introduction to the physical and chemical processes which 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
Prerequisite: A.O. & S..S. 304, Math. 215. II. (3 credits)
A continuation of A.O. & S.S. 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: A.O. & S.S. 202, or preceded or accompanied by A.O. & S.S. 304. I. (1 credit)
An introduction to weather observations, analyses, displays and forecasting.

311.
Synoptic Laboratory II
Prerequisite: A.O.& S.S. 310 and preceded or accompanied by A.O & S.S. 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
Prerequisites: Junior standing. I and 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.

350. (Nav. Arch. 350)
Ocean Engineering Systems
Prerequisite: Mech. Eng. 320. II. (3 credits)
Engineering analyses of work systems for operation in and on the oceans. Offshore drilling platforms, submersibles and semi-submersibles, cables, and moorings. Buoy systems, pipe laying, salvage and rescue systems, ocean lining. Selected aspects of physical oceanography underwater acoustics and instrumentation.

401.
Geophysical Fluid Dynamics
Prerequisite: Physics 240; preceded or accompanied by Aero. Eng. 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
Prerequisite: 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: A.O.& S.S. 330 and Chem. 365. 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; air cleansing by rain; rain chemistry; and the dynamics of rain systems.

412.
Dynamics of Climate
Prerequisite: A.O. & S.S. 312 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: A.O. & S.S. 305 or A.O. & S.S. 401. II. (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: A.O. & S.S. 305 or A.O. & S.S. 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. (Nav. Arch. 425)
Physics of the Oceans
Prerequisite: A.O. & S.S. 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 thermodynamics and equations of state of sea water, optical and acoustical properties of sea water, currents, tides, waves, and turbulent phenomena.

429. (Nat. Res. 429)
Great Lakes Limnology
Prerequisite: Nat Res. 311 or Zool. 443, or A.O. & S.S. 423 (Nat. Res. 423). II. (2 credits)
Lectures on the physics, chemistry, and biology of the Great Lakes ecosystems are presented by instructors and invited outside speakers. Each student is required to research a topic mentioned in the introductory lectures, prepare an abstract and list of references, and make an oral presentation as the basis for a class discussion.

430.
Thermodynamics of the Atmosphere
Prerequisite: Preceded or accompanied by Math 216.
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 and Radiative Processes
Prerequisite: 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: A.O. & S.S. 414 or A.O. & S.S. 451. I. (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 cyclogenesis, and recent cyclone models will be discussed.

442.
Oceanic Dynamics I
Prerequisite: A.O. & S..S. 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.

450. (Nav. Arch. 450)
Design of Offshore Facilities
Prerequisite: Mech. Eng. 320 and Nav. Arch. 350. I. (3 credits)
Loading and motions of offshore structures. Morison's equation. Current and wind loads. Wave loading. Design methodologies for offshore structures. Conceptual design alternatives, evaluation, preliminary design, launching and installation. Ice resistant structures. Students will do two computer design mini-projects on risers, towing, cables, mooring, pipelines, redesign or tower dynamics.

451.
Atmospheric Dynamics I
Prerequisite: A.O. & S.S. 401. II. (4 credits)
Quasi-geostrophic energetics; fronts; the mean circulation; planetary and equatorial waves: overview of the dynamics of the middle atmosphere; wave-mean flow interaction; spectral methods; and tropical meteorology.

454.
Weather Analysis and Forecasting Laboratory
Prerequisites: A.O. & S.S. 311, preceded or accompanied by A.O. & S.S. 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 frontogenesis. Description of operational numerical forecast models and facsimile products. Daily weather discussion and forecasting.

460.
Satellite Meteorology
Prerequisite: permission of instructor. 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: permission of instructor. 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: A.O. & S.S. 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: permission of instructor. 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. Eng. 464)
Upper Atmospheric Science

Prerequisite: senior or graduate standing in a physical science or engineering. I. (3 credits)

An introduction to physical processes in the upper atmosphere; density, temperature, composition, and winds; atmospheric radiation transfer processes and heat balance; the ionosphere; rocket and satellite measurement techniques.

465.
Space System Design for Environmental Observations

Prerequisite: Senior Standing. II. (3-4 credits. Credit hours to be arranged with instructor.)

An aerospace 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.
Biogeochemical Cycles

Prerequisites: Math 116, Chem 210, Phys 240. II. (3 credits)

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

469. (Nav. Arch. 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.

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

Prerequisite: Chem. 130 or 210, 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

Prerequisite: Math. 216, Physics 240, Chem. 130 or 210. I. (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. I. (4 credits)

Basic physical processes significant to the structure and characteristics of the upper atmosphere; photochemistry, diffusion, ionization, distribution of neutral and charged particles; thermal structure of the upper atmosphere; atmospheric motions, geomagnetic storms.

499.
Directed Study for Undergraduate Students

Prerequisite: permission of instructor. I, II, III, IIIa and IIIb. (To be arranged)

Directed reading, research, or special study for advanced undergraduate students.

501.
Seminars in Limnology and Oceanography

Prerequisite: graduate standing. I and 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 A.O. & S.S. 401. I (alternate, odd years). I. (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. (Nav. Arch. 528)
Remote Sensing of Ocean Dynamics

Prerequisite: A.O. & S.S. (Nav. Arch.) 335 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-Thermal Processes
Prerequisite: A.O. & S.S. 332. II. (3 credits)
Fundamental principles of molecular radiative transfer applicable to planetary atmospheres; macroscopic and microscopic forms of the transfer equation for both grey and non-grey cases; line broadening mechanisms; band models; non-local thermodynamic equilibrium source functions; applications to, and results from climate studies.

533.
Radiative Transfer-Scattering
Prerequisite: A.O. & S.S. 332. II. (3 credits)
Theory of atmospheric scattering. Single scattering, Rayleigh scattering, introduction to the Mie Theory; multiple scattering in planetary atmospheres, scattering by clouds and aerosols, optical phenomena, approximate methods of solution of radiative transfer equations.

550. (Nav. Arch. 550)
Offshore Engineering Analysis II
Prerequisite: Nav. Arch. 420, Nav. Arch. 440, and Nav. Arch. 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: A.O. & S.S. 451. I. (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.

554.
Advanced Synoptic Meteorology: Middle Lat. Weather Systems
Prerequisite: A.O. & S.S. 401 (which may be taken concurrently) or A.O. & S.S. 454. I. (3 credits)
Review of governing equations. Extratropical cyclones and cyclogenesis; jet streams and upper waves in the westerlies; fronts and frontogenesis. Diagnosis of vertical velocity. Quasi-geostrophic and semi-geostrophic theory. Diabatic effects. Lectures, map discussions, and laboratory exercises.

555.
Spectral Methods
Prerequisite: Math. 216 and Eng. 103 or knowledge of FORTRAN. II. (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.

563.
Air Pollution Dispersion Modeling
Prerequisite: A.O. & S.S. 463. I. (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: A.O. S.S. 464. I, 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. II. (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.

566.
Topics in Planetary Electrodynamics

Prerequisites: permission of instructor. I. (3 credits)

This is a topics/seminar course providing an overview of modern research in electro-magnetic phenomena at the Earth and planets. Topics include dynamo theories of planetary magnetic fields, lightning and lower atmospheric potentials, the ionospheric dynamo, and atmosphere/magnetosphere coupling.

567. (Chem 567)
Chemical Kinetics

Prerequisites: Chem 469 or A.O. & S.S. 479. II. (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.

578. (E.I.H. 666)
(Environ. Health 666)
Air Pollution Chemistry

Prerequisite: A.O. & S.S. 479, or Chem. 365. II. (3 credits)

Tropospheric and stratospheric air pollution are discussed following a review of thermochemistry, photochemistry, and chemical kinetics. Gaseous and particulate air pollutants are considered in terms of their origins and transformations.

595.
(Elec.-Comp. Eng. 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. Eng. 532)
Gaskinetic Theory

Prerequisites: 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.
Fundamentals of Space Plasma Physics

Prerequisite: Senior level statistical physics. 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 and 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
Prerequisite: A.O. & S.S. 442 or 451, and Eng. 103 and 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: A.O. & S.S. 451. I. (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 and II. (To be arranged)
Supervised analysis of selected problems in various areas of meteorology and oceanography.

731. (EECS 731)
Space Terahertz Technology and Applications
Prerequisites: 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.

749.
Space Science Seminar
Prerequisites: 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, and III (2-8); IIIa and 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, and III (8 credits); IIIa and 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.

Bioengineering (Division 242)

Department Office
3304 G.G. Brown
(313) 764-9588

Charles A. Cain, Ph.D., P.E., *Professor of Electrical Engineering and Computer Science; and Chair, Bioengineering Program*

See page 205 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. (Mat. Sci. & Eng. 410) Biomedical Materials Considerations

Prerequisite: Mat. Sci. & Eng. 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 vs. transplants and relevant biological components. Tours of relevant university facilities.

417. (EECS 417) Electrical Biophysics

Prerequisite: EECS 210 or 213 or 314 or 416 and, preceded or accompanied by EECS 300 . I. (3 credits)

Electrical biophysics of muscle, nerve, and synapse; electrical conduction in excitable tissue; models for nerve, muscle, and sensory recep-tors, including the Hodgkin-Huxley equations; biopotential mapping, cardiac electrophysiology, and biological noise.

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.

434. (Chem. Eng. 434) (Civ. Eng. 580) (Microb. 434) Microbiology for Engineers

Prerequisite: Chem. 225. I and II. (4 credits)

Principles and techniques of microbiology with an introduction to their application in the several fields of engineering. Lectures and laboratory.

456. [546] (Appl. Mech. 456) (Mech. Eng. 456) Biomechanics

Prerequisite: Mech. Eng. 211, 240. II. (3 credits)

Definition of biological tissue behaviors, including elastic, viscoelastic, an 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: permission of instructor. I and 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. (Mech. Eng. 476) Thermal-Fluid Sciences in Bioengineering

Prerequisite: None. Credit restrictions. Not open to Mech. Eng. 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.

481. (Nuc. Eng. 481) Engineering Aspects of Radiology and Nuclear Medicine

II. (2 credits)

An introduction to the physical principles, instrument systems, and analytical method of importance in radiation-related medical procedures. Topics are drawn from research and clinical activities in diagnostic radiology, nuclear medicine, and radiation therapy.

495. (Appl. Mech. 495) Introduction to Bioengineering

Prerequisite: permission of instructor. II. (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.

516. (Chem. Eng. 516) Cellular Bioengineering

Prerequisite: a course in physical chemistry and a course in biology. I. (3 credits)

Use of reaction/transport theory systems science to explain the function and design of cells and subcellular components. Methods of analysis: order of magnitude analysis, temporal decomposition and non-linear dynamics. Applications to: Metabolic reaction networks, epigenic systems, cellular growth, and differentiation. Surveys of genetic engineering and large-scale cell culture.

519. (Physiol 519) Bioengineering Physiology

Prerequisite: Biol. 105 or 112 or equivalent, and 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

Prerequisite: Biol. 105 or 112 and Math. 215. II. (3 credits)

This course is designed to equip the student with appropriate concepts and tech-niques 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. (I.&O.E. 534) (E.I.H. 556) Occupational Biomechanics

Prerequisite: I.&O.E. 333 and I.&O.E. 334, or I.&O.E. 433. II. (3 credits)

New techniques to predict the anatomical and physiological basis for human performance in various man-machine systems. Models to 1) muscle contraction speed, strength, and endurance, 2) skeletal strength and movement, 3) human metabolism and cardiopulmonary system responses to work stress, and 4) motor system control functions. Biomechanical and physiological monitoring systems, and applications to the design of man-machine systems.

535. (I.&O.E. 535) Laboratory in Biomechanics and Physiology of Work

Prerequisite: I.&O.E. 534 (Bioeng. 534). II. (2 credits)

This laboratory is offered in conjunction with the Biomechanics and Physiology of Work course to allow students to experimentally determine 1) musculoskeletal reactions to volitional acts, 2) how EMG is used in muscle actions and fatigue evaluation, and 3) how the cardiopulmonary systems respond to various work stressors.

569. (EECS 569) Introduction to Neurophysiological Systems

Prerequisite: EECS 360 or EECS 460. II. (3 credits)

Application of systems theory to neurophysiology; a theoretical and experimental study of the application of linear and nonlinear theory, state-space concepts, and stability criteria to several neurophysiological systems; neuromuscular systems, pupillary control, eye tracking, temperature regulation, and central nervous system function.

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

Prerequisites: 2 hrs of 590. I, II, III. (Arr).

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. *To be graded on a satisfactory/unsatisfactory basis only.*

635. (I.&O.E. 635) Biomechanics and Physiology of Work Laboratory

Prerequisites: I.&O.E. 333 & 334, or I.&O.E. 433, and enrollment in 534. (2 credits)

This laboratory course is offered in conjunction with the Occupational Biomechanics lecture course (IOE/BIOE 534) to enable students to experimentally examine, 1) musculoskeletal reactions to volitional acts, 2) the use of EMGs to evaluate muscle function, and 3) the cardiopulmonary system in response to various common manual activities in industry.

690. (Physiol. 690) (Zool. 691) (Anat. 690) (Psych. 690) (Pharmacol. 690) (Neurol. 690) Neuroscience

Prerequisite: graduate standing and permission of instructor. I. (3 credits)

Study of nervous system including comparative aspects, structure, function, chemistry, behavior, and pathology.

691. (Physiol. 691) (Zool. 691) (Anat. 691) (Neurol. 691) Neuroscience Laboratory

Prerequisite: Physiol. 690 and permission of instructor. I. (3 credits)

Laboratory exercises and demonstrations in neurobiology.

890. Bioengineering Seminar

(1 credit)

990. Dissertation/ Pre-Candidate

I, II, and III. (2-8 credits); IIIa and 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, and III. (8 credits); IIIa and 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
1235 Business Administration
(313) 763-5796

Engineering undergraduate students interested in pursuing the Master of Business Administration degree, following the completion of their Bachelor's degree in Engineering, are encouraged to consult with counselors in the Office of Admissions and Student Services, 1235 Business Administration. Undergraduate engineering study is a particularly good preparation for the MBA degree program and excellent career opportunities exist for engineers who earn the MBA degree.

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 Economics Department of the College of Literature, Science, and the Arts, and the Accounting area of the School of Business Administration.

Juniors may elect courses numbered 300 to 399 inclusive, and seniors may elect any courses numbered 300 to 499 inclusive, provided they have satisfied particular course prerequisites.

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 *(3 credits)*
A 272. Principles of Accounting *(3 credits)*

Business Economics and Public Policy

BE 300. Economics of Enterprise *(3 credits)*

Computer and Information Systems.

CIS 301. Information Systems and Data Processing *(3 credits)*

Finance

F 300. Financial Management *(3 credits)*

Law, History, and Communication

LHC 305. Business Law *(3 credits)*
LHC 306. Business Law *(3 credits)*

Marketing

M 300. Marketing Management *(3 credits)*

Organizational Behavior and Industrial Relations

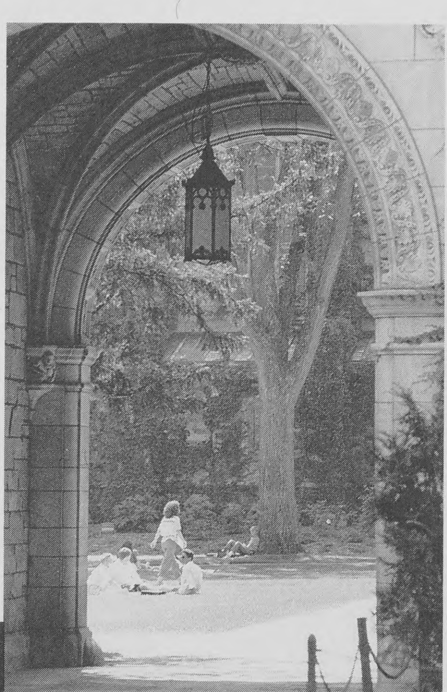
OB 300. Behavioral Theory in Management *(3 credits)*
OB 315. Management of Personnel *(3 credits)*
OB 322. Management-Union Relations *(3 credits)*

Operations Management

OM 311. Operations Management *(3 credits)*

Statistics and Management Science

SMS 301. Introductory Probability and Statistics *(3 credits)*



Chemical Engineering (DIVISION 245)

Department Office
3074 Dow Building
(313) 764-2383

Johannes Schwank, 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.
Robert H. Kadlec, Ph.D., P.E.
Henry Y. Wang, M.S., Ph.D.
James Oscroft Wilkes, Ph.D. *Assistant Dean for Admissions and Instruction*
Gregory S. Y. Yeh, Ph.D., *also Materials Engineering*

Adjunct Professor

Howard Klee, Jr., Sc.D.

Professor Emeritus

Lloyd L. Kempe, Ph.D., P.E., *also Microbiology, Medical School*
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., *also Metallurgical Engineering*
Edwin Harold Young, M.S.E., P.E., *also Metallurgical Engineering*

Associate Professor

Costas Kravaris, Ph.D.
Bernhard O. Palsson, Ph.D.
Phillip E. Savage, Ph.D.
Robert Ziff, Ph.D.

Assistant Professor

Stacy G. Bike, Ph.D.
Mark Burns, Ph.D.
Jennifer J. Linderman, Ph.D.
Levi T. Thompson, Jr., Ph.D.

See page 205 for statement on course equivalence.

230.
Thermodynamics I
Prerequisite: Eng. 103, Chem. 130, Math. 116. I and II. (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: Chem. Eng. 230 (Mat. Sci. & Eng. 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 Chem. Eng. 230. II. (3 credits)
A study of fluid mechanics for Chemical Engineering. Mass, energy, and momentum

Note. Laboratory fees are required to be paid in advance for each course involving laboratory work.

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
Prerequisite: Chem. Eng. 230 and 341; 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: Chem. Eng. 230 (Mat. Sci, & Eng. 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
Prerequisite: Chem. Eng. 330, preceded or accompanied by Chem. Eng. 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: Chem. Eng. 342. I and 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.

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.
Waste Management in Chemical Engineering
Prerequisite: Ch. E. 342 and Ch. E. 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.

452.
(Mat. Sci. & Eng. 452)
(Macro. Sci. 452)
Applied Polymer Processing
(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.

457.
(Mat. Sci, & Eng. 457)
Fundamentals of Polymeric Materials
Prerequisite: Mat. Sci. & Eng. 250. I. (3 credits)
Basic preparation, characterization, identification of bulk polymers and polymer molecules including the amorphous, glassy, and crystalline states; basics of forming and processing techniques, engineering and design properties including tensile behavior, creep and stress relaxation, fracture, fatigue.

460.
Chemical Engineering Laboratory II
Prerequisite: Chem. Eng. 343. I and 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
Prerequisite: Chem. Eng. 343 and 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
Prerequisite: Chem. Eng. 343 and 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.

485.
Biochemical Engineering Process Design
Prerequisite: Chem. 225 and preceded or accompanied by Chem. Eng. 340 or Chem. Eng. 343. II. (3 credits)
Selection and design of processes and equipment for the industrial manufacture of biochemical including foods, pharmaceuticals, and potable water, and for industrial waste treatment. Recitation and calculation periods.

486.
Chemical Process Simulation and Design I
Prerequisite: preceded or accompanied by Chem. Eng. 342, 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, petrochemical, and petroleum industries.

487.
Chemical Process Simulation and Design II
Prerequisite: Chem Eng. 344, 486, preceded or accompanied by Chem. Eng. 466. I and 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. Where the subject covers some aspect of plant work, as in summer employment in industry, arrangements should be made in advance. Not open to graduate students.

507.
Mathematical Modeling in Chemical Engineering
Prerequisite: Chem. Eng. 344 and 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.
(Mat. Sci. & Eng. 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.
(Mat. Sci. & Eng. 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.

516. (Bioeng. 516)
Cellular Bioengineering

Prerequisite: a course in physical chemistry, and a course in biology. I. (3 credits)

Use of reaction/transport theory systems science to explain the function and design of cells and sub-cellular components. Methods of analysis: order of magnitude analysis, temporal decomposition and non-linear dynamics. Applications to: Metabolic reaction networks, epigenic systems, cellular growth, and differentiation. Surveys of genetic engineering and large-scale cell culture.

525.
Catalysis, Kinetics, and Research Reactors

Prerequisite: 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: Chem. Eng. 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: Chem. Eng. 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. Multiphase 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: Chem. Eng. 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: Chem. Eng. 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: Chem. Eng. 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: Chem. Eng. 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: Chem. Eng. 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: Chem. Eng. 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: Chem. Eng. 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
Prerequisite: Chem. Eng. 341 and 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.
Process Control in the Chemical Industries
Prerequisite: Chem. Eng. 343 and 460. (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.
(Mat. Sci. & Eng. 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.

585.
Production and Processing of Petrochemicals
Prerequisite: Chem. Eng. 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: Chem. Eng. 407 or 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. Nonlinear systems, stability, bifurcation. Perturbation methods and chaotic systems.

608.

Applied Numerical Methods II

Prerequisite: Chem. Eng. 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.

Analysis of Chemical Signalling and Cellular Networks

Prerequisite: Biochem. and Chem. Eng. 516. 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. In the second half of the course, cellular networks, including immune and neural networks and tissue differentiation, will be analyzed.

617.

Advanced Biochemical Technology

Prerequisite: Chem. Eng. 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

Prerequisite: Chem. Eng. 528, and 526 or 527 or 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: Chem. Eng. 527 or Chem. Eng. 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 birfurcation analysis.

628.

Industrial Catalysis

Prerequisite: Chem. Eng. 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: Chem. Eng. 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) (Macr. Sci. 751) (Mat. Sci. & Eng. 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, and III (2-8 credits); IIIa and IIIb. (1-4 credits)
Election for dissertation work by doctoral student who has 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, and III (8 credits); IIIa and 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

Note. Safety regulations forbid the wearing of contact lenses in the laboratory.

* College of Literature, Science, and the Arts
Professor Kuczkowski, *Chair*

Professors Ashe, Barker, Bartell, Blinder, Coucouvanis, Coward, Curtis, Dunn, Ege, B.J. Evans, Francis, Gland, Gordus, Griffin, Kopelman, Koreeda, Lawton, Lohr, Lubman, Marino, Meyerhoff, Morris, Nordman, Pecoraro, Rasmussen, Sacks, Sharp, Townsend, Wiseman, Yocum; **Associate Professors** Carroll, Laine, Lee, Pearson, Penner-Hahn; **Assistant Professors** C.E. Evans, Glick, Goldstein, Korzeniewski, Moore, Pugh, Schnitker, Sension, Toogood; **Lecturers** Coppola, Hallada, Kerner, Weathers; **Professors Emeritus** Longone, Smith, Tamres, Taylor, Westrum

105. (AO&SS 105)
Our Changing Atmosphere

Prerequisite: none. I, II. (2 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.

125.
General and Inorganic Chemistry Laboratory

Prerequisite: to be elected by students who are eligible for (or enrolled in) Chem. 130. I, II and IIIa. (2 credits)

One four-hour laboratory and one pre-lab lecture. Basic laboratory techniques and their application to simple chemical systems.

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 and IIIa. (3 credits).

Introduction to the major concepts of chemistry, including the microscopic picture of atomic and molecular structure, periodic trends in chemical reactivity, the energetics of chemical reactions and the nature of chemical equilibria. Students are introduced both to the fundamental principles of modern chemistry and to the underlying theories that account for observed macroscopic behavior. Students learn to think critically, examine experimental data, and form generalizations about data as chemists do. Three lectures and one discussion. A special section of 130 is reserved for students who would benefit from a smaller lecture section and more frequent contact with both senior faculty and teaching assistants. Four lectures and one discussion. Approval of a counselor is required for registration in this special section.

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 and IIIa. (4 credits)

The content of organic chemistry is used to introduce students to major concepts of chemistry including ideas about bonding, energy, equilibrium, kinetics, stereochemistry, and the relationship between the structure and the reactivity of a chemical species.

211. Investigations in Chemistry

Prerequisites: To be taken with Chem. 210. I, II and IIIa. (1 credit)

An introduction to laboratory techniques in chemistry using inorganic and organic compounds, with emphasis on thin layer chromatography, stoichiometry, acid-base chemistry, and microscale organic reactions.

215. Structure and Reactivity II

Prerequisites: Chem. 210 and 211, concurrent enrollment in Chem. 216. I, II, IIIa. (3 credits)

A continuation of Chemistry 210. Students get further practice in applying the major concepts of chemistry to predicting the physical and chemical properties of organic compounds, including macromolecules, both synthetic and biological.

216. Synthesis and Characterization of Organic Compounds

Prerequisites: Chemistry 210, 211. Must be taken with Chemistry 215. I, II, IIIa. (2 credits)

Students participate in a number of projects in which they have to decide how to synthesize an organic compound on a microscale, then how to purify and how to characterize the compound using chromatographic and spectroscopic techniques.

230. Physical Chemical Principles and Applications

Prerequisites: Chem 215 or permission of instructor. No credit for students with credit for Chem. 340. I, II. (3 credits)

An introduction to the physical principles underlying some of the major topics of inorganic and analytical chemistry. The liquid and solid states of matter, phase transitions, solutions, electrochemistry, coordination complexes, spectroscopy, and the principles of thermodynamics that explain observed chemical reactions are studied from the view-point of the experimental scientist, with an emphasis on the application of chemical principles to a wide range of professions.

302. Inorganic Chemistry: Principles of Structure, Reactivity, and Function

Prerequisites: Chem. 215 and 216, or permission of instructor. I, II. (3 credits)

This course provides an introduction to the structure and properties of those elements other than carbon. Topics include the electronic structure of atoms, molecules and extended solids, bonding, periodicity, main group and transition element chemistry, catalysis and bioinorganic chemistry.

312. Synthesis and Characterization

Prerequisites: Chem. 215 and Chem 216. Prior or concurent enrollment in Chem. 302. I, II. (2 credits)

Introduces students to advanced techniques used in the synthesis, purification, and characterization of inorganic and organic compounds.

340. Principles of Physicochemical Measurements and Separations

Prerequisites: Math. 116 or Math 114, Chem. 215 and Chem. 216. Prior enrollment in Chem. 302 is recommended but not required. Students with credit for Chem 230 receive 2 credits for a subsequent election of Chem 340. I, II, IIIa. (5 credits)

Emphasizes the fundamentals of thermochemistry, equilibria, kinetics and spectra. Computer acquisition and analysis of data, modern physicochemical measurements, and techniques used in chemical separations are emphasized in the laboratory.

365. Principles of Physical Chemistry

Prerequisite: 2 terms of Chemistry, Physics 140-141 or 190 and preceded or accompanied by Math. 215 or 285. II. (4 credits)

Kinetic theory of gases, first and second laws of thermodynamics, applications including chemical and phase equilibria, kinetics of chemical reactions. A self-contained one term course (in Physical Chemistry) less detailed than the sequence Chemistry 468/Chemistry 469.

402.
Intermediate Inorganic Chemistry

Prerequisite: Chem. 302 and 340. I. (3 credits)

A second course in inorganic chemistry at the undergraduate level for juniors or seniors planning to go on to graduate school in chemistry. Topics will emphasize the interrelations of ideas presented earlier in the curriculum. Key topics include acid-base chemistry, theories of bonding, periodic properties and d-metal complexes. Additional topics selected from issues in catalysis, bioinorganic chemistry structure-property relations, solid state chemistry, organometallic chemistry, kinetics of organometallic reactions, f-block compounds, electron deficient clusters and quantum models of structure and bonding.

420.
Intermediate Organic Chemistry

Prerequisite: Chem. 215 and 216 or equivalents). II. (3 credits)

Chemistry 420 is an exploration of selected topics in organic chemistry. The course builds on the basic concepts of structure and reactivity considered in Chemistry 210 and 215. Condensation reactions, the chemistry of aromatic and heterocyclic compounds are among the topics to be included with an emphasis on stereochemistry, mechanism, and synthesis. The course is intended to strengthen the student's understanding of modern organic chemistry. It may serve as a terminal course in the topic or as a bridge between the first year of organic chemistry and further study in the area.

436.
Polymer Synthesis and Characterization

Prerequisite: Chem. 340 or equivalent or permission of instructor (3 credits). Lab.

This course introduces, in one hour of lecture and eight hours of laboratory per week, the special techniques that are appropriate for the study of macromolecules. The laboratory work includes the synthesis as well as the analysis of polymers. The kinetics of polymerization, determination of properties of polymers, special applications of NMR to polymers, and a computer simulation of polymer characteristics in solution are among the topics that are discussed and carried out.

447.
Physical Methods of Analysis

Prerequisite: Chem. 340. I and II. (3 credits)

Theory and applicability of principal physical and physicochemical approaches used in chemical analysis, including electrical, optical, and radiochemical methods. Lecture.

468.
Physical Chemistry

Prerequisite: Physics 240-241, and Math. 215 and Chemistry 340. I, II, IIIa. (4 credits)

Nature of the gaseous and liquid states, solution theory, homogeneous and heterogeneous equilibria, thermochemistry, and thermodynamics. Graduate students elect Chemistry 468 for 3 hours of credit.

469.
Physical Chemistry

Prerequisite: Math. 216 and Physics 240-241 and Chemistry 340; Chem. 468 is recommended. I, II. (4 credits)

Chemical kinetics, statistical thermodynamics, solid state; quantum chemistry, molecular structure and spectroscopy.

480.
Physical and Instrumental Methods

Prerequisite: Chem. 447 and 468 (or 396); corequisite Chem 469 (or 397). (3 credits)

An exploration of methods for the measurement of the physical and spectroscopic properties of substances and the application of these methods in instrumental analysis. The course is focused upon essential laboratory principles and operations as they relate to physicochemical properties of organic, inorganic, and macromolecular chemical species. Experiments study the areas of equilibria, chemical structure, chemical change, and computer simulation and calculation. Emphasis is placed upon the effective design of experiments together with synergistic coupling of modern instrumentation and computers. The course includes literature searches for physical data. Laboratory reports constitute an important component of the course. Students who wish to use the course to meet the English Composition Board requirements for a writing course in chemistry must elect Chemistry 479 concurrently. Ten to twelve hours a week in the laboratory. Grading is based on laboratory performance, laboratory records, and reports.

485.
Projects Laboratory

Prerequisite: Chem. 480 or the equivalent. (2 credits)

A projects-oriented laboratory in which students work on one or two projects in depth during the term.

530.
Introduction to Bioorganic Mechanisms

Prerequisite: Chem. 215 and 216 or equivalents). (3 credits)

Application of organic mechanistic chemistry to the problems of biochemistry, biotechnology and molecular cell biology. Chemistry of fatty acids, carbohydrates, alkaloids and peptides and other natural products will be discussed.

535.
Physical Chemistry of Macromolecules

Prerequisite: Chem. 469. II. (2 credits)

Theory and description of experimental methods for studying the properties of natural and synthetic macromolecules in solution.

536.
Laboratory in Macromolecular Chemistry

Prerequisite: Chem. 535 or Physics 418 or permission of instructor. I. (2 credits)

Experimental methods for the study of macromolecular materials in solution and in the bulk state.

538.
Organic Chemistry of Macromolecules

Prerequisite: Chem. 215/216 and 340. I. (2 credits)

The preparation, reactions, and properties of high molecular weight polymeric material of both natural and synthetic origin.

565.
Nuclear Chemistry

Prerequisite: Permission of instructor. Intended for graduate students and seniors. (3 credits)

The properties of the nucleus and a review of techniques for studying properties. Radioactive decay processes, nuclear models, nuclear reactions, and interactions of radiation with matter, applications of nuclear techniques to non-nuclear problems.

567. (AO&SS 567)
Chemical Kinetics

Prerequisite: Chem. 469 or A.O.&S.S. 479. II. (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.

570.
Molecular Physical Chemistry

Prerequisite: Chem. 468/469 or equivalent. I. (3 credits)

Basic concepts in modern chemical physics; molecular symmetry, group theory, operators, introduction to the electronic structure of atoms and molecules.

575.
Chemical Thermodynamics

Prerequisite: Chem. 469. II. (3 credits)

Application of classical thermodynamics to chemical phase equilibria, solutions, and chemical reactions. Introduction to statistical mechanical calculations and nonequilibruim thermodynamics.

Civil & Environmental Engineering (Division 248)

Department Office
2340 G. G. Brown
(313) 764-8495

E. Benjamin Wylie, Ph.D., P.E., *Professor and Chair*
Richard D. Woods, Ph.D., P.E., *Professor and Associate Chair*

Professor

Jonathan W. Bulkley, Ph.D., P.E.
Raymond P. Canale, Ph.D., P.E.
Robert I. Carr, Ph.D., P.E.
Eugene Andrus Glysson, Ph.D., P.E.
Subhash C. Goel, Ph.D., P.E.
Donald H. Gray, Ph.D.
Robert D. Hanson, Ph.D., P.E.
Movses Jeremy Kaldjian, Ph.D.
Victor C. Li, Ph.D.
Antoine E. Naaman, Ph.D.
Andrzej S. Nowak, Ph.D.
Walter Jacob Weber, Jr., Ph.D., P.E., *Earnest Boyce Professor of Civil and Environmental Engineering*
James Kenneth Wight, Ph.D., P.E.
Steven J. Wright, Ph.D., P.E.

Professor Emeritus

Glen Virgil Berg, Ph.D., P.E.,
Ernest Frederick Brater, Ph.D., P.E., *Hydraulic Engineering*
Donald E. Cleveland, Ph.D., P.E.
Donald Nathan Cortright, M.S.E., P.E.
Robert Blynn Harris, M.S.C.E., P.E.
Frank Edwin Richart, Jr., Ph.D., P.E., *Walter J. Emmons Professor Emeritus of Civil Engineering*
Wadi Saliba Rumman, Ph.D.
Victor Lyle Streeter, Sc.D., P.E., *Hydraulics*
Egons Tons, Ph.D., P.E.

Associate Professor

Linda Abriola, Ph.D.
Will Hansen, Ph.D.
Roman D. Hryciw, Ph.D.
Photios G. Ioannou, Ph.D.
Nikolaos D. Katopodes, Ph.D.

Associate Professor Emeritus

John M. Armstrong, Ph.D.,

Adjunct Associate Professor

Charles J. Hurbis, B.S.E. (I.E.), J.D.

Assistant Professor

Avery H. Demond, Ph.D.
John G. Everett, Ph.D., P.E.
Kim F. Hayes, Ph.D.
Ralf Peek, Ph.D., P.E.
Iris D. Tommelein, Ph.D.
Timothy M. Vogel, Ph.D.

Adjunct Lecturer

Rajendra K. Aggarwala, M.S.

See page 205 for statement on course equivalence.

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

Prerequisite: Eng. 103 and preceded or accompanied by Math. 216. I and 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: Mech. Eng. 110. I, II, IIIa. (3 credits)

Calculations of reactions, shears, and bending moments , axial forces and deflections in statically determinate structures. Influence lines. Flexibility method for simple indeterminate structures. Introduction to matrix displacement method of structural analysis.

315.
Design of Structures

Prerequisite: Mech. Eng. 210. 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

Prerequisite: Mech. Eng. 240, preceded or accompanied by Mech. Eng. 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

Prerequisite: 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

Prerequisite: Mat. Sci. & Eng. 250 and Mech. Eng. 110. 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 and II. (2 credits)
Principles of contracts including formation, interpretation, performance, discharge and remedies; other Engineering related legal issues and professional ethics.

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. Eng. 411) (Nav. Arch. 411)
Finite Element Applications
Prerequisite: Eng. 103, Mech. Eng. 211 or Mech. Eng. 210. I and 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
Prerequisite: CEE 312 and 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
Prerequisite: CEE 312 and 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
Prerequisite: Eng. 103 or 120, 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 groundwater; chemical and physical properties of the groundwater environment; basic principles of groundwater flow; measurement of parameters; pump test design and analysis; transport of contaminants; use of computer models for the simulation of flow and transport problems.

430.
Special Problems in Construction Engineering
Prerequisite: permission of instructor. I, II, IIIa, and 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 and 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. I and 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: Mech. Eng. 210. 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
Prerequisite: Chem. 130, CEE 280, and 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 groundwaters, treatment operations, and other systems of concern in environmental engineering. Lectures, problems, and laboratory.

485.
Water Supply and Waste-Water Engineering
Prerequisite: junior or senior standing. I and IIIa. (3 credits)
Design of works for the collection and purification of water for municipal use, fundamentals of design of waste-water collection systems and waste-water treatment plants. Lecture and recitation.

490.
Independent Study in Civil Engineering
Prerequisite: Permission of instructor. I, II, IIIa and 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.
Artificial Intelligence Applications in Civil Engineering

Prerequisites: 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. (Nav. Arch. 512)
Finite element Methods in Solid and Structural Mechanics

Prerequisites: graduate standing. (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

Prerequisite: Mech. Eng. 210, Math. 450 or Aero. Eng. 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
Prerequisite: CEE 413 and 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
Prerequisites: 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
II. (3 credits)
Plastic analysis of structural frames. Rules of practice for the plastic design of steel structures. Design problems and reports.

520.
Deterministic and Stochastic Models in Hydrology
Prerequisite: CEE 420 and 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 (Mech. Eng. 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 (Mech. Eng. 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
Prerequisite: CEE 420 and 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 economic design of an hydraulic engineering project. Application of the digital computer to engineering design.

527.
Coastal Hydraulics
Prerequisite: CEE 325. (Mech. Eng. 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; the 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.

531.
Construction Cost Engineering

Prerequisite: graduate standing and preceded or accompanied by CEE 431. I.
(3 credits)

Cost engineering for construction organizations, projects, and operations. Construction financing; breakeven, 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: graduate standing and preceded or accompanied by CEE 431. I.
(3 credits)

Planning, organizing, staffing, directing, and controlling construction firms, departments, projects, and operations. Strategic planning; organization design and behavior; construction business functions; marketing; management information systems. Project organizations; man-power planning; jobsite layout; labor, material procurement; time, cost, quality control. Construction operation planning, supervision, analysis work improvement. Case studies, projects from construction.

533.
Construction Performance Management

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

Dimensions of performance: effectiveness, efficiency, safety, quality, profitability, productivity, quality of work life, innovation. Factors that influence performance: environment, structure, organizational and behavioral processes such as planning, controlling and motivation. Measurement, analysis, and improvement of performance. Examples and cases from construction settings.

534.
Heavy Industrial Construction

Prerequisite: senior or graduate standing. IIIa.
(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. Deep excavation procedures related to support of excavation systems, methods of installation and dewatering.

536.
Critical Path Methods
Prerequisite: senior or graduate standing. I, II and 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
Prerequisite: CEE 351 and 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.

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 electro-kinetic stabilization. Geotechnical aspects of disposal fills, e.g., tailings, fly ash, sanitary landfills, and hazardous waste.

544.
Rock Mechanics
Prerequisite: Mech. Eng. 210. I. (3 credits)
Engineering properties and classification of rocks. Strength and deformability of intact and jointed rock; in-situ stresses; lab and field test methods. Stereonets and structural geology. Rock slopes; stability and reinforcement. Foundations on rock. Rock blasting; explosives; shot design; vibration problems.

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 drawdown, 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 bulkheads. 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.

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, heavyweight, high strength, and ultra high strength.

554.
Materials in Engineering Design
Prerequisite: CEE 351 or per 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 & 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 multi-mode 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, and 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
Prerequisites: 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. (E.I.H. 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
II. (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-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 biochemical 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 biomass 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

Prerequisites: 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

Prerequisites: 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.

599. (E.I.H. 699) Hazardous Wastes: Regulation, Remediation, and Worker Protection

Prerequisite: graduate standing and E.I.H. 503 or E.I.H. 508 or E.I.H. 541 or E.I.H. 650 or E.I.H. 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. Eng. 614)
Advanced Theory of Plates and Shells

Prerequisite: CEE 514 or Aero. Eng. 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. Eng. 615) (ME/AM 649)
Random Vibrations

Prerequisite: CEE 513 or ME/ AM 541 or Aero. Eng. 543. II. (3 credits)

Accelerated coverage ot 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 pre-stressed 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

Prerequisite: CEE 523 and Chem. Eng. 508. II. (3 credits)

Development of computa-tional techniques for two- and three-dimensional flow problems. Simulation of shallow-water flow in rivers and estuaries. Floodwaves 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 multdimensional flow problems.

622.
Special Problems in Hydraulic Engineering or Hydrology

Prerequisite: permission of instructor. I. and 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

Prerequisite: 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 and 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 S.&M.S. 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

Prerequisite: CEE 531 and 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.

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

Prerequisite: CEE 611 and 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: Per instructor. I. (3 credits)

Fracture mechanics fundamentals and micromechanics of cement, ceramic and polymer based fibrous composites. Topics include elastic crack mechanics, energy principles, interface mechanics; shear lag models; residual stress; 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

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, and 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. (E.I.H. 617)
Special Problems in Solid Waste Engineering

Prerequisite: CEE 585 and permission of instructor. I, II, IIIa and 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 and II. (To be arranged)

Preparation and presentation of reports covering assigned topics.

830.
Construction Engineering and Management Seminar

I and 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 and 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 and 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 and 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 and 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

Prerequisites: Per instructor. I and 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 and II, (2-8 credits); IIIa and IIIb (1-4 credits).

Election for dissertation work by doctoral student not yet admitted to status as Candidate.

995.
Dissertation/Candidate

Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II, and III (8 credits); IIIa and 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*

Department Office
Room 238 Lorch Hall
(313) 764-2355

*College of Literature, Science, and the Arts
Professor Alan Deardorff, *Chair*
Professors David Lam & Matthew Shapiro, *Associate Chairs*

Professors W. Adams, R. Barlow, T. Bergstrom, K. Binmore, C. Brown, P. Courant, J. Cross, A. Deardorff, R. Dernberger, G.J. Duncan, M. Gersovitz, R. Gordon, E. Gramlich, R. Holbrook, E.P. Howrey, S. Hymans, G. Johnson, T. Juster, J. Kmenta, J. Laitner, L. F. Lee, R. Porter, S. Salant, G. Saxonhouse, C. Simon, J. Slemrod, F. Stafford, R. Stern, H. Varian, T. Weisskopf, M. White; **Emeritus Professors** G. Ackley, M. Bornstein, W.H. Locke-Anderson, P. Feldstein, D. Freedman, D. Fusfeld, H. Levinson, J. Morgan, E. Mueller, W. Palmer, P. Steiner, W. Stolper; **Associate Professors** R. Barsky, J. Bound, D. Lam, M. Kimball, J. Levinsohn, J. Mackie-Mason, M. Shapiro, G. Solon, W. Whatley; **Assistant Professors** M. Genius, A. Katz, S. Kossoudji, M. Levenstein, D. Li, D. O'Brien, S. Oppers, D. Roth, G. Shaffer, E. Stacchetti, J. Swierzbinski, R. Thomas, R. Wells; **Lecturers** J. Gerson, F. Thompson, J. Wolfe

Introductory Courses
Students who want to take advanced courses in Economics must elect Economics 201 and 202.

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.

201.
Principles of Economics I
No credit granted to those who have completed Econ. 400. I, II, IIIa and IIIb. (4 credits)
The basic ideas of microeconomics: production, consumption, and the markets for outputs and inputs. The virtues of competitive markets are exposed, and the causes and remedies of such market failures as monopoly, indivisibility, spillover costs and inequity are examined.

202.
Principles of Economics II
Prerequisite: Econ. 201. No credit granted to those who have completed Econ. 400. I, II, IIIa, and IIIb. (4 credits)
The basic ideas of macroeconomics: employment, inflation, output and growth. The determinants of the state of the market economy are explored, and the influence of monetary, fiscal and other public policies are examined.

310.
Money and the Economy
Prerequisite: Econ. 201 and 202. No credit granted to those who have completed or are enrolled in Econ. 411 or 412. (3 credits)
A general course on the structure of financial institutions and the role of money in the economy. Emphasis is placed on important contemporary problems in the area of monetary and fiscal policy.

320.
Survey of Labor Economics

Prerequisite: Econ. 201 and 202. Credit is not granted to those who have taken Econ. 421 and/or 422. (3 credits)

A general course that introduces students to the labor market; problems of wages and unemployment; trade unionism and collective bargaining; aspects of public policy toward labor-market issues.

330.
Industrial Performance and Public Policy

Prerequisite: Econ. 201 and 202. Credit is not granted for Econ. 330 concurrently with or after Econ. 431 or 432. (3 credits)

A survey course that develops an analytic framework for evaluating the performance of major U.S. industries and examines the principal government policy instruments affecting industrial performance.

350.
Comparative Economic Systems

Prerequisite: Econ. 201 and 202. No credit granted to those who have completed or are enrolled in Econ. 451. (3 credits)

Theories of capitalism and socialism and of market and planned economies, and their application in selected countries, including the United States and the Soviet Union.

380.
Public Finance

Prerequisite: Econ. 201 and 202. Credit is not granted for Econ. 380 concurrently with or after Econ. 481 or Econ. 482. (3 credits)

A survey of government expenditure and revenue issues, designed for students wishing to take a single comprehensive course in the field of public finance.

Electrical Engineering and Computer Science (Division 252)

Department Office
3316 EECS Building
(313) 764-2390

George I. Haddad, Ph.D., *Professor and Department Chair, Robert J. Hiller Professor of Engineering*

David J. Anderson, Ph.D., *Professor and Associate Chair, Systems Science and Engineering Division*

Kang G. Shin, Ph.D., *Professor and Associate Chair, Computer Science and Engineering Division*

Thomas B. A. Senior, Ph.D., *Professor and Associate Chair, Electrical Science and Engineering Division*

Professor

Daniel E. Atkins, Ph.D.
Peter Banks, Ph.D., *Dean; also Atmospheric, Oceanic and Space Sciences*
Spencer L. BeMent, Ph.D.
Pallab K. Bhattacharya, Ph.D.
Theodore G. Birdsall, Ph.D.
Charles A. Cain, Ph.D., *also Director of the Bioengineering Program*
Donald A. Calahan, Ph.D.
Kan Chen, Sc.D.
Kuei Chuang, Ph.D.
Lynn Conway,M.S.E.E., *Associate Dean for Instructional Technology*
Edward S. Davidson, Ph.D.
Anthony W. England, Ph.D.
Ward D. Getty, Sc.D., P.E.
Elmer G. Gilbert, Ph.D., *also Aerospace Engineering*
Daniel G. Green, Ph.D.
Yuri Gurevich, Ph.D.
John P. Hayes, Ph.D.
John H. Holland, Ph.D.
Keki B. Irani, Ph.D.
Ramesh C. Jain, Ph.D.
Janice M. Jenkins, Ph.D.
Stephen Kaplan, 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.
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.
Andrejs Olte, Ph.D.
Yale Patt, Ph.D.
Dimitris Pavlidis, Ph.D.
William B. Ribbens, Ph.D.
William C. Rounds, Ph.D.
Jasprit Singh, Ph.D.
Duncan G. Steel, Ph.D.
Quentin F. Stout, Ph.D.
Demosthenis Teneketzis, Ph.D.
Toby J. Teorey, Ph.D.
Fawwaz T. Ulaby, Ph.D., *R. Jamison and Betty Williams Professor of Engineering*
William J. Williams, Ph.D.
Herbert G. Winful, Ph.D.
Kensall D. Wise, Ph.D., *J. Reid and Polly Anderson Professor of Manufacturing Technology*

Adjunct Professor

William Becher, Ph.D.
William M. Brown, Ph.D.
George J. Zissis, Ph.D.

Professor Emeritus

Ben F. Barton, Ph.D.
Frederick J. Beutler, Ph.D.
Arthur W. Burks, Ph.D., Sc.D.
John J. Carey, M.S., P.E.
Chiao-Min Chu, Ph.D.
William G. Dow, M.S.E., P.E.
Hansford W. Farris, Ph.D.
Aaron Finerman, Sc.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.
William L. Root, Ph.D.
Norman R. Scott, Ph.D.
Charles B. Sharpe, Ph.D.

Melville B. Stout, M.S.
Chen-To Tai, Sc.D.
Herschel Weil, Ph.D.
Chai Yeh, D.Sc.

Associate Professor

Richard B. Brown, Ph.D.
Kevin J. Compton, Ph.D.
Larry K. Flanigan, Ph.D.
James S. Freudenberg, Ph.D.
Jessy W. Grizzle, Ph.D.
Alfred O. Hero III, Ph.D.
Mohammed Islam, Ph.D.
Pisti B. Katehi, 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.
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.
Elliot Soloway, Ph.D.
Wayne E. Stark, Ph.D.
Fred Terry, Ph.D.
John L. Volakis, Ph.D.
Gregory H. Wakefield, Ph.D.
Andrew Yagle, Ph.D.

Associate Professor Emeritus

E. Lawrence McMahon, Ph.D.

Adjunct Associate Professor

Peter Honeyman, Ph.D., *also Associate Research Scientist, CITI*
Juris Upatnieks, M.S.E.

Assistant Professor

Santosh G. Abraham, Ph.D.
William P. Birmingham, Ph.D.
Peter Chen, Ph.D.
John T. Coffey, Ph.D.
Edmund H. Durfee, Ph.D.
Emad Ebbini, Ph.D.
Brian E. Gilchrist, Ph.D.
Martin D. Giles, Ph.D.
Farnam Jahanian, Ph.D.
Carlos Mastrangelo, Ph.D.
Theodore Norris, Ph.D.
Atul Prakash, Ph.D.
Elke Rundensteiner, Ph.D.
Kamal Sarabandi, Ph.D.
Stuart Sechrest, Ph.D.
Nandit Soparkar, Ph.D.
Michael Wellman, Ph.D.
Kim A. Winick, Ph.D.

Research Scientist

Jack R. East, 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*
Michael Elta, Ph.D.
Patrick J. McCleer, Ph.D.P.E.
Kurt Metzger, Ph.D.
Kent Moncur, Ph.D.
Terry Weymouth, Ph.D.

Assistant Research Scientist

Yaochong Chen, Ph.D.
Selden Crary, Ph.D.
Nihad Dib, Ph.D.
M. Craig Dobson, M.A.
Heribert Eisele, Ph.D.
Randy Jones, Ph.D.
Weigi Li, Ph.D.
Richard K. Mains, Ph.D.
James Moyne, Ph.D.
Geok Ng, Ph.D.
Leland Pierce, Ph.D.
Donald Umstadter, Ph.D.
Steve Underwood, Ph.D.
John F. Whitaker, Ph.D.

Adjunct Research Scientist

John H. Bryant, Ph.D.

Adjunct Lecturer

A. Ford-Holevinski
Randall Frank, B.S., *Director of CAEN*
S. Thomas

See Page 205 for statement on Course Equivalence.

181. (CS 181)
Introduction to Computer Systems

Prerequisite: none. I and II. (4 credits). A student can receive credit for only one: EECS 181, Eng. 103, or Eng. 104

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

Prerequisites: None. I, II, and IIIa. (4 credits). Not intended for CS or Computer Engineering majors

Introduction to a high level programming language, top-down analysis, and structured programming. Basic searching and sorting techniques. No previous experience in computer or programming is assumed. Students will write and debug several computer programs.

216. (CS 216)
Circuit Analysis

Prerequisite: preceded or accompanied by Math. 216. I, II and IIIa. (4 credits)

Resistive circuit elements; mesh and node analysis; network theorems; network graphs and independence; energy storage elements; one- and two-time-constant circuits; phasors and a.c. steady-state analysis; complex frequency and network functions; frequency response and resonance. Lecture and laboratory.

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

I, II and IIIa. (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, PLA's ROM's RAM's arithmetic circuits, computer-aided design. Laboratory includes hardware design and CAD experiments.

280. (CS 280)
Programming and Introductory Data Structures

Prerequisite: Math. 115 and (EECS 183 or EECS 284 or Eng. 104 or passing a placement test in PASCAL.). Allow two credits for students who have already taken EECS 283. I and II. (4 credits)

Techniques of algorithm development and effective programming, top-down analysis, structured programming, testing, and program correctness. Program language syntax and static and run-time 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.

283. (CS 283)
Programming and Computer Systems

Prerequisite: EECS 183 or Engr. 104 or (Engr. 103 and basic knowledge of Pascal). I. (4 credits)

Advanced topics in PASCAL

including the implementation of linked lists, trees, and hashing. Searching and sorting techniques. Selected topics in programming language theory. Students will write several programs in PASCAL.

284. (CS 284)
Introduction to a Programming Language or System

Prerequisite: Some programming knowledge. I and II. (1 credit). Note: Credit will not be given for the C minicourse to students who have taken EECS 280.

A 7-week mini course covering the fundamentals of a programming language such as C, PASCAL, LISP, SNOBOL, Prolog, or Modula-2; or a system such as UNIX. Programming problems will be assigned. Specific languages or systems to be offered will be announced in advance.

300. (Math. 300)
Mathematical Methods in System Analysis

Prerequisite: Math. 216, Math. 316, or equivalent. I, II and IIIa. (3 credits).

An introductory course in operational mathematics as embodied in Laplace Transforms, Fourier Series, Fourier Transforms, and Complex Variables, with emphasis on their application to the solution of systems of linear differential equations. The response of linear systems to step, impulse and sinusoidal forcing functions.

303.
Discrete Structures

Prerequisite: Math. 115. I and 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

Prerequisite: Math. 216 and Physics 240. I, II and IIIa. (3 credits). Not open to electrical engineering or engineering science students.

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. I and II. (1 credit). Not open to electrical engineering or engineering science students.

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.
Circuits and Systems

Prerequisite: EECS 216 and EECS 300. I, II and IIIa. (3 credits)

Mesh, node, and state-variable analysis. Complex frequency and s-domain analysis. Feedback. Discrete signals and z-transform methods. Frequency response. Two-port parameters. Convolution. System concepts.

317.
Solid-State Devices and Digital Electronics

Prerequisite: EECS 270 and EECS 216. I, II and IIIa. (3 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
Prerequisite: EECS 316 and 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
Prerequisite: EECS 216 or EECS 314 and Physics 242. I, II and IIIa. (3 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
Prerequisite: Physics 240, Math. 216. I and 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 and 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
Prerequisites: EECS 300. I. II. (3).
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
Prerequisites: EECS 316 or ME/AM 360. II. (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
Prerequisite: EECS 270 and EECS 280. I and 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
Prerequisite: EECS 270 and junior standing. I and 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
Prerequisite: EECS 280 and EECS 303. I and 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.

381. (CS 381)
Systems Programming
Prerequisite: EECS 380. I and II. (4 credits)
Design and implementation of basic systems programming tools and infrastructure. Topics to be covered include assembly language programming, assemblers, macro processors, linkers and loaders, and I/O drivers, etc., and programming projects will involve the design and implementation of such systems. Students will also write some programs in assembly language.

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. I and II. (3 credits). Not open to students with credit for Math. 417 or 513
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: EECS 300. I, II and IIIa. (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
Prerequisite: EECS 318 and 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 and Physics 240. II. (3).
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. (Bioeng. 417)
Electrical Biophysics
Prerequisite: EECS 216 or EECS 314 and preceded or accompanied by EECS 300. I. (3 credits)
Electrical biophysics of muscle, nerve, and synapse; electrical conduction in excitable tissue; models for nerve, muscle, and sensory receptors, including the Hodgkin Huxley equations; biopotential mapping, cardiac electrophysiology, and biological noise.

421.
Properties of Transistors
Prerequisite: EECS 320 and 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. (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.
Integrated Circuit Process Technology and Process Integration
Prerequisites: 320 and 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 and 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
Prerequisite: EECS 280 and 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 and 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. (3 credits)

Basic concepts of optics and electromagnetics relevant to optoelectronic devices. Optical processes in semiconductors, luminescence, absorption, transition rates, and carrier lifetimes. LEDs, semiconducting lasers, and photodetectors. Device structures and material considerations.

430.
Radiowave Propagation

Prerequisite: EECS 332. II. (3 credits)

Electromagnetic waves; simple antennas; noise; free-space link; propagation near the Earth – ground waves, diffraction, and multi-path interference; propagation in the troposphere – refraction, absorption, and scattering; and propagation in the ionosphere – sky wave refraction and absorption. Student teams will design a radio link and demonstrate critical technologies.

431.
Fields and Optics Laboratory

Prerequisite: preceded or accompanied by EECS 332. I and II. (2 credits)

Experiments and lectures to demonstrate the behavior and practical aspects of electromagnetic fields at microwave and optical frequencies. Microwave experiments involving transmission lines, waveguides, antennas, sources, and detectors.

432. (Bioeng. 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

Prerequisite: Physics 240 and 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; geometric 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
Prerequisite: EECS 300, 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
Prerequisite: Physics 240 and 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 CCD's); LED's 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
Prerequisite: EECS 303 and 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 senior standing in Elec. or Comp. Eng. 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
Prerequisites: EECS 316. I. II. IIIa. (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
Prerequisites: EECS 316. 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, and a six-week real-time DSP project of the student's choice.

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

Prerequisite: EECS 316 and 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. (Bioeng. 458)
Biomedical Instrumentation and Design

Prerequisite: permission of instructor. I. (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.

459.
Advanced Electronic Instrumentation

Prerequisite: EECS 360 or 359 or EECS 453 or EECS 458. II. (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

Prerequisite: Mech. Eng. 240 and EECS 316 or EECS 360 and senior standing. I, II, and IIIa. (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.
Modern Control Systems Design

Prerequisite: EECS 460. II. (3 credits)

Introduction to concepts and techniques of modern control in the context of control system design. Topics include: state variable feedback, optimal control, nonlinear control, state estimators, and adaptive control. Both analog and digital control design techniques are presented. Design application is emphasized through use of selected case studies.

467. (Mech. Eng. 467)
Robotics: Theory, Design and Application

Prerequisite: Mech. Eng. 360; or EECS 360; and senior standing. I and 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 and 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. Hardwired and microprogrammed control. Nanaprogramming. Memory hierarchies. Virtual memory. Cache design. Input-output architectures. Interrupts and DMA. I/O processors. Parallel processing. Pipelined processors. Multiprocessors.

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

Prerequisite: EECS 280 and EECS 303 or equivalent. I and II. (4 credits)

An introduction to computation theory: finite automata, regular languages, pushdown automata, context-free languages, Turing machines, recursive languages and functions, and computational complexity.

477. (CS 477)
Introduction to Algorithms

Prerequisites: EECS 380. I. II. (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

Prerequisite: EECS 303 and EECS 270 and senior or graduate standing. I and 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 and 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

Prerequisite: EECS 370 and EECS 381. I, II. (4 credits)

Operating system functions and implementations: multitasking; 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 multitask environment.

483. (CS 483)
Compiler Construction

Prerequisite: EECS 370 and 381. I and 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) (I.&O.E. 484) Database Management Systems

Prerequisite: EECS 380 or I.&O.E. 473. I and II. (3 credits)

Concepts and methods in the definition and management of large integrated database for organizational information systems. Functions and objectives of existing file and data management systems will be considered and methods of analyzing proposals for new data management software will be studied; database administration, database design, and data security problems.

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) (I.&O.E. 478) Interactive Computer Graphics

Prerequisite: EECS 380 or I.&O.E. 373, and senior standing. I and 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

Prerequisites: 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, and 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, IIIa, and IIIb. (1-6 credits)

Individual study of selected topics in Electrical Engineering and Computer Science. May include experimental investigation or library research. Primarily for undergraduates.

500.
Tutorial Lecture Series in System Science

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. Eng. 552)
Probability and Random Processes

Prerequisite: EECS 401 or graduate standing. I and 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. Eng. 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.

505. (I.&O.E. 511)
(Math. 562)
(Aero. Eng. 577)
Continuous Optimization Methods

Prerequisite: Math. 217, Math. 417 or Math. 419. I. (3 credits)

Survey of continuous optimization problems. Unconstrained optimization problems: unidirectional search techniques; gradient, conjugate direction, quasi-Newton methods. Introduction to constrained optimization using techniques of unconstrained optimization through penalty transformations, augmented Lagrangians and others. Discussion of computer programs for various algorithms.

506. (CS 506)
Computing System Evaluation

Prerequisite: EECS 280 or EECS 283, and EECS 370 and EECS 501. II. (3 credits)

Theory and application of analytic methods for evaluating the performance of 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. (I.&O.E. 503)
Social Decision Making
Prerequisite: Stat. 310 or EECS 401 or EECS 501 or I.&O.E. 315. II. (3 credits)
Elementary decision analysis, examples in public sector; basic problems in social decision making; social values and preferences, multiattribute utility functions, subjectivity measurement, Pareto optimality, Arrow's impossibility theorem; group decision analysis, two-person game theory; social decision processes, strategy of conflicts.

510.
Intelligent Vehicle-Highway Systems Research Topics
Prerequisites: Two IVHS-Certificate courses (may be taken concurrently). II. (3 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, IVHS 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. (3 credits)
General theory of waveguides; inhomogeneously filled waveguides. Surface waveguides. Circuit theory of waveguiding systems. Passive microwave devices; directional couplers, filters, isolators, circulators.

514.
Intelligent Vehicle-Highway Systems Technologies
Prerequisite: 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. Following by EECS 515, the laboratory portion.

515.
Intelligent Vehicle-Highway Systems Technologies Laboratory
Prerequisite: II. (1 credits)
This is the laboratory portion of IVHS Technologies. Experience applying the concepts and techniques learned in the lecture part of the course.

516.
Medical Imaging Systems.
Prerequisites: EECS 451. I. (3 credits).
Principles of modern medical imaging systems. For each modality the basic physics is described leading to a systems model of the imager. Fundamental similarities between the imaging equations of different modalities will be stressed. Modalities covered include radiography, x-ray computed tomography (CT), NMR imaging (MRI) and real-time ultrasound.

517.
Physical Processes in Plasmas
Prerequisite: EECS 332. II. (3 credits)
Collision phenomena, diffusion and mobility; development of the Boltzmann-Vlasov equation; conductivity and dielectric tensors of a plasma; hydromagnetic equations; wave propagation in gaseous plasmas; applications to fusion research and gas lasers.

518. (A.&O. Sci. 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. (Nuc. Eng. 575) Plasma Dynamics and Particle Optics Lab

Prerequisite: Preceded or accompanied by a course in plasmas or physical electronics. II. (3 credits)

Experimental techniques for plasma dynamics, electron and ion beam technology, and vacuum technology. Experiments on microwave and probe diagnostics of plasmas, plasma instabilities, vacuum systems, plasma generation, electron and ion beam generation and optics, and other topics of current interest. Lectures given for background material.

520. Theoretical Methods for Solid-State Electronics

Prerequisite: EECS 422. II, even 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.

Prerequisites: 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, hetorojunction 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

Prerequisite: 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, EECS 421 and either 525 or 528.. II. (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

Prerequisite: EECS 411 and EECS 421. II. (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 multiprocessors, simulated annealing and other optimization techniques and their applications in CAD, layout transformation and compaction, fault-repair algorithms for RAM's & PLA's hardware synthesis from behavioral modeling, artificial intelligence-based CAD.

528.
Principles of Microelectronics Process Technology

Prerequisite: EECS 422 and EECS 424. I. (3 credits).

Theoretical analysis of the chemistry and physics of process technologies used in microelectronics 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. (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

Prerequisite: EECS 332 and graduate standing. I. (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.

534.
Design and Characterization of Microwave Devices and Monolithic Circuits

Prerequisites: Graduate Standing and EECS 421 or EECS 525. I. (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

Prerequisite: EECS 300, 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 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 waveguide and device fabrication. Introduction to nonlinear optical phenomena in waveguide structures.

538. (Appl. Phys. 550) (Physics 650)
Optical Waves in Crystals

Prerequisite: EECS 434. I. (3 credits)

Propagation of laser beams: Gaussian wave optics and the ABCD law. Manipulation of light by electrical, acoustical waves; crystal properties and the dielectric tensor; electro-optic, acousto-optic effects and devices. Introduction to nonlinear optics; harmonic generation, optical rectification, four-wave mixing, self-focusing, and self-phase modulation.

539. (Appl. Phys. 551) (Physics 651)
Lasers

Prerequisite: EECS 433 or EECS 434. 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 femtosecond lasers and ultra high power lasers.

540. (Appl. Phys. 540)
Applied Quantum Mechanics I

Prerequisite: 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. II. (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

Prerequisite: EECS 442 and 492 and permission of instructor. II. (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. (3 credits)

Survey of recent research on learning in artificial intelligent 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.

547. (CS 547) Cognitive Architecture

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.

550. Information Theory

Prerequisite: EECS 501. II. (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

Prerequisites: 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 and 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

Prerequisite: EECS 316 and EECS 401. I. (3 credits)

Digital transmission of information across discrete and analog channels. Sampling; quantization; noiseless source codes for data compression: Huffman's algorithm and entropy; block and convolutional channel codes for error correction; channel capacity; digital modulation methods: PSK, MSK, FSK, QAM; matched filter receivers. Performance analysis: power, bandwidth, data rate, and error probability.

555.
Digital Communication Theory

Prerequisite: EECS 501 and 554. I. (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

Prerequisite: EECS 551 and 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

Prerequisite: Graduate standing and 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

Prerequisite: EECS 501 and 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

Prerequisite: EECS 551 and 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. Eng. 550) Linear Systems Theory

Prerequisite: graduate standing. I and II. (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. Eng. 571) Digital Control Systems

Prerequisite: EECS 460/Aero. Eng. 471/Mech. Eng. 461. I. (3 credits)

Sampling and data reconstruction in computer control systems. Z-transforms and state equations to describe discrete and mixed data systems. Analysis of digital feedback systems using root locus, Nyquist and Jury tests. Design of digital feedback systems using frequency domain techniques and state space techniques. Nonlinear digital feedback systems.

562. (Aero. Eng. 551) Nonlinear Dynamical Systems

Prerequisite: graduate standing. II. (3 credits)

Introduction to and analysis of phenomena which occur in nonlinear dynamical systems. Topics include: equilibria, limit cycles, second order systems and phase plane analysis, bifurcations and chaos, Liapunov and input-output stability theory, asymptotic analysis including averaging theory and singular perturbations, numerical techniques.

563. (Aero. Eng. 576) Optimal Control

Prerequisite: EECS 560/Aero. Eng. 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. Eng. 578) Estimation, Filtering, and Detection

Prerequisite: EECS 501 and EECS 560. 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. Eng. 580) Linear Feedback Control Systems

Prerequisite: EECS 460/Aero. Eng. 471/Mech. Eng. 461 and EECS 560/Aero. Eng. 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.

566. (Aero. Eng. 572) Nonlinear Control Systems

Prerequisite: EECS 460/Aero. Eng. 471/ Mech. Eng. 461 and EECS 562/Aero. Eng. 551. I. (3 credits)

Methods of analysis and design of nonlinear control systems. Topics include: stabilizing controllers, absolute stability theory, describing function methods, input-output stability of feedback systems. Control techniques for nonlinear systems: dither, vibrational control, variable structure systems and sliding mode control, linearization by nonlinear feedback.

567. Introduction to Robotics: Theory and Practice

Prerequisite: EECS 380. I. (3 credits)

Methods of design and operation of computer-based robots. Kinematics and dynamics of a six-jointed arm; force, moment, torque, compliance, control methods, trajectory planning. Integration of computer vision systems to form hand-eye coordinated systems. Man-machine communication via high-level language.

569. (Bioeng. 569) Introduction to Neurophysiological Systems

Prerequisite: EECS 360 or 460. II, odd years. (3 credits).

Application of system theory to neurophysiology, a theoretical and experimental study of the application of linear and nonlinear systems theory, state-space concepts, and stability criteria to several neurophysiological systems; neuromuscular systems, pupillary control, eye tracking, temperature regulation, and central nervous system function.

570. (CS 570) Parallel Computer Architecture

Prerequisite: EECS 470. 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

Prerequisite: EECS 470 and 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.

572. (CS 572) Digital Computer Arithmetic

Prerequisite: EECS 470 or 370, and 478. I. (3 credits)

Classification and structure of finite number systems and arithmetic including weighted, redundant and signed digit classes of number systems. Theory of modern high-speed computer arithmetic including fast carry logic, multiplier recoding and SRT division. Case studies of general and special purpose arithmetic processors.

574. (CS 574) Theoretical Computer Science I

Prerequisite: EECS 476. I and II. (4 credits).

Formal grammars, recursive functions, logic, complexity theory.

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

Prerequisite: EECS 478 and 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.

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, modelling and analysis, etc.

583. (CS 583)
Programming Languages

Prerequisite: EECS 483 and 476. I. (4 credits)

Various programming languages are compared to understand general principles. To do this systematically and ignore inessential details, a formal 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)
Distributed Database Concepts

Prerequisite: EECS 484. II. (3 credits)

Database design methodologies, distributed database technology, and developments in heterogeneous systems. Distributed database design and implementation issues such as transaction management, concurrency control, security, and query optimization. Database design includes semantic data modeling, transformation to SQL, normalization theory, physical design, and data allocation strategies.

585. (CS 585)
Object-Oriented Databases

Prerequisite: 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 and 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)
(I.&O.E. 578)
(Mech. Eng. 551)
Geometric Modeling

Prerequisite: EECS 487 (I.&O.E. 478), Mech Eng. 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. I and 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

Prerequisite: graduate standing and 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

Prerequisite: EECS 303 and Math 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 science.

595. (CS 595)
(Ling. 541)
Natural Language Processing

Prerequisites: Senior standing. I. (3 credits)

A survey of syntactic and semantic theories for natural language processing, including unification-based grammars, methods of parsing, and 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.

597.
Technology Planning and Assessment

Prerequisite: senior or graduate standing. I. (3 credits)

Interdisciplinary lecture and project course in strategic planning and management of technology in both private and public sectors, and policy-oriented assessment of societal effects of technology. Typical projects; planning and assessment of microcomputers, communications, transportation systems, and alternative energy sources.

598. (CS 598)
Special Topics in Electrical Engineering and Computer Science

Prerequisite: permission of instructor or counselor. I, II, III, IIIa and IIIb. (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, IIIa, and IIIb. (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. Eng. 651)
Function Space Methods in System Theory

Prerequisite: EECS 400. 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 concept in systems problems.

623.
Integrated Sensors and Sensing Systems

Prerequisite: 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.
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

Prerequisite: 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 and graduate standing. 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. (3 credits)

Numerical techniques in antennas; solutions of integral equations: method of moments, Galerkin's technique, conjugate gradient FFT and finite element/ boundary integral methods. Planar antennas: strip dipoles and patches, infinite and finite arrays. High frequency methods; applications to aperture antennas, Hybrid techniques. Antenna synthesis and design.

634. (Phys. 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 (Physics 609) (Applied Physics 609).
Quantum Theory of Light.

Prerequisites: One graduate level course in quantum mechanics. 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

Prerequisite: EECS 501 and EECS 400. II, odd 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

Prerequisite: EECS 456, 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 Event Systems
Prerequisites: EECS 560 or EECS 476 or equivalent. I. odd 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.

670.
Advanced Topics in Computer Architecture
Prerequisite: EECS 570, graduate standing & permission of instructor. II. (3 credits)
Advanced concepts and specialized areas in computer system 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
Prerequisite: EECS 481 and either EECS 581, EECS 582, EECS 583, or EECS 584. I. (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. I or 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.

691.
Advanced Natural Language Processing
Prerequisite: EECS 595 or permission of instructor. II. (3 credits)
An in-depth look at state-of-the-art systems for natural language understanding, processing, and generation. Content will vary from year to year. Example topics: integrated syntactical and semantic systems; implementation of new semantic paradigms; learning systems.

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, IIIa, IIIb, 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

Prerequisite: graduate standing and 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 & Applications

Prerequisites: 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 and permission of instructor. Term to be arranged. (1-4 credits)

Key topics of current research interest in ultrafast phenomena, short wave-length 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

Prerequisites: permission of instructor. Term 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. Arr. (3 credits)

Advanced topics on stochastic systems such as stochastic calculus, nonlinear filtering, stochastic adaptive control, decentralized control, and queueing networks.

770.
Special Topics in Computer Systems

Prerequisite: permission of instructor. (To be arranged)

820.
Seminar in Solid-State Electronics

Prerequisites: Graduate standing and permission of instructor. I. (1 credit).

Advanced graduate seminar devoted to discussion 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 and 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

Prerequisites: Graduate standing in EECS or permission of instructor.May be taken more than once since topics will vary each term. I and 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. Occasional speakers from other universities.

892.
Seminar in Artificial Intelligence

Prerequisite: EECS 592 or equivalent. I and 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 and III. (2-8 credits); IIIa and IIIb. (1-4 credits)

Election for dissertation work by a doctoral student not yet admitted to Candidate status.

995.
Dissertation/Candidate

Prerequisite: Graduate School authorization for admission as a doctoral candidate. I, II and III. (8 credits); IIIa and IIIb. (4 credits)

Election for dissertation work by a doctoral student who has been admitted to Candidate status.

Engineering Division (Division 258)

See Page 205 for statement on Course Equivalence.

103.
P.C. FORTRAN

Prerequisites: None. Credit restrictions. ***Student may receive credit for only one of the following courses: Engr. 103, Engr. 104, Engr. 105.***

I and II. (3 credits).

Introduction to personal computers, operating systems, and applications. Word processing. FORTRAN-77 for numerical and non-numerical calculations. Spreadsheets, graphics, and symbolic mathematics. Networks, electronic mail, and the CAEN environment.

104.
P.C. Pascal

Prerequisites: None. Credit restrictions. ***Student may receive credit for only one of the following courses: Engr. 103, Engr. 104, Engr. 105.***

I and II. (3 credits).

Introduction to personal computers, operating systems, and applications. Word processing. Pascal for numerical calculations. Spreadsheets, graphics, and symbolic mathematics. Networks, electronic mail, and the CAEN environment.

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 of the following courses: Engr. 103, Engr. 104, Engr. 105.*** *I and 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.

All undergraduate degree programs in the College of Engineering will accept up to four credit hours of elective courses from this group as free and/or technical electives.

150.
(Mat. Sci. & Eng. 150)
Introduction to Engineering Materials

Prerequisite: Chem. 123 or 124. Open only to freshmen; satisfies any program requirement of Mat. Sci. & Eng. 250. II. (4 credits).

A course in engineering materials covering the structure, properties and processing of metals, polymers and ceramics.

151. (Chem. Eng. 151)
Plastics

Prerequisite: high school chemistry. (3 credits)

Plastics such as nylon, lucite, and polystyrene will be synthesized, analyzed, molded and tested mechanically by the students. The instructor will demonstrate advanced methods of characterization and processing. Lecture followed by a three-hour laboratory. Local plant visits.

160.
Engineering and Technical Communications

Prerequisites: 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.

195.
Selected Topics in Engineering

(To be arranged)

Engr. 200.
Study Abroad.

Prerequisites: 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

(Required for some programs, see your advisor)
Prerequisite: Eng. 103 and preceded or accompanied by Math 216. I and 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 non-linear 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, Eng. 104 or equivalent, Math 216. I and 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 FORTRAN 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, and III. No Credit

Off-campus work within the cooperative education program. Engineering work experience in government or industry.

401.
Total Quality Management

Prerequisites: none. I and 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.
Technology and Society

I and II. (3 credits). Open for undergraduate credit only.

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

Prerequisites: 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.

490.
Special Topics in Engineering

(To be arranged)

Individual or group study of topics of current interest selected by the faculty.

503.
Scientific Visualization

Prerequisites: 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.

Geological Sciences* (Division 377)

Department Office
1006 C.C. Little
(313) 764-1435

* *College of Literature, Science and the Arts*

Professor Rob Van der Voo, *Chair*

Professors Essene, Farrand, Fisher, Gingerich, Halliday, Kelly, Kesler, Lohmann, Meyers, Moore, O'Neil, Outcalt, Owen, Peacor, Pollack, Rea, Smith, Van der Voo, Walker, Wilkinson; **Associate Professors** Gurnis, Mukasa, Ruff, van der Pluijm, Walter; **Assistant Professors** Foote, Lange, McShea, Satake, Zhang; **Adjunct Professors** McElhinny, Simmons

100.

100. Coral Reefs

(1 credit). (NS). Lecture

Coral Reefs will be an in-depth tour of the biological and physical processes active in modern reef systems to provide a detailed understanding of the ecology of the individual organisms and the complex nature of their interactions within the reef community. Evolution of the reef community will be examined, ranging from crude framework structures formed over one billion years ago by primitive algae, luxuriant and diversified reefs of the modern-day oceans, and evolutionary strategies of reef building organisms. By tracking these evolutionary strategies through geologic time, the implications of man's intervention with the Earth's hydrosphere and atmosphere on the character of future reef communities will be considered.

101. Waves and Beaches

(1 credit). (NS). Lecture

This short course approaches the subject of "waves and beaches" by combining relevant topics in both oceanography and geology, although no previous background in these subjects is required. We shall attempt to understand this dynamic place where land and sea interact by emphasizing the processes responsible for the major types of coastlines and the geologic/oceanographic phenomena associated with them. Some of the topics which will be considered include: fundamentals of wave and tide theory; the impact of waves and tides upon beaches; coastal geology; coastal processes on a short- and long-term time scale; estuaries; and, the impact of plate tectonics upon coasts. Instruction will be by lecture. Grades will be based on one exam at the end of the course.

102. Energy from the Earth

(1 credit). (NS). Lecture

A survey of the principal non-nuclear energy resources of the earth: oil (petroleum), natural gas, coal, tar sands, oil shale. Includes discussions of the geology of these materials, their composition and/or mineralogy, types of magnitude of earthquakes; earthquakes and the generation of seismic waves; seismic wave propagation and the study of the internal structure of the earth; earthquake hazards and potential for prediction. Instruction by lecture, evaluation on the basis of a final exam.

108. Minerals in the Modern World

(1 credit). (NS). Lecture

This course concerns the geology, politics and economics of strategic minerals, such as chromium, manganese, nickel and cobalt, which are essential for industrial and defense applications, but which are in short supply in the U.S. The course begins with an overview of strategic mineral positions for major world powers and continues with detailed discussions of production methods, uses, markets, international trade, sources, and remaining reserves of each of the strategic minerals. Particular emphasis is placed on understanding the geologic processes that form deposits of each of the strategic minerals in order to better appreciate the accuracy of world and U.S. reserve estimates and the capacity of the U.S. for self-sufficiency. The course closes with an evaluation of means to reduce U.S. dependence on foreign suppliers, including a discussion of the Strategic Stockpile. A course pack (Dollar Bill Copy) is strongly recommended and a book (Skinner, "Earth Resources") is recommended. Grading is by means of a final exam.

110.
The History of the Oceans

(1 credit). (NS)

The history of past oceanic life, events, and environments as recorded in sea floor sediments is examined and discussed.

111.
Climate and Mankind

(1 credit). (NS)

The intent of GS 111 is to give a heightened awareness to students of the nature and fragility of the Earth's climate, and how changes in climate have affected past civilizations and may affect our future. Course topics will include: a description of the climate systems of the Earth, the atmosphere, oceans and polar ice caps; the information we gather to understand the history of those systems; how changes in climate have affected past civilizations, and what we think will happen to the planet when the long expected "Greenhouse Effect — Global Warming" finally arrives.

112.
Geological History of Michigan

(1 credit). (NS)

An introduction to the geological history of Michigan, from the Precambrian to the present, and the evidence for this changing panorama. Michigan has not always been a land of upland temperate forests surrounded by the Great Lakes. During major intervals of time, what is now Michigan lay under broad tropical seas or was beset by extensive volcanism. At other times vast ice sheets a mile thick sculpted the surface of Michigan. Remains of animal and plant life from these times are distinctively different from those of the present day. This mini-course presents an introduction to the evidence from which this changing geological panorama has been inferred. Topics to be considered include the nature of the Precambrian world and its life; Early Paleozoic coral reefs and associated salt deposits; Late Paleozoic coal swamps; glacial geology of the recent past, the geologic development and history of the Great Lakes; and the rise and fall of the diverse Pleistocene megafauna of mammoths and mastodons. There will be an opportunity to examine some excellent fossil specimens in the collection of the Museum of Paleontology. Grades will be based on a final examination.

113.
Planets and Moons

(1 credit). (NS)

"Planets and Moons" is a survey of the geology of the "solid" bodies of the solar system as revealed by both the manned exploration of our own moon and unmanned, "robotic" exploration of the inner planets and moons of the outer planets. The course will not only provide qualitative description of planetary surfaces as revealed by photographic reconnaissance, but will also provide physical explanations of what we see in terms of external cratering processing and internal dynamic processes. Exploration of the planets reveals that impact cratering is the single most pervasive process in the solar system. Particular emphasis will be placed on why the various bodies have such different morphologies, especially why they are so different from the Earth. Nevertheless, planetary exploration does provide the framework to understand our own Earth better, especially the first billion years of terrestrial evolution.

114.
The Elements

Prerequisites: high school math, physics and chemistry. (1 credit). (NS).

This course introduces the origin, abundance and distribution of elements in the solar system. It is intended for students with an interest in science. The topics will include a review of the periodic table of elements; chemical and nuclear properties of elements; nuclide stability and nuclear reactions; nucleosynthesis (i.e., why do the stars shine?) and element formation in stars (hydrogen burning, helium burning, and subsequent processes, and s-, r-, and x-processes); abundance and distribution of elements and isotopes in the sun, Earth, and planets. Introduction by lecture and evaluation on the basis of final exam.

115.
Geologic Time

(1 credit). (NS). Lecture

This course will introduce non-specialists to the subject of the time span over which the earth has developed, the processes that are involved in the formation of rocks and minerals, the determination of the rates at which these processes occur, and the ways in which we can use the current behavior of the earth to deduce how rocks formed in the past. The course will also include relevant aspects of the historical development of geological theory. It will be scientifically rigorous but, at the same time, draw upon examples meaningful to the student to illustrate the principle. Lectures twice weekly for half the term. A final examination.

116.
Introductory Geology in the Field

Not open to those who have had an introductory course in geology on campus. IIIb. (8 credits)

An introduction to geology in the field. This course is the equivalent of G.S. 117 or 121 but is taught at Camp Davis, the University's Rocky Mountain Field Station near Jackson, Wyoming. The principles and procedures involved in the study of earth materials and processes are stressed. Minerals, rocks, and fossils are studied in their natural settings. Lectures are given both in camp and in the field, but a majority of time is spent outdoors in the nearby Teton, Hoback, Gros Ventre, and Snake River Ranges. Trips are also taken to areas of special significance, including the Wind River Range, Craters of the Moon, and Yellowstone Park. Lectures, laboratory, extensive field studies. Application forms for admission are available from the departmental in 1006 C.C. Little Building in January of the year that the course is to be elected.

117.
Introduction to Geology

Not open to those who have had an introductory course in geology. I. (5 credits)

A basic single-term course in introductory geology concentrating on the evolution of the Earth in physical and chemical terms. Reference to the interaction of the external biosphere-atmosphere-hydrosphere with the Earth's interior is an essential component of the course. The laboratory provides a practical study of minerals, rocks, fossils, and geologic maps. One hour each week is scheduled for review and discussion topics covered in class. Lectures, laboratory, discussion.

119.
Introductory Geology Lectures

Not open to those who have had an introductory course in geology. I. (4 credits)

This course consists of lectures shared with geology 117 but does not include the laboratory section. A separate discussion section is also scheduled to ensure continuity with class material and student teacher contact. Students interested in a one-term laboratory introductory science course should elect geology 117. Lectures and discussion.

120.
Geology of National Parks and Monuments

Credit is not granted for G.S. 120 to those with credit for an introductory course in geology. II. (4 credits)

This course approaches earth history by examining the geology of places rather than geological processes. There are three lectures each week and one two-hour demonstration. Lecture material covers the geologic history of selected National Parks and Monuments chosen so that those in which the oldest rocks are exposed are discussed first. The demonstrations provide first-hand experience with rocks, minerals, and fossils and an opportunity to discuss these in small groups.

123.
Life and the Global Environment

II. (2 credits).

A hard look at the Gaia hypothesis. Do organisms cooperate to control the compositions of ocean atmosphere? Can life prevent harmful changes in the global environment? Does the geologic record provide answers to these questions? What future change in the global environment can we expect?

125.
Evolution and Extinction

II. (3 credits)

This course will describe the linkage of the phenomena of evolution with the historical extinction of species.

135.
History of the Earth

II. (3 credits). (NS)

This lecture course is intended for students with a strong high school background in math and science. It will serve as a broad introduction to the earth sciences for students considering a Geological Sciences concentration, as well as for students interested in studying the earth sciences as part of a general science background. Topics covered include methods of determining relative and absolute ages, the early history of the earth, its accretion and chemical differentiation, the development of continental and oceanic lithosphere, the evolution of plate tectonics, the history of the crust, sediments, oceans, atmosphere, and life. The unique aspects of earth history will be highlighted by viewing the development of the earth from the perspective of the evolution of the moon and the other terrestrial planets. Evaluation will be based on three examinations.

205.
How the Earth Works: The Dynamic Planet

(2 credits) (NS)

This course examines the evolution of the earth since its formation 4.56 billion years ago to today. The goal of this course is to present a fully integrated approach to earth formation and its subsequent history as expressed by earthquake and volcanic activity, ocean and continent evolution, and mountain building. The unifying concept of plate tectonics and a continuously evolving earth contains the clue to the shape and changes in the physical environment of the solid earth. Conceptual and factual material and classroom demonstrations will be used to explain the physical and chemical principles of the dynamic earth. Extensive use will be made of audio/visual and other classroom aides. Two lectures and one discussion/demonstration session will be given each week. No special background is required. Evaluation will be based on a mid-term and a final exam. The readings for this course consist of a textbook, "How to build a habitable planet," by W.S. Broecker, and a course pack (van der Pluijm and Lange.)

206.
How the Earth Works: The Water Cycle and the Environment

(2 credits) (NS)

This course describes the processes which control the surficial environment of the planet earth and its ability to sustain life. Water is the main transport agent in the geological cycle of elements; it's unique properties and rates of movement among earth surface reservoirs (oceans, lakes, rivers, groundwater, and atmospheric moisture) will be one focus of the course. On a more global scale, the rates of chemical and material exchange among unconsolidated sediment, various types of surficial rocks (evaporite salts, limestone, shale, granite, basalt) on continents and the ocean floor, and the hydrosphere will be discussed. The impact of human activities on surficial processes will be a unifying theme of this course. Anthropogenic inputs and imbalances can have a profound effect on the surficial hydrologic and geochemical cycle, manifested in changes in chemistry of natural water, sediment, biota and the atmosphere. Two lectures and one discussion session will be held each week. No special background is required. Evaluation will be based on three examinations and on participation in class and discussion section. Readings for the course will include "The Global Water Cycle: Geochemistry and Environment" (Berner and Berner) and a coursepack. This course, and its companion course (The Dynamic Planet: GS 205) may be taken singly or concurrently.

222.
Introductory Oceanography

No credit granted to those with credit for A.O. & S.S. 203. (3 credits) (NS)

This course introduces students to the scientific study of the oceans. Contents include the shape, structure, and origin of the ocean basins: the sedimentary record of oceanic life and conditions in the past; the composition of seawater and its influence on life and climate: waves and currents; the life of the oceans and how it depends upon the marine environment; the resources of the ocean and their wise use by society. The course format consists of lectures and readings from an assigned textbook. The course grade will be based on several hour exams.

223.
Introductory Oceanography, Laboratory

Concurrent enrollment in G.S. 222. (1 credit). (NS)

This course is an optional laboratory intended to provide students with opportunities to explore further marine topics presented in the G.S. 222 lectures. Laboratory sessions will include sampling procedures, use of equipment, discussions, and demonstrations of how data are generated. The course grade will be based on written laboratory exercises and a final exam.

270.
Plate Tectonics

(3 credits)

The theory of plate tectonics explains the mobility of continental and oceanic domains ("continental drift") with respect to each other. Earthquakes, volcanoes and fossil magnetism in rocks provide the evidence.

271.
Natural Hazards

(3 credits)

This seminar will explore various kinds of natural hazards, with emphasis on earthquakes, volcanic eruptions, or tsunamis. Will include current status of prediction research.

272.
Seminar: Environmental Geology

(3 credits)

This seminar will focus on a wide spectrum of possible interactions between people and their physical environment and could be described as a course in applied geology. Students can study this subject without any previous exposure to the geological sciences. Fundamental principles important to the study of environmental geology will be presented followed by readings of case histories and discussions of selected environmental problems including natural hazards (flooding, earthquakes, volcanic eruptions), water resources, global warming, nuclear waste disposal, and geological aspects of environmental health. The goal of the seminar is to provide a scientific basis for making informed decisions on the myriad of environmental problems that challenge a modern technocratic society.

273.
Contemporary Dinosaurs

Prerequisites: none.
(3 credits)

Paleontologists' understanding of dinosaurs and other fossil reptiles has undergone a revolutionary transformation since the mid-1970s. New data, new methodologies, and new assumptions about the basic biology of extinct reptiles have resulted in a more complex and dynamic picture of dinosaurian behavior, ecology, and morphology, and new estimates of their evolutionary history and relationships. In this course, we will investigate both these new scientific conceptions of fossil reptiles – including dinosaurs, pterosaurs, aquatic reptiles, and other related groups – and examine the history and philosophy of paleobiological work. We will also develop a basic understanding of some aspects of contemporary evolutionary theory and introduce background information on geological processes needed to understand the field. Course requirements include one brief (5 page) paper and one term paper of about 15 pages, a mid-term and final exam, and vigorous class participation. Weekly readings will be assigned from reserve materials, text, and course pack.

274.

Seminar: What is Science Anyway?

(3 credits) (NS)
This course will examine philosophical aspects of some contemporary controversies in geology and evolutionary biology, in particular, creationism's perennial challenge to evolution, the Alvarez meteor-impact hypothesis for explaining the extinction of the dinosaurs, and global warming. Readings will be drawn both from the primary scientific literature and from some of the major twentieth century works in the philosophy of science, especially those of Popper, Quine, Kuhn, and Feyerabend. Lectures and discussions will focus on both the scientific issues and on certain philosophical questions: 1) How do we distinguish science from non-science?, and 2) What is the role of social and historical factors in the construction of scientific theories and in the fixing of belief?

275.

The Ice Ages: Past and Present

(3 credits) (NS)
This course explores the characteristics of the Earth's climate system and how the various components of that system operate to produce times when extensive ice sheets cover large parts of the Earth's surface. The role of each of the major components of the climate system will be discussed in detail. These include the ice sheets themselves, the astronomical inputs, the oceans, the atmosphere, and the movement of the continental and ocean boundaries. Reconstructions of past climatic conditions are presented and discussed in terms of how they are developed, what they can tell use about climatic extremes, and how they can be used to test the models that simulate modern climate patterns. The long term climate change associated with the most recent ice age is then contrasted with more rapid climatic oscillations, particularly the climatic warming which has been associated with the recent large increase in atmospheric "greenhouse gases."

276.

Coastal Systems and Human Settlements

(3 credits) (NS)
In a small class setting, Coastal Systems and Human Settlements will introduce students to those geologic processes which have given rise to coastlines of the world, will establish a basis for understanding why these regions have been in a state of rapid change for thousands of years, will examine the reasons why human modification of coasts and adjacent rivers has commonly exacerbated this situation, and will explore the ramifications of anticipated global warming and attendant global sea level rise in the coming decades.

277.

Humans and the Natural World

(3 credits) (NS)
How humans affect and are affected by the natural environment, including other living creatures, the chemistry of air, water, and land, and the physical environment, particularly climate. Problems of pollution, changes in land use i including destruction of natural habitats, population pressure, and climate change. The histories of these assaults on the environment and their underlying causes, with possible solutions. Ethical and political aspects of human interaction with the natural world and the place of humans in nature, particularly from the perspective of biological evolution and Earth history.

278.

Earthlike Planets

(3 credits) (NS)

In a small classroom setting, Earthlike Planets introduces the freshman or sophomore undergraduate to the terrestrial planets: Mercury, Venus, Earth, moon, and Mars. Studies of solid planets will be used as a vehicle to better understand our own world and the methodology and limitations of science in the presence of conflicting hypotheses and ambiguous data. Since western society has made a significant commitment of resources toward the exploration of the planets, we must consider not only the scientific merits of this human endeavor but also its historical origins. As an introduction to its importance in nature generally, the concept of dynamic feedback will be considered and we will discuss its importance in the evolution of planets. Attention will be given to the surface evolution of Mars and the present atmospheric conditions of Mars and Venus: we will show how an understanding of these topics may help us understand climate change on Earth. Grades will be based upon in-class participation, a single mid-term exam, and a final project.

279.

Ocean Resources

(3 credits) (NS)

Ocean Resources: Oceanography combines elements of biology, chemistry, geology, and physics, and is a good overall introduction to science and the scientific method for students from all majors. In this course we will address a number of the somewhat equivocal issues facing ocean scientists and makers of marine policy. Critical thinking will be required for students to understand the conflicting demands placed on the oceans. This is exemplified by questions about preservation of the coastal environment as opposed to construction of marinas and by the protection of endangered species as opposed to the undeniable need for more food for more people. Questions to be addressed will include: Should Russians be permitted to catch lobsters off New England? Why has the U.S. refused to ratify the Law of the Sea treaty? What is the future of the sea and of mariculture in feeding the growing population of the world? Can a clean and renewable energy supply be obtained from waves and tides? Why save the whales? There will be a major whole-class assignment. Students will each select one of the weekly topics and lead class discussions on this topic.

280.

Mineral Resources, Economics and the Environment

I. (2 credits). No previous knowledge of geology is required for this course.

This course concerns the origin, distribution, and remaining supplies of mineral resources such as gold, iron, oil, and salt. These and other important mineral resources are discussed in terms of the economic, engineering, political, and environmental restrictions that govern their recovery, processing, and use. Among topics considered are mineral discovery, rated strip mining, smelting methods, oil and gas transport, nuclear waste disposal, taxation, royalties, and corporate profits in the mineral industry.

305.

Sedimentary Geology

Prerequisites: An introductory geological sciences laboratory course; or permission of the instructor. I.
(4 credits).

Properties of sediments and their origin, transportation, deposition, lithification, and diagenesis followed by ecology and environmental analysis, paleoecology and facies analysis and an introduction to stratigraphic methods and principles. Lectures, laboratory and field trip.

310.

Petrology

G.S. 231 and either an introductory geological sciences course or G.S. 351 to be elected prior to or concurrently with G.S. 310. II. (4 credits)

A review of the rock-forming minerals is followed by a discussion of the origin, modes of occurrence, alterations, classification, and methods for the determination of the important rocks based on megascopic characteristics.

351.
Structural Geology
G.S. 305 or permission of instructor. II. (4 credits)
Sedimentary, metamorphic, and igneous rock structures and the mechanics of rock deformation. Three-dimensional structure problems and geologic map interpretation given in the laboratory. Lectures and laboratory.

415.
Introductory Economic Geology (Metals)
G.S. 310, 351, or permission of instructor. I. (4 credits)
This is a survey economic geology course whose main emphasis is on gaining an understanding of how we study and describe ore deposits as well as studying specific examples of each major type. Fossil fuels and most nonmetallic ore deposits are left to other courses in the department. Such a study of the processes, controls on, and extent of different kinds of ore deposits, will allow the student to better understand the problems in locating concentrations of natural resources as well as the technical, practical, environmental and monetary considerations that decide whether or not an elemental concentration is an ore. The course is directed to the senior/first-year graduate student who has completed the core courses in geology, and is an elective outside the required departmental sequence. The method of teaching will combine lecture and discussion with a one hour per week lab session devoted to problem solving the first half of the term, and small lab exercises the second half. There will be a midterm and final as well as a term paper on a subject of the students' choosing. No text books are required but the Geology of Ore Deposits by Guilbert and Park is recommended.

420.
Introductory Earth Physics
Math. 116. I. (3 credits)
This course is intended to be a comprehensive introduction to the physics of the solid earth. Topics to be included are: seismology and structure of the earth's interior; geodynamics; gravity and the figure of the earth; isostasy; geomagnetism and paleomagnetism and its implications for plate tectonics; geothermics and the thermal history of the earth.

422.
Principles of Geochemistry
G.S. 231, 305, 310, and Chem. 126. II. (3 credits)
Instruction is directed toward how geochemical methods, such as stable isotope and trace element analysis, radioactive age dating, determination of phase relations of minerals and melts at low to high temperature and pressure, and computation of or experimentation on equilibria in the hydrosphere, hydrothermal solutions, and metamorphic and igneous systems, can unravel and provide insight into the origin and chemical evolution of the earth and its parts (core, mantle, crust, crustal rocks).

424.
Introductory Cosmochemistry and Early Evolution of Planets
(3 credits) (NS)
This course introduces the basics of cosmochemistry aimed at students from geology, chemistry, astronomy, physics, atmospheric and space physics and related fields. Topics include nuclear reactions and models, nucleosynthesis and element formation, basic types and compositions of meteorites, abundances of nuclides in the solar system and models on the abundances, extinct nuclides and isotopic anomalies (how they can be identified and what they can tell), and the chemistry of the terrestrial planets (moon and the Apollo project, Venus, Mars and SNC meteorites, and Earth).

442.
Geomorphology
I. (4 credits)
A study of the processes that affect the Earth's surface and that determine its form. Geomorphology is concerned with both modern and ancient landscapes. The course is designed for geology concentrators and advanced students in the natural sciences and archaeology. Lectures, discussions, and field trips.

444.
Soils and Their Development

An introductory geological sciences course or permission of the instructor. I. (3 credits)

Field identification and laboratory analysis of soils; study of their genesis as controlled by geologic, biotic, and climatic determinants and of their evolution through time; and consideration of soils as environmental factors. Lectures, laboratory, and required field trips.

446.
Permafrost, Snow, and Ice

Math 116 or equivalent. II. (3 credits)

Introduction to the environmental conditions in high altitudes and latitudes for students of natural sciences and engineering. Topics include general climatology and geography of alpine and arctic regions, economic development, environmental protection problems.

447.
Archaeological Geology

G.S. 442 or 448 or equivalent and one course in archaeology (Anthro. 282, or 581, or Class. Arch. 323. II. (3 credits)

In-depth treatment of geological concepts and techniques important in and applicable to the study of archaeological sites. Lectures, laboratory, and optional field trips.

448.
Geomorphology—Glacial and Periglacial

An introductory physical geology course or permission of instructor. I. (4 credits)

Study of geologic phenomena characteristic of the Pleistocene epoch, including glaciation, pluviation, and marine phenomena. Three required field trips, including at least one overnight. Lectures, recitation, and field trips.

449.
Marine Geology

G.S. 222/223 or introductory physical geology. II. (3 credits)

Topography, geomorphology, sediments, processes, and environments of the oceans; characteristics of oceanic segments of the Earth's crust; theories of structural development. Sedimentary record of past oceans and climates.

455.
Determinative Methods in Mineralogical and Inorganic Materials

One term of elementary chemistry and physics. II. (4 credits)

Introduction to the principal quantitative methods of characterizing the chemistry and structure of inorganic phases, including X-ray diffraction, XRF, microprobe, SEM, wet chemical, optical, resonance, and Mössbauer spectroscopy. Laboratory provides student with practical experience with principles covered in lectures.

458.
X-ray Analysis of Crystalline Materials

G.S. 455 or permission of instructor. II. (3 credits)

X-ray diffraction theory through a review of crystal structure determination. Emphasis is on the Weissenberg and precession single-crystal methods with extensive laboratory participation.

466.
Computational Models of Geochemical Processes

Ability to program computers in the BASIC language and introductory course in a natural science. (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 environment. Geological history of atmospheric and oceanic composition.

467.
Stratigraphy

G.S. 305, G.S. 310, and G.S. 351. I. (3 credits)

Principles underlying correlation, sedimentation, and paleogeographic interpretation. Regional stratigraphy and sedimentary tectonics.

473.
Fundamentals of Organic Geochemistry

G.S. 305 or Chem. 226. (3 credits)

An introduction to the fundamentals of the sources, transport, accumulation, and alterations of organic matter in sediments and sedimentary rocks. elemental, isotopic, and molecular indicators of origins, diagenetic and catagenetic pathways of constituents of organic matter, and carbon biochemical cycles, formation of petroleum and coal.

477.
Hydrogeology

Basic Chemistry, Physics, Calculus (e.g., Math 115 & 116; Physics 140/141, Chem. 125/130). (3 credits)

Introduction to physical and chemical hydrogeology, with emphasis on process and application to geological settings. Quantification of the hydrologic cycle and physical framework and properties of aquifer systems. Development of transport equations and examples of fluid, energy, and chemical transport in porous and fractured media.

478.
Aqueous Geochemisty

Chem. 365 or the equivalent. (3 credits)

The application of chemical principles to the study of rock/water interactions in natural systems. Importance of kinetics, thermodynamics and activity/concentration relative to geologic problems.

479.
Marine Geochemistry

Chem. 124 or the equivalent. (3 credits)

Distribution and composition of marine sediments, marine cycles and budgets of the elements, paleoceanograph, conceptual and quantitative models of ocean composition, thermodynamic and kinetic controls on composition, sea floor hydrothermal systems, current research topics.

480. (A.O.&S.S. 480)
The Planets: Composition, Structure and Evolution

Math 216, Physics 240, Chem. 126. I. (3 credits)

Origin and distribution of material in the solar system, gross composition and radial distribution of material in the planets and satellites; gravity fields and their relationship to shape and internal density distribution; origin and significance of surface topography; thermal, ionospheric and extended structure of planetary atmospheres; magnetism; energetics and dynamics of planetary interiors and atmospheres, thermal histories and evolution of solid interiors, devolatilization, origin, and evolution of atmospheres.

483.
Geophysics: Seismology

Math. 215 at least concurrently and Phys. 240; or permission of instructor. II. (4 credits)

Elastic properties of rocks, elastic waves, seismological instruments and data, use of body wave travel times, surface wave dispersion, and periods of free vibrations to infer the structure and composition of the earth's interior; earthquake intensity and magnitude scales; spatial, temporal and magnitude distribution of earth dynamics and global tectonics, moonquakes, underground nuclear explosions and "man-made" earthquakes, earthquake prediction and control. Lectures and laboratory.

484.
Geophysics: Physical Fields of the Earth

Math 216 at least concurrently and Physics 240, or permission of instructor. II (4 credits)

Newtonian attraction; the potential function, spherical harmonics; attraction of special distributions, gravity exploration techniques; isostasy, the figure of the earth; earth tides, the magnetic field of the earth, spatial and temporal variations, theories of origin; rock magnetism, paleomagnetism, contributions to earth dynamics and global tectonics; magnetic field of special distributions, magnetic exploration techniques; temperatures and heat transport in the earth, geothermal measurements, implications for tectonic processes. Lectures and optical laboratory.

485.
Computer Utilization in the Earth Sciences

Calculus and experience in computer programming. II. (3 credits)

Application of computers to earth science problems. Utilization of existing programs, data inventories, and specialized equipment. Topics include mapping, data management, and analysis and simulation.

486.
Geodynamics

G.S. 420 and prior or concurrent election of Math. 215 and Physics 240 or permission of instructor. (3 credits)

Analysis of dynamic problems in geology through application of continuum the thermal physics. Concepts of stress, strain and elasticity; flow of viscous fluids; and conduction and advection of heat will be developed in geological contexts. Physical basis for plate tectonics considered in detail.

540. (CEE 540)
Seminar in Engineering Geology

CEE 445 and a 400-level course in physical geology or geomorphology. II. (2 credits)

Study of case histories in engineering geology, dealing with dam sites, slope stability, waste disposal, foundation and bridge problems, power plant siting, groundwater and other problems.

589. (A.O.&S.S. 589)
Global Geochemical Cycles and Fluxes

Prerequisite: permission of instructor. II. (2 credits)

The processes that control the composition of the lithosphere, hydrosphere, and atmosphere. The budgets of major constituents and of isotopes. Quantitative modeling of possible changes with time in the compositions of oceans, sedimentary rocks, and atmosphere. Global productivity and the impact of life. Climatic consequences of geochemical change.

Industrial and Operations Engineering

(Division 272)

Department Office
240 Industrial and Operations Engineering Building
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John R. Birge, Ph.D.,
Professor and Chair

Professor

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., *William Clay Ford Professor of Product Manufacturing*
Gary D. Herrin, Ph.D.
Katta G. Murty, Ph.D.
Stephen M. Pollock, Ph.D.
Ramesh Saigal, Ph.D.
Robert L. Smith, Ph.D.
Daniel Teichroew, Ph.D.
Chelsea C. White III, Ph.D., *Senior Associate Dean, College of Engineering*
Tony C. Woo, 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.

Associate Professor

Thomas Armstrong, Ph.D.
Yavuz Bozer, Ph.D.
W. Monroe Keyserling, Ph.D.
David C. Kieras, Ph.D.
Jeffrey J. Liker, Ph.D.
James M. Miller, Ph.D., P.E.

Adjunct Associate Professor

Paul A. Green, Ph.D.

Assistant Professor

Izak Duenyas, Ph.D.
Ching Yee Teresa Lam, Ph.D.
Yili Liu, Ph.D.
Bernard J. Martin, Ph.D.
Medini R. Singh, Ph.D.

Adjunct AssistantProfessor

Richard J. Coffey, Ph.D.

Lecturer

James A. Foulke, B.S.E. (E.E.)

See Page 205 for statement on Course Equivalence.

200.
Introduction to Industrial and Operations Engineering
Prerequisites: None. Credit restrictions: ***not open to seniors****. (1 credit)*

This course will provide a survey of a broad range of problems and issues in Industrial and Operations Engineering. Students will investigate some of these problems in weekly homework assignments using computer software packages, and work on a small term project that involves integration of several aspects of the discipline.

301.
Industrial and Operations Management
Prerequisites: None. (Creates entry point for I&OE undergraduate curriculum). I and 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 I.&O.E. 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 and I.&O.E. 301. I and 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.

333.
Ergonomics
I and 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 I.&O.E.. 333. I and 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
Prerequisite: I.&O.E. 315 or Stat. 310, or Math. 215 and Eng. 103. I and 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 and 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: I.&O.E. 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: I.&O.E. 301 and 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

Prerequisite: Senior standing and permission of instructor. I and II. (3 credits)

Student teams will work with an organization on a design project with potential benefit to the organization and to the students.

425.
Manufacturing Strategies

Prerequisites: 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: I.&O.E. 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)
Occupational Ergonomics

I. (3 credits). Not open to students who have credit for I.&O.E. 333.

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: I.&O.E. 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. (EECS 493)
(CS 493)
User Interface Design and Analysis

Prerequisites: 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. I. (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.
Production and Inventory Control

Prerequisite: I.&O.E. 310 and I.&O.E. 365. I and 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.
Facility Planning

Prerequisite: I.&O.E. 310, I.&O.E. 315, and I.&O.E. 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.
Material Handling Systems

Prerequisites: I.&O.E. 310, I.&O.E. 315 and I.&O.E. 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

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: I.&O.E. 365 and I.&O.E. 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

Prerequisite: I.&O.E. 310 and I.&O.E. 315, and 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.
Work Measurement and Prediction

Prerequisite: I.&O.E. 333, I.&O.E. 334 and I.&O.E. 365. II. (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: I.&O.E. 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. (Stat. 466) Statistical Quality Control

Prerequisite: I.&O.E. 365. I and 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: I.&O.E. 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

Prerequisite: I.&O.E. 315, I.&O.E. 365 and I.&O.E. 373. I and II. (3 credits)

Digital simulation of complex discrete-event systems with applications in industrial and service organizations. Course topics include modeling and programming simulations in FORTRAN; use of a high-level simulation language as SIMSCRIPT, GPSS, SLAM, or SIMAN; input distribution specification; random number generators; generating random variables; statistical analysis of simulation output data.

478. (EECS 487) (CS 487) Interactive Computer Graphics

Prerequisite: I.&O.E. 373 or EECS 380, and senior standing. I and II. (3 credits)

Graphics devices and fundamentals of operation. Two- 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.

479. (IPPS 479) Operations Research for Public Policy

Prerequisite: Math. 413 and Pub. Pol. 529. I. (3 credits). Not open to students with credit for I.&O.E. 472 or I.&O.E. 460.

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

Prerequisite: Senior standing and permission of instructor. I and 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. (EECS 484) (CS 484) Database Management Systems

Prerequisite: EECS 380; or I.&O.E. 473. I and II. (3 credits)

Concepts and methods in the definition and management of large integrated databases for organizational information systems. Functions and objectives of existing file and data management systems will be considered and methods of analyzing proposals for new data management software will be studied; database administration, database design, and data security problems.

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 measure-ment, 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

Prerequisite: Senior standing and permission of instructor. I and II. (3 credits)

Selected design projects in industrial and operations engineering to be conducted for clients.

503. (EECS 509) Social Decision Making

Prerequisite: Stat. 310 or I.&O.E. 315 or EECS 401 or EECS 501. (3 credits)

Elementary decision analysis, examples in public sector; basic problems in social decision making; social values and preferences; multiattribute utility functions, subjectivity measurement; Pareto optimality. Arrow's impossibility theorem; group decision analysis, two-person game theory; social decision processes, strategy of conflicts.

510. (Math. 561) (S.&M.S. 518) Linear Programming I

Prerequisite: Math. 217, 417, or 419. I, II, and 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. (EECS 505) (Math. 562) (Aero. Eng. 577) Continuous Optimization Methods

Prerequisite: Math. 217, 417, or 419. I. (3 credits)

Survey of continuous optimization problems. Unconstrained optimization problems; unidirectional 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 I.&O.E. 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: I.&O.E. 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.
Traffic Modeling

Prerequisite: I.&O.E. 510 and 515 or equivalent. I. (3 credits)

Traffic modeling and its analysis in the context of IVHS (Intelligent Vehicle Highway Systems). Those aspects of traffic theory relevant to IVHS 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: I.&O.E. 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.
Human Factors in Engineering Systems I

Prerequisite: I.&O.E. 365 and I.&O.E.333/I.O.E. 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. (BI.&O.E.ng 534)
Occupational Biomechanics

Prerequisite: I.&O.E. 333 and I.&O.E. 334, or I.&O.E. 433/ E.I.H. 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.

539.
Occupational Safety Engineering

Prerequisite: I.&O.E. 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.
Inventory Analysis and Control

Prerequisite: I.&O.E. 310 and I.&O.E. 315 and I.&O.E. 365 and I.&O.E. 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.
Theory of Scheduling

Prerequisite: I.&O.E. 315 or I.&O.E. 515, and I.&O.E. 310. I. (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.

547.
Plant Flow Systems

Prerequisite: I.&O.E. 310 and I.&O.E. 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, microload automatic storage/retrieval systems and automated guided vehicle systems.

560. (Stat. 550) (Stat. & Mgt. Sci. 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: I.&O.E. 463 or I.&O.E. 433. (3 credits)

A case study approach to engineering related issues in union-management relations, professional and product liability, and worker rights legislation.

564. (Mech. Eng. 554) Computer Aided Design Methods

Prerequisite: Mech. Eng. 454 or Appl. Mech. 501 or I.&O.E. 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; non-linear 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: I.&O.E. 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.
Advanced Quality Control
Prerequisites: I&OE 466. II. (3 credits)
An applied course on Quality Control including Statistical Process Control Modifications, Linear, Stepwise & Ridge Regression Applications, Quality Function Deployment, Taguchi Methods, Quality Policy Deployment, Tolerancing Systems, Process Control Methodologies & Measurement Systems & Voice of the Customer Methodologies Time Series, Experimental Design, Total Quality Management and case studies.

567.
Advanced Work Measurement and Design
Prerequisite: I.&O.E. 433 or I.&O.E. 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.

573.
Analysis, Design, and Management of Large-Scale Administrative Information Processing Systems
Prerequisite: I.&O.E. 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: I.&O.E. 474. (3 credits)
Underlying probabilistic aspects of simulation and statistical methodology of designing simulation experiments and output 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: I.&O.E. 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. (EECS 588) (CS 588) (Mech. Eng./ Appl. Mech. 551)
Geometric Modeling
Prerequisite: EECS 487 or I.&O.E 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.

579.
Performance Modeling and Evaluation of Large Systems

Prerequisite: I.&O.E. 416 or EECS 501. (3 credits)

Introduction to queueing models, isolated queues, open and closed networks of queues, concept of local balance, algorithms for analysis of closed networks, model calibration and workload characterization simulation of models, applications in computer networks: routing and flow control, cyclic service models for token ring networks; models of flexible manufacturing systems.

581.
Hospital Systems Engineering

Prerequisite: I.&O.E. 365 or Hosp. Admin. 654. (3 credits)

Systems methodologies to aid in the more efficient and effective operation of the major administrative systems in hospitals. Inpatient admissions scheduling, operating room scheduling, patient classification, nurse staffing, departmental productivity, patient flow processes, facility planning; including bed and ancillary facilities, and length of stay determinants.

590.
Directed Study, Research, and Special Problems II

Prerequisite: permission of instructor. (3 credits maximum)

Continuation of I.&O.E. 490.

591.
Special Topics

Prerequisite: permission of instructor. (To be arranged)

Selected topics of current interest in industrial and operations engineering.

610. (Math. 660)
Linear Programming II

Prerequisite: I.&O.E. 510. (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)
Non-linear Programming

Prerequisite: I.&O.E. 510. (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 non-linear equations.

612.
Network Flows

Prerequisite: I.&O.E. 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. Multicommodity flow problem, biflows. Matching problems in graph theory.

614.
Integer Programming

Prerequisite: I.&O.E. 510. (3 credits)

Modeling with integer variables, total unimodularity, cutting plane approaches, branch-and-bound methods, Lagrangean relaxation, Bender's decomposition, the knapsack, and other special problems.

616.
Queueing Theory
Prerequisite: I.&O.E. 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 Gl/M/s queues. Preemptive and non-preemptive priority systems.

633.
Man-Machine Systems
Prerequisite: I.&O.E. 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 readings and laboratory demonstrations where appropriate.

634. (EIH 705)
Work-Related Upper Limb Disorders
Prerequisite: 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, 3) oral and written reports comparing published papers chosen by the students.

635. (Bioeng. 635)
Laboratory in Biomechanics and Physiology of Work
Prerequisite: I.&O.E. (Bioeng.) 534. II. (2 credits)

This laboratory is offered in conjunction with the Biomechanics and Physiology of Work course to allow students to experimentally determine (1) musculoskeletal reactions to volitional acts, (2) how EMG is used in muscle actions and fatigue evaluation, and (3) how the cardiopulmonary systems respond to various work stressors.

639.
Research Topics in Safety Engineering
Prerequisite: I.&O.E. 439 or I.&O.E. 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
Prerequisite: I.&O.E. 310 and I.&O.E. 365 and I.&O.E. 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: I.&O.E. 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.
Reliability, Replacement, and Maintenance
Prerequisite: I.&O.E. 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: I.&O.E. 510 or I.&O.E. 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 I.&O.E. 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: I.&O.E. 800; concurrent with I.&O.E. 802. (1-3 credits)
Directed research on a topic of mutual interest to the student and the instructor. This course complements I.&O.E. 800, First-Year Doctoral Seminar. Research presented in I.&O.E. 802.

802.
Research Presentation
Prerequisites: I&OE 800; concurrent with I&OE 801. II. (1 credit)
Students present oral and written technical material, including research in I&OE 801.

810. (Math. 861)
Seminar in Mathematical Programming
Prerequisite: Permission of instructor. (1 or 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 and 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 or 2 credits)

Study of recent developments and ongoing research in OR methodology, operational science and OR practice.

873.
Seminar in Administrative Information Processing Systems

Prerequisite: I.&O.E. 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: I.&O.E. 578. (1-3 credits)

Selected lectures and readings on recent developments in computer graphics.

881.
Research Seminar in Hospital and Medical Systems

Prerequisite: I.&O.E. 581 or graduate standing. To be arranged)

The use of quantitative techniques in hospital and medical care research. Discussion and review of current research and related methodological techniques in this area of interest. Outside speakers will present selected research topics. Readings, survey, and development of research projects. May be elected more than once.

899.
Seminar in Industrial and Operations Engineering

Prerequisite: Permission of instructor; not for master's degree credit. I and II. (1 credit)

Presentation by I.&O.E. 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, and III. (2-8 credits); IIIa and 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, and III. (8 credits); IIIa and 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
4116 IST 2099
(313) 763-2316

**College of Literature, Science and the Arts*

Frank E. Filisko, Ph.D., *Acting Chair*

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.
Richard E. Robertson, Ph.D.
George Summerfield, Ph.D.
Alan Wineman, Ph.D.
Albert F. Yee, Ph.D.
Robert Zand, Ph.D.

Associate Professor

Richard M. Laine, Ph.D.
Robert M. Ziff, Ph.D.

Assistant Professor

Stacy G. Bile, Ph.D.
David C. Martin, Ph.D.
Jeffrey S. Moore, Ph.D.
Coleen Pugh, Ph.D.

See Page 205 for statement on Course Equivalence.

412. (Mat. Sci. & Eng. 412) (Chem. Eng. 412) Polymeric Materials

Prerequisite: Mat. Sci. & Eng. 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. (Mat Sci & Eng. 414) (Chem. Eng. 414) Applied Polymer Processing

(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. (Phys. 418) StructuralMacromolecular Physics

Prerequisite: Math 216, Physics 242, 402, 417 or by permission of instructor. (3 credits).

Introduction to physical techniques used to study the ultrastructure of macromolecules and biomolecules: characterization of macromolecular structure; factors influencing conformational stability; an elementary study of structural techniques; scattering theory (such as x-ray diffraction, light scattering, etc.) and spectroscopic methods (such as infrared, Raman, UV, etc.) with application to macromolecules.

511. (Ch.E. 511) (Mat. Sci. & Eng. 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.
(Mat. Sci. & Eng. 512)
(Chem. Eng. 512)
Polymer Physics

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.

514.
(Mat. Sci. & Eng. 514)
Composite Materials

Prerequisite: MSE 351. II. (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.
(Mat. Sci. & Eng. 515)
Mechanical Behavior of Solid Polymeric Materials

Prerequisite: MSE 457, ME 210 or 211, or permission of instructor. II. (3 credits).

The mechanical behavior of polymers from linear viscoelastic to yield and fracture are covered. Specific topics include dynamic-mechanical relaxations, creep, yielding, crashing ,fatigue, and fracture mechanics. The materials include toughened plastics, polymer alloys and blends, and composite materials. Structural design with plastics is also considered.

517. (AMES 517)
Theory of Linear Viscoelasticity I

Prerequisite: Appl. Mech. 407. II. (3 credits).

Viscoelastic stress-strain relations; generalized creep and relaxation models, operational approach. Correspondence between viscoelastic and elastic solutions of boundary value problems. Three dimensional theory of linear viscoelastic media. Quasi-static problems; sinusoidal oscillation problems; use of complex modulus and compliance; dynamic problems, impact.

535. (Chem 535)
Physical Chemistry of Macromolecules

II. (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 birefringence, 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

Prerequisites: Chem 535 or Phys 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. 215/216 and Chem. 230 or Chem. 340. I. (2 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 and II. (2 credits).

800.
Macromolecular Seminar

I and II. (2 credits).

Student presentation of selected seminar topics in macromolecular science and engineering.

890.
Introduction to Research Techniques

Permission of Chairman. Every term. (1-8 credits).

This course serves a dual purpose: 1) selection of Research Supervisor, and 2) research carried out to earn the Master's degree.

990.
Dissertation Research/ Precandidacy

Permission. Every term. (1-8 credits).

This course number is used for doctoral research by students not yet admitted to candidacy.

995.
Dissertation Research/ Candidacy

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.

Materials Science and Engineering (Division 281)

Department Office
3062 Dow Building
(313) 763-4970

Ronald Gibala, Ph.D., *Professor and Chair*

Professor

John C. Bilello, Ph.D., *also Applied Physics*
I-Wei Chen, Ph.D.
Frank E. Filisko, Ph.D., P.E.
Amit K. Ghosh, Ph.D.
John W. Halloran, Ph.D.
William F. Hosford, Jr., Sc.D.
Robert D. Pehlke, Sc.D., P.E.,
Richard E. Robertson, Ph.D.
David J. Srolovitz, Ph.D., *also Applied Physics*
Tseng-Ying Tien, Ph.D.
Gary S. Was, Sc. D., *also Nuclear Engineering*
Albert F. Yee, Ph.D.

Professor Emeritus

Wilbur C. Bigelow, Ph.D.
Edward E. Hucke, Sc.D.
William Cairns Leslie, Ph.D.
Lawrence H. Van Vlack, Ph.D., P.E.
Edwin Harold Young, M.S.E., P.E., *also Chemical Engineering*

Associate Professor

J. Wayne Jones, Ph.D.
Richard M. Laine, Ph.D., *also Chemistry*

Assistant Professor

David C. Martin, Ph.D.
David C. Van Aken, Ph.D., P.E.
Steven M. Yalisove, Ph.D.

See Page 205 for statement on Course Equivalence.

150. (Eng. 150) Introduction to Engineering Materials
Prerequisite: Chem 130 or Chem 210. II. (4 credits)
Engineering materi-als, covering the structure, properties, and processing aspects of metals, polymers, and ceramics.

250. Principles of Engineering Materials
Prerequisite: 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: Mat. Sci. & Eng. 250 I. (3 credits)
Structure and reaction kinetics of crystalline and amorphous engineering materials. Phase diagrams. Equilibrium and nonequilibrium phase transformations. Crystal chemistry. Defects. Surfaces. Diffusion. Sintering.

356.
Materials Laboratory I
Prerequisites: Mat. Sci. Eng. 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 240, Mat. Sci. Eng. 250. I. (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. (Bioeng. 410)
Biomedical Materials
Prerequisite: Mat. Sci. & Eng. 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 vs. transplants and relevant biological components. Tours of relevant university facilities.

412 (Chem. Eng. 412) (Macro. Sci & Eng. 412)
Polymeric Materials
Prerequisites: 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.
(Chem. Eng. 414) (Macro. Sci. & Eng.414)
Applied Polymer Processing
(3 credits). Prerequisites: Mat. Sci. & Eng. 350.
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
Prerequisite: Mech. Eng. 210 or Mech. Eng. 211, Mat. Sci. & Eng. 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
Prerequisite: Chem. 365, Physical Chemistry. I. (3 credits)
Application of basic thermodynamic principles to problems involving solid and liquid materials. Mass and energy balances. Gas reactions. Ellingham, phase, stability and Pourbaix diagrams. Defects in solids. Interfaces. Non-stoichiometric phases. Statistical thermodynamics.

435.
Transport Phenomena in Materials Engineering
Prerequisites: Math. 216, Mat. Sci. Eng. 250. II. (3 credits)
Principles of fluid, energy and mass transport with applications to materials systems.

440.
Ceramic Materials
Prerequisite: Mat. Sci. & Eng. 350. II. (3 credits)
Chemistry, structure, processing, microstructure

and property relationships, and their applications in the design and production of ceramic materials.

456.
Materials Laboratory II

Prerequisite: Mat. Sci. & Eng. 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: Mat. Sci. & Eng. 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. Sterographic 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: Mat. Sci.. & Eng. 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.
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.
Design Problems in Materials Science and Engineering

Prerequisite: Mat. Sci. & Eng. 480. I and II. (To be arranged: 4 credit hours maximum.)

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.
Materials Process Design

Prerequisite: preceded or accompanied by Mat. Sci. & Eng. 430 and Mat. Sci. and Eng. 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

I, II, IIa, IIIb, and III. (To be arranged). Not open to graduate students.

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: Mat. Sci. & Eng. 350 (To be arranged).

Selected topics of current interest for students entering industry.

501.
Structure and Processing of Electrical Materials
Prerequisite: Mat. Sci. & Eng. 440 or EECS 314. (2 credits)
The role of chemistry, structure, and processing in determining the properties of electrical materials.

511. (Chem. Eng. 511) (Macro. Sci. & Eng. 511) Rheology of Polymeric Materials
Prerequisites: 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 . (Chem. Eng. 512) (Macro. Sci. & Eng. 512) Polymer Physics
Prerequisites: 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.
(Macro. Sci. & Eng. 514) Composite Materials
Prerequisites: MSE 351. I. (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 .
(Macro. Sci. & Eng. 515) Mechanical Behavior of Solid Polymeric Materials
Prerequisites: MSE 457, ME 210 or ME 211, or permission of Instructor. II. (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. (Mech. Eng. 582) Metal-Forming Plasticity
(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.

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
Prerequisites: Mat. Sci. & Eng. 420 or Mat. Sci. & Eng. 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: Mat. Sci. & Eng. 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: Mat. Sci. & Eng. 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.
Reactions in Ceramic Processes

Prerequisites: MSE 440 or graduate standing. (3 credits)

Dissociation, sintering, vitrification, devitrification, and thermochemical reactions in ceramic processing.

543.
Structures of Ceramic Compounds

Prerequisites: MSE 440 or graduate standing. (3 credits)

Structures and crystal chemistry of ceramic compounds.

544.
Properties of Ceramic Compounds

Prerequisites: 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

Prerequisite: 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

Prerequisites: 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: Mat. Sci. & Eng. 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: Mat. Sci. & Eng. 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. (Chem. Eng. 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: Mat. Sci. & Eng. 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.
Failure Analysis of Materials
Prerequisite: Mat. Sci. & Eng. 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.
Materials Science and Engineering Design
Not open to students who have taken Mat. Sci. & Eng. 480. I. (4 credits)
Design of materials processing systems. Selection and utilization of materials in engineering applications, economic aspects of design, estimating procedures.

585.
Materials or Metallurgical Design Problem
Prerequisite: Mat. Sci. & Eng. 480 or to be taken concurrently with Mat. Sci. & Eng. 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
(2 credits)
Research activities and opportunities in the Materials Science and Engineering programs. Lecture by faculty and guest lecturers. Brief weekly reports.

622. (Nucl. Eng. 622)
Ion Beam Modification and Analysis of Materials
Prerequisites: Nucl. Eng. 421/521 or Mat. Sci. Eng. 350 or Permission of Instructor. I. (3 credits)
Ion-solid interactions, ion beam mixing, compositional changes, phase changes, microstructural 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: Mat. Sci. & Eng. 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, and II
(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.
(Chem. Eng. 751)
(Chem. 751)
(Macro. Sci. 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 and III. (2-8 credits)
IIa and 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, and III. (8 credits); IIIa and 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* (Division 428)

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**College of Literature, Science and the Arts.*

Professor D.J. Lewis, *Chair*

Professors Blass, Brown, Burns, Conlon, Dickson, Dolgachev, Duren, Federbush, Fornaess, Gehring (T.H. Hildebrandt Distinguished University Professor), Griess, Hanlon, Higman, Hinman, Hochster, (R.L. Wilder Professor), Kister, Krause, Lewis, McLaughlin, Milne, Montgomery, Prasad, Ramanujan, Rauch, Raymond, P. Scott, Simon, Smoller, Stafford, Storer, Taylor, Wasserman, Winter, Woodroofe; **Associate Professors** Barrett, Borgers, Goldberg, Grillakis, Hales, Harabetian, Krasny, Lott, Megginson, Moy, Schwartz, Shih, Spatzier, Stembridge, Stensones, Uribe, Weinstein; **Assistant Professors** Bohus, Butler, Canary, Cholak, Dean, Draghicescu, Gavosto, Giaquinto, Gitik, Heinonen, Hu, Koskela, Lu, Markman, Minsky, Pitt, Tahvildar-Zadeh, Torres, Trapp, Wang, Wooley, Ye, Zhang; **Hildebrandt Research Assistant Professors** Dummigan, Jokusch, Langesen, Swanson; **Lecturer** Shure; **Adjunct Professor** Young; **Professors Emeriti** Bartels, Dolph, Harary, Hay, D. Jones, P. Jones, Kaplan, Kincaid, Lee, Nesbitt, Pearcy, Piranian, Reade, Rosen, Titus, Ullman, and Wendel.

Other courses in mathematics are listed in the Literature, Science and the Arts Bulletin and the Horace H. Rackham School of Graduate Studies Bulletin.

105. Algebra and Analytic Trigonometry

Prerequisite: See LSA Bulletin. I and II. (4 credits). No credit for engineering students.

Number systems; factoring; fractions; exponents and radicals; systems of equations; linear, quadratic, trigonometric, exponential, and logarithmic functions, their graphs and properties; triangle solutions; curve sketching.

106. Algebra and Analytic Trigonometry

Prerequisite: See LSA Bulletin. I and II. (4 credits) (No credit for Engineering students).

Course content is identical with Math. 105. There are no lectures—students are assigned to a tutor in the Math Lab for individualized instruction.

109. Pre-calculus

Prerequisite: See LSA Bulletin. I and II. (2; No credit for students who already have 4 credits for pre-calculus mathematics courses.)

Linear, quadratic, and absolute value equations and inequalities. Algebra of functions; trig identities. Functions and graphs: trig and inverse trig, exponential and logarithmic, polynomial and rational. Analytic geometry of lines and conic sections.

110. Pre-calculus

(Self-paced) See Math 109.

115. Analytic Geometry and Calculus I

Prerequisite: 3-4 years high school math including trigonometry. I, II, IIIa, and IIIb. (4 credits)

Functions and graphs; derivatives, differentiation of algebraic functions, applications; definite and indefinite integrals, applications to polynomial functions.

116.
Analytic Geometry and Calculus II

Prerequisite: Math. 115. I, II, IIIa, and IIIb. (4 credits)

Review of transcendental functions; techniques of integration; conic sections; infinite sequences and series; power series.

175.
Combinatorics and Calculus I

Prerequisites: Permission of a counselor. I. (4 credits)

There are two major topic areas: graph theory and enumeration theory. The first will include basic definitions and some of the more interesting and useful theorems of graph theory. The emphasis will be on topological results and applications to computer science and will include (1) connectivity; (2) trees, Prufer codes, and data structures; (3) planar graphs, Euler's formula and Kuratowski's Theorem; (4) coloring graphs, chromatic polynomials, and orientation; and (5) optimization of network flows. The section on enumeration theory will emphasize classical methods for counting including (1) binomial theorem and its generalizations; (2) solving recursions; (3) generating functions; and (4) inclusion-exclusion.

176.
Dynamic Systems and Calculus

Prerequisite: Math. 175 or permission of instructor. (4 credits)

Discrete-time and continuous-time dynamical systems. Topics include iterates of functions, simple differential equations, attracting and repelling fixed points and periodic orbits, chaotic motion, self-similarity, and fractals. Tools such as limits, continuity, Taylor expansions, exponentials.

185.
Honors Analytic Geometry and Calculus I

Prerequisite: permission of a counselor. I. (4 credits)

Topics covered include functions and graphs, derivatives, differentiation of algebraic and trigonometric functions and applications, definite and indefinite integrals and applications. Other topics will be included at the discretion of the instructor.

186.
Honors Analytic Geometry and Calculus II

Prerequisite: Math 185 or permission of a counselor. II. (4 credits)

Topics covered include transcendental functions, techniques of integration, introduction to differential equations, conic sections, and infinite sequences and series. Other topics will be included at the discretion of the instructor.

195.
Honors Mathematics I

Prerequisite: permission of a counselor. I. (4 credits)

Functions of one variable and their representation by graphs; limits and continuity; derivatives and integrals with applications; parametric representation; polar coordinates; applications of mathematical induction; determinants and systems of linear equations.

196.
Honors Mathematics II

Prerequisite: Math 195 or permission of a counselor. II. (4 credits)

Transcendental functions, methods of integration, infinite series, linear algebra.

215.
Analytic Geometry and Calculus III

Prerequisite: Math. 116 or 186. I, II, IIIa and IIIb. (4 credits)

Topics include vector algebra and vector functions; analytic geometry of planes, surfaces, and solids; functions of several variables and partial differentiation; line, surface, and volume integrals and applications; vector fields and integration; Green's Theorem and Stokes' Theorem.

216.
Introduction to Differential Equations

Prerequisite: Math. 215. I, II, IIIa, and IIIb. (4 credits; no credit after 316)

Topics include first-order differential equations, higher-order linear differential equations with constant coefficients, linear systems.

217.
Linear Algebra

Prerequisite: Math. 215 or 285. I and II. (3 credits; no credit after 417)

The topics covered are systems of linear equations, matrices, vector spaces (subspaces of R^n), linear transformations, determinants, Eigenvectors and diagonalization, and inner products.

285.
Honors Analytic Geometry and Calculus III

Prerequisite: Math. 186 or permission. I. (4 credits)

Topics include vector algebra and vector functions; analytic geometry of planes, surfaces, and solids; functions of several variables and partial differentiation; line, surface, and volume integrals and applications; vector fields and integration; Green's Theorem and Stokes' Theorem.

286.
Honors Differential Equations

Prerequisite: Math. 285. II. (3 credits)

Topics include first-order differential equations, higher-order linear differential equations with constant coefficients, linear systems.

288.
Math Modelling Workshop

Prerequisite: Math. 216, 316, or 286 and 217, 417, or 419. I. (1 credit). Offered mandatory credit/no credit. May be elected for a total of 3 credits.

During the weekly workshop students will be presented with real-world problems on which techniques of undergraduate mathematics offer insights. They will see examples of (1) how to approach and set up a given modelling problem systematically, (2) how to use mathematical techniques to begin a solution of the problem, (3) what to do about the loose ends that can't be solved, and (4) how to present the solution to others. Students will have a chance to use skills developed by participating in the UM Undergraduate Math Modelling Competition.

289.
Problem Solving

Prerequisite: permission of instructor. I and II. (1 credit). May be repeated for credit with permission of adviser.

Students and one or more faculty and graduate student assistants will meet in small groups to explore problems in many different areas of mathematics. Problems will be selected according to interests and background of the students.

295.
Honors Analysis I

Prerequisites: Math. 196 or permission. I. (4 credits)

This course studies functions of several real variables. Topics include elementary linear algebra; vector spaces, subspaces, bases, dimension, solution of linear systems by Gaussian elimination; elementary topology: open, closed, compact, and connected sets, continuous and uniformly continuous functions; differential and integral calculus of vector-valued functions of a scalar; differential calculus of scalar-valued functions on Euclidean spaces; linear transformations: null space, range, matrices, calculations, linear systems, norms; differential calculus of vector-valued mappings on Euclidean spaces: derivative, chain rule, implicit and inverse function theorems.

296.
Honors Analysis II

Prerequisite: Math. 295. II. (4 credits)

Differential and integral calculus of functions on Euclidean spaces.

300. (EECS 300)
Mathematical Methods in Systems Analysis

Prerequisite: Math. 216. I and II. (3 credits). Credit is not granted for both Math. 300 and Math. 448.

An introductory course in operational mathematics as embodied in Laplace transforms, Fourier series, Fourier transforms, and complex variables with emphasis on their application to the solution of systems of linear differential equations. The response of linear systems to step, impulse, sinusoidal forcing functions.

312.
Applied Modern Algebra

Prerequisite: Math. 116. I, II, and occasionally IIIa. (3 credits)

There are many possible topics which are natural here including counting techniques, finite state machines, logic and set theory, graphs and networks, Boolean algebra, group theory, and coding theory. Each instructor will choose some from this list and consequently the course content will vary from section to section.

316.
Differential Equations

Prerequisites: Math. 215 and 217 or equivalent. I and II. (3 credits). Credit can be received for only one of Math. 216 or 316, and credit can be received for only one of Math. 316 or 404.

Math. 316 is a rigorous course on differential equations for math, science, and engineering majors with a good background in both calculus and linear algebra. As well as material normally included in a junior level differential equations course, Math. 316 will include qualitative theory, and existence and uniqueness theorems. The use of microcomputers and standard commercial programs available for such a course will be encouraged.

350. (Aero. Eng. 350)
Aerospace Engineering Analysis

Prerequisite: Math. 316 or equivalent. (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.

354.
Fourier Analysis and its Applications

Prerequisites: Math 216, 316, or 286. (3 credits)

Introduction to Fourier analysis emphasizing applications. Main topics: Fourier series, discrete Fourier transforms, and continuous Fourier transforms, with applications to subjects such as signal processing and filtering, Fourier optics, partial differential equations (Poisson heat and wave), probability theory (random walks), and Weyl's theorem on equidistribution of arithmetic sequences.

362.
Applications of Calculus and Linear Algebra

Prerequisites: Math 216 or 217. (3 credits)

This course focuses on applications of calculus and linear algebra in the natural and social sciences. The knowledge required to understand the applications is taught in the course. The goal is to deepen the students' understanding of calculus and linear algebra, and motivate them to pursue mathematics further.

371. (Eng. 371)
Numerical Methods for Engineers and Scientists

Prerequisite: Eng. 103 or 104, or equivalent; and Math. 216. I and II. (3 credits)

This is a survey course of the basic numerical methods which are used to solve scientific problems. In addition, concepts such as accuracy, stability and efficiency are discussed. The course provides an introduction to MATLAB, an interactive program for numerical linear algebra as well as practice in computer programming.

404.
Intermediate Differential Equations

Prerequisite: Math. 216. I, II, IIIa and IIIb. (3 credits; no credit after 286 or 316)

Linear systems, solutions by matrices, qualitative theory, power series solutions, numerical methods, phase-plane analysis of non-linear differential equations.

412.
Introduction to Modern Algebra

Prerequisite: Math. 215 or 285 and prior or concurrent election of 217, 417, or 419 recommended. No credit granted to those who have completed or are enrolled in 512. Students with credit for 312 should take 512 rather than 412. One credit granted to those who have completed 312. I and II. (3 credits)

Sets, functions (mappings), relations, and the common number systems (integers to complex numbers). These are then applied to the study of groups and rings. These structures are presented as abstractions from many examples. Notions such as generator subgroup, direct product, isomorphism and homomorphism.

416.
Theory of Algorithms

Prerequisite: Math. 312 or 412 or EECS 303, and EECS 308 or permission. I and II. (3 credits)

Sorting, searching, matrix multiplication, graph problems (flows, traveling salesman), and primality and pseudoprimality testing (in connection with coding). Algorithm types as divide-and-conquer, backtracking, greedy, and dynamic programming are analyzed using generating functions, recurrence relations, induction and recursion, graphs and trees, and permutations. Also often sections on complexity theory and NP completeness.

417.
Matrix Algebra I

Prerequisite: 3 courses beyond Math. 110. I, II, IIIa and IIIb. (3 credits; none after 217)

Topics include matrix operations, vector spaces, Gaussian and Gaussian-Jordan algorithms for linear equations, subspaces of vector spaces, linear transformations, determinants, orthogonality, characteristic polynomials, eigenvalue problems, and similarity theory. Applications include linear networks, least squares method (regression), discrete Markov processes, linear programming, and differential equations.

419. (EECS 400)
Linear Spaces and Matrix Theory

Prerequisite: four courses beyond Math. 110. I and II. (3 credits; 1 after 417, no credit after 217 or 513)

Basic notions of vector spaces and linear transformations: spanning, linear independence, bases, dimension, matrix representation of linear transformations, determinants, eigenvalues, eigenvectors, Jordan canonical form, inner-product spaces; unitary, self-adjoint, and orthogonal operators and matrices, applications to differential and difference equations.

420.
Matrix Algebra II

Prerequisite: Math. 417 or 419. II. (3 credits)

Similarity theory, Euclidean and unitary geometry, applications to linear and differential equations, interpolation theory, least squares and principal components, B-splines.

425.
Introduction to Probability
Prerequisite: Math. 215 or 285. I, II, IIIb. (3 credits)
Topics include the basic results and methods of both discrete and continuous probability theory. Different instructors will vary the emphasis between these two theories.

433.
Introduction to Differential Geometry
Prerequisite: Math. 215. II. (3 credits)
Curves and surfaces in three-space, using calculus. Curvature and torsion of curves. Curvature, covariant differentiation, parallelism, isometry, geodesics, and area on surfaces. Gauss-Bonnet Theorem. Minimal surfaces.

450.
Advanced Mathematics for Engineers I
Prerequisite: Math. 216, 316 or 286. I, II, IIIa, and IIIb. (4 credits)
Topics include a review of curves and surfaces in implicit, parametric, and explicit forms; differentiability and affine approximations; implicit and inverse function theorems; chain rule for 3-space; multiple integrals; scalar and vector fields; line and surface integrals; computations of planetary motion, work, circulation, and flux over surfaces; Gauss' and Stokes' Theorems, derivation of continuity and heat equation. Some instructors include more material on higher dimensional spaces and an introduction to Fourier series.

451.
Advanced Calculus I
Prerequisite: Math. 285, or 215 and one subsequent course. I, II, IIIa. (3 credits)
A rigorous single variable calculus course, including completeness of the real numbers and various consequences such as the Balzano-Weierstrass and Heine-Borel Theorems. Also limits, sequences, series, and tests for convergence. Required for Math undergraduate majors, this is considered a remedial course for Masters students.

452.
Advanced Calculus II
Prerequisite: Math. 217, 417, or 419 (may be concurrent) and 451. (3 credits)
Topics include (1) partial derivatives and differentiability, (2) gradients, directional derivatives, and the chain rule, (3) implicit function theorem, (4) surfaces, tangent plane, (5) max-min theory, (6) multiple integration, change of variable, etc. (7) Green's and Stokes' theorems, differential forms, exterior derivatives (8) introduction to the differential geometry of curves and surfaces.

454.
Boundary Value Problems for Partial Differential Equations
Prerequisite: Math. 216, 316, or 286. I, II, IIIa and IIIb. (3 credits)
Classical representation and convergence theorems for Fourier series; separation of variables for the one-dimensional heat and wave equation; heat and wave equations in higher dimensions; spherical and cylindrical Bessel functions; Legendre polynomials; asymptotic integrals; discrete Fourier transforms; applications to linear input-output systems, etc.

462.
Mathematical Models
Prerequisite: Math. 216, 286, or 316; and 217, 417, or 419. II. (3 credits)
Construction and analysis of mathematical models in the natural or social sciences. Content varies considerably with instructor. Recent versions: Use and theory of dynamical systems (chaotic dynamics, ecological and biological models, classical mechanics), and mathematical models in physiology and population biology.

471.
Introduction to Numerical Methods

Prerequisite: Math. 216, 316, or 286; and 217, 417, or 419; and a working knowledge of one high-level computer language. I and II. (3 credits)

Topics include computer arithmetic, Newton's method for nonlinear equations, polynomials interpolation, numerical integration, systems of linear equations, initial value problems for ordinary differential equations, quadrature, partial pivoting, spline approximations, partial differential equations, Monte Carlo methods.

481.
Introduction to Mathematical Logic

Prerequisite: Math. 412 or 451 or equivalent experience with abstract mathematics. I. (3 credits)

In the first third of the course the notion of a formal language is introduced and propositional connectives ('and', 'or', 'not', 'implies'), tautologies and tautological consequences are studied. The heart of the course is the study of first-order predicate languages and their models. The new elements here are quantifiers ('there exists' and 'for all'). The study of the notion of truth, logical consequence, and provability lead to the completeness and compactness theorems. The final topics include some applications of these theorems, usually including non-standard analysis.

490.
Introduction to Topology

Prerequisite: Math. 412 or 451 or equivalent experience with abstract mathematics. I. (3 credits)

The topics covered are fairly constant but the presentation and emphasis will vary significantly with the instructor. Point-set topology, examples of topological spaces, orientable and non-orientable surfaces, fundamental groups, homotopy, covering spaces. Metric and Euclidean spaces are emphasized.

512.
Algebraic Structures

Prerequisite: Math. 285 or one 400 level course or permission of instructor. Math. 512 requires more mathematical maturity than 412. Credit is not given for both Math. 412 and 512. I. (3 credits)

Description and in-depth study of the basic algebraic structures groups, rings, fields, including: set theory, relations, quotient groups, permutation groups, Sylow's Theorem, quotient rings, field of fractions, extension fields, roots of polynomials, straightedge and compass solutions, and other topics.

513.
Introduction to Linear Algebra

Prerequisite: Math. 412. I and II. (3 credits)

Vector spaces; linear transformations and matrices, equivalence of matrices and forms, canonical forms; application to linear differential equations. One credit for 513 will be given to those with credit for Math. 417.

516.
Topics in the Theory of Algorithms

Prerequisite : Math. 416 and 417, EECS 480, or equivalent. (3 credits)

Graph Theory, Algorithms, Planarity - Graphs, planarity, Kuratowski subgraphs, polynomial time planarity tests, 3-connectivity, Tarjan's algorithm. Matchings - the Edmonds algorithm, Gabow's extension, applications.

525. (Stat. 525)
Probability

Prerequisite: Math. 450 or 451; or permission of the instructor. I and II. (3 credits)

Axiomatic probability; combinatorics; random variables and their distributions; expectation; the mean, variance, and moment generating function; induced distributions; sums of independent random variables; the law of large numbers; the central limit theorem. Optional topics drawn from: random walks, Markov chains, and/or martingales. Carries one unit of credit for students with credit for Math./Stat. 425.

555.
Introduction to Complex Variables

Prerequisite: Math. 450 or 451. I, II, IIIa, and IIIb. (3 credits; 1 after 554).

Differentiation and integration of complex valued functions of a complex variable, series, mappings, residues, applications.

556.
Methods of Applied Mathematics I

Prerequisite: Math. 217, 419, or 513; and 454. I. (3 credits)

Topics include Green's functions for ordinary differential equations, distributions, integral operators on L^2, Hilbert spaces, complete orthonormal sets, compact self-adjoint operators, and scattering theory on R. Other topics may include material on the basic partial differential equations of mathematical physics. (Laplace's Equation, the Heat Equation, the Wave Equation, and Schrödinger's Equations.)

557.
Methods of Applied Mathematics II

Prerequisite: Math. 217, 419, or 513; 454 and 555. II. (3 credits)

Topics include transform methods for partial differential equations, asymptotic expansions, regular and singular perturbation problems, non-linear stability theory, bifurcations, non-linear evolution equations, and associated phenomena.

559.
Selected Topics in Mathematics

Prerequisite: Math. 451 and 419 or equivalent. I. (3 credits)

Covers a branch of mathematics which has been strongly influenced by another science. The instructor will educate the student in the intuitions of that science as well as present mathematical proofs.

561. (S&M.S. 518) (I.&O.E. 510)
Linear Programming I

Prerequisite: Math. 217, 417 or 419. I, II, and 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; applications and interpretations. Introduction to transportation and assignment problems; special purpose algorithms and advanced computational techniques. Students have opportunities to formulate and solve models developed from more complex case studies and to use various computer programs.

562. (EECS 505) (I.&O.E. 511) (Aero. Eng. 577)
Continuous Optimization Methods

Prerequisite: Math. 217, 417, or Math. 419. (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 for unconstrained optimization through penalty transformations, augmented Lagrangians, and others. Discussion of computer programs for various algorithms.

565.
Combinatorics and Graph Theory

Prerequisites: Math. 412 or 451 or equivalent experience with abstract mathematics. I. (3 credits)

Graph Theory topics include Trees; k-connectivity;

Eulerian and Hamiltonian graphs; tournaments; graph coloring; planar graphs, Euler's formulas, and the 5-Color Theorem; Kuratowski's Theorem; and the Matrix-Tree Theorem. Enumeration topics include fundamental principles, bijections, generating functions, binomial theorem, partitions and q-series, linear recurrences and rational generating functions, and Polya theory.

566.
Combinatorial Theory

Prerequisite: Math. 216, 316, or 286 or permission of instructor. (3 credits)

Permutations, combinations, generating functions, and recurrence relations. The existence and enumeration of finite, discrete configurations. Systems of representatives, Ramsey's Theorem, and extremal problems. Construction of combinatorial designs.

567.
The Combinatorics of Communication Theory

Prerequisite: Math. 217 or 417 or equivalent.

This course is an introduction to coding for error correction. Topics include algebraic coding theory, Golay codes and the miracle octad generator; coding for constrained channels using finite state machines.

571.
Numerical Methods for Scientific Computing I

Prerequisite: Math. 217, 419, or 513 and 454 or permission. I and II. (3 credits)

Direct and iterative methods for solving systems of linear equations (Gaussian elimination, Cholesky decomposition, Jacobi and Gauss-Seidel iteration, SOR, introduction to multigrid methods, steepest descent, conjugate gradients), introduction to discretization methods for elliptic partial differential equations, methods for computing eigen values and eigen vectors.

572.
Numerical Methods for Scientific Computing II

Prerequisite: Math. 217, 419, or 513 and 454 or permission. II. (3 credits)

Finite difference methods for ordinary differential equations and for parabolic and hyperbolic partial differential equations. Topics include one-step and multistep methods, A-stability, root condition, Lax-Richtmyer Equivalence Theorem, CFL-condition, von Neumann stability condition, discrete energy method, Kreiss matrix theorem.

593.
Algebra I

Prerequisite: Math. 513. I. (3 credits)

Rings and modules. Euclidean rings, PIDs, classification of modules over a PID. Jordan and rational canonical forms. Structure of bilinear forms. Tensor products of modules; exterior algebras.

594.
Algebra II

Prerequisites: Math. 593. (3 credits)

Group theory. Permutation representations, simplicity of alternating groups for n>4. Sylow theorems. Series in groups; solvable and nilpotent groups. Jordan-Holder theorem for groups with operators. Free groups and representations. Field extensions, norm and trace, algebraic closures. Galois theory. Transcendence degree.

596.
Analysis I

Prerequisite: Math. 451. (3, 2 hours credit for those with credit for Math. 555.)

Review of analysis in R^2 including metric spaces, differentiable maps, Cauchy-Riemann equations, automorphisms. Analytic functions, Cauchy integral formula. Power series and Laurent expansions, fundamental theorem of algebra, harmonic functions. Functions analytic in a disk. Global properties of analytic functions. Riemann mapping theorem. Normal families.

597.
Analysis II

Prerequisite: Math. 451 and 513. I. (3 credits)

Lebesgue measure and integration on the line; convergence theorems, functions of bounded variation, absolute continuity, differentiation theory in one and several variables; general measure spaces; product spaces, Fubini's theorem; Radon-Nikodym theorem.

602.
Real Analysis II

Prerequisite: Math. 590 and Math 597. II. (3 credits)

Introduction to functional analysis; metric spaces, completion, Banach spaces, Hilbert spaces, L_p spaces; linear functionals, dual spaces; Riesz representation theorems; principle of uniform boundedness, closed graph theorem. Hahn-Banach theorem, Baire category theorem; applications to classical analysis.

604.
Complex Analysis II

Prerequisite: Math. 596. I. (3 credits)

Selected topics such as normal families, Riemann mapping theorem, conformal mapping of multiply connected domains; elliptic functions; entire and meromorphic functions, Picard's theorem, value distribution theory; Phragmen-Lindelof theorems; harmonic functions, Dirichlet problem; Schlicht functions.

607.
Theory of Distributions

Prerequisite: Math. 597. (3 credits)

Theory of distributions. Sobolev spaces. Fundamental solution of partial differential equations. Boundary value problems. Solutions of problems of optimization with partial differential equations as side conditions. Theorems of regularity. Characterization of singularities.

625. (Stat. 625)
Probability and Random Processes I

Prerequisite: Math. 597. II. (3 credits)

Axiomatics; measures and integration in abstract spaces. Fourier analysis, characteristic functions. Conditional expectation. Kolmogorov extension theorem. Stochastic processes; Wiener-Levy, infinitely divisible, stable. Limit theorems, law of the iterated logarithm.

626. (Stat. 626)
Probability and Random Processes II

Prerequisite: Math. 625. I. (3 credits)

Selected topics from among: diffusion theory and partial differential equations; spectral analysis; stationary processes and ergodic theory; information theory; martingales and gambling systems; theory of partial sums.

651.
Foundations of Applied Mathematics I

Prerequisite: Math. 451, 555, and one other 500 level course in analysis or differential equations or consent of the instructor. I. (3 credits)

The regular Sturm-Liouville theory for ordinary and partial differential equations including the rudiments of spectral theory and operator theory.

652.
Foundations of Applied Mathematics II

Prerequisite: Math. 651 or consent of instructor. II (3 credits)

A continuation of Math. 651. Spectral theory of self-adjoint operations and an introduction to the singular Sturm-Liouville theory.

656.
Advanced Partial Differential Equations

Prerequisite: Math. 558, 597, and 603 or permission of instructor. (3 credits)

Modern developments in the theory of partial differential equations.

658.
Ordinary Differential Equations
Prerequisite: Math. 602. (3 credits)
Existence theorems, linear systems, Sturm-Liouville theory. Qualitative study of flows and vector fields in the plane and on 2-manifolds. Periodic solutions, Hamiltonian systems, stability.

660. (I.&O.E. 610)
Linear Programming II
Prerequisite: Math. 561. II. (3 credits)
For description, see I.&O.E. 610.

663. (I.&O.E. 611)
Non-linear Programming I
Prerequisite: Math. 561, 594, or 490. I. (3 credits).
For description, see I.&O.E. 611.

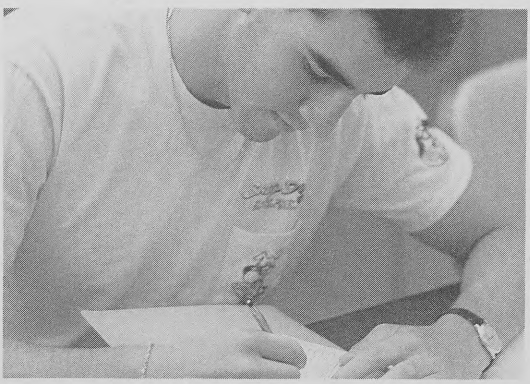
664.
Combinatorial Theory I
Prerequisite: Math. 512. I. (3 credits)
An introduction to the techniques of enumeration. Basic material for the first of this course is found in Stanley's "Enumerative Combinatorics, Vol. I." The second half consists of such topics as ordinary and exponential generating functions, Sieve methods, partitions and q-series, Polya Theory and other optional topics as time permits.

665.
Combinatorial Theory II
Prerequisite: Math. 664 or equivalent. II. (3 credits)
Selected topics from among: diffusion theory and partial differential equations; spectral analysis; stationary processes and ergodic theory; information theory; martingales and gambling systems; theory of partial sums.

668.
Topics in Graph Theory
Prerequisite: Math. 565 or 566, or permission of instructor. (3 credits)
Selected subjects chosen usually from the areas of graphs and matrices, graphs and their groups, topological graph theory, and extremal problems.

669.
Topics in Combinatorial Theory
Prerequisite: Math. 565 or 566, or permission of instructor. (3 credits)
Selected topics from the foundations of combinatorics, including the analysis of general partially ordered sets, combinatorial designs in loops and structures in abstract systems, enumeration under group action, combinatorial aspects of finite simple groups.

671.
Analysis of Numerical Methods I
Prerequisite: Math. 571, 572, or permission of instructor. (3 credits)
Special topics in numerical analysis, including subjects of current research interest. Recent versions: Finite difference methods for hyperbolic problems, mulitgrid methods for elliptic boundary value problems, finite element methods. Students can take this class for credit repeatedly.



Mechanical Engineering

(Division 280)

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Joseph E. Shigley, M.S.E., P.E.
Hadley J. Smith, Ph.D.
Chia-Shun Yih, Ph.D., *Stephen P. Timoshenko University Professor Emeritus of Fluid Mechanics*

Associate Professor

Claus Borgnakke, Ph.D.
Arvind Atreya, Ph.D.
David E. Cole, Ph.D. *Director of Office for Study of Automotive Transportation-UMTRI*
Spilios Fassois, Ph.D.
John W. Holmes, Ph.D.
Glen E. Johnson, Ph.D.
Elijah Kannatey-Asibu, Jr., Ph.D.
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Gregory M. Hulbert, Ph.D.
Allen C. Ward, Ph.D.

Lecturer

Donald M. Geister, M.S.E.
Thomas D. Gillespie, Ph.D.

Research Scientist

Robert D. Ervin, M.S.

Associate Research Scientist

James Ashton-Miller, Ph.D.
Jun Ni, Ph.D.

Assistant Research Scientist

Johann Borenstein, D.Sc.
Ahmet Selamet, Ph.D.

See Page 205 for statement on Course Equivalence.

101.
Introduction to Computer Aided-Design
I, II and IIIa. (2 credits)
High end engineering computer workstations and CAD software with 3D wireframe, surfacing and solids. Use of such computers and software to generate the necessary geometry and data for the engineering analysis/design/ manufacturing process. Graphical communication via freehand sketching.

110.
Statics
Prerequisite: Math 115. I, II. Not open to ME majors. (2 credits)
Basic principles of mechanics; concepts of statics, vectors, and vector additions and products; moments and couples; resultants and equilibrium of general force systems; free body method of analysis; applications to simple problems in all fields of engineering, elementary structures, cables, friction, centroids. Two lecture-recitation classes per week.

210.
Introduction to Solid Mechanics
Prerequisite: Math 116, and Mech. Eng. 110. I, II. Not open to ME majors. (3 credits)
Introduction to mechanics of deformable bodies; concepts of stress and strain, classification of material behavior, stress-strain relations, and generalized Hooke's law. Applications involve members under axial load, torsion of circular rods, bending, and shear stresses in beams, combined stresses, deflection of beams. Three lectures per week and six two-hour laboratories per term.

211.
Introduction to Solid Mechanics
Prerequisite: Physics 140 and Math. 116. I, II, IIIb. (4 credits).
Principles of statics including equilibrium and static equivalence. Determination of moment and force resultants in slender members. Introduction to mechanics of deformable bodies; concepts of stress and strain, classifications of material behavior, stress-strain relations and generalized Hooke's law. Application to engineering problems involving members under axial load, torsion of circular rod and tubes, bending and shear stresses in beams, combined stresses, deflection of beams. Four lecture-recitation classes per week.

235.
Thermodynamics I
Prerequisite: Chem 130, 125, or Chem 210, 211 and Math 116. I, II, and IIIa. (4 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
Prerequisite: Physics 140 and preceded or accompanied by Math 216. I, II, IIIa. (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 visual thinking, engineering drawing, and manufacturing processes and their capabilities. Use of computers in various phases of design and manufacturing. Exposure to CAD systems and basic machines shop technique. Design/manufacturing project.

281.
Mechanical Behavior of Engineering Materials
Prerequisite: Mat. Sci. 250 and Mech. Eng. 211. I and 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: Mech. Eng. 311. I. (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: Mech. Eng. 211 and Math 216. I, II, and 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: Mech. Eng. 235 and Mech. Eng. 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
Prerequisites: ME 235. I. II. (3 credits).
Thermodynamic power and refrigeration systems; availability and evaluation of thermodynamic properties; general thermodynamic relations, equations of state,

and compressibility factors; chemical reactions; combustion; gaseous dissociation; phase equilibrium. Design and optimization of thermal systems.

350.
Mechanical Design I

Prerequisite: Mech. Eng. 211 and Mech. Eng. 281. I and II. (4 credits).
Principles of mechanical design; synthesis and selection of machine components. Design project. Three hours lecture and one hour recitation.

360.
Modeling, Analysis & Control of Dynamic Systems

Prerequisite: Mech. Eng. 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

Prerequisites: Mech. Eng. 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: Mech. Eng. 281. II and 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: Mech. Eng. 320, preceded or accompanied by Mech. Eng. 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.

396.
Mechanical Science Laboratory

Prerequisites: Mech. Eng. 211, preceded or accompanied by Mech. Eng. 281 and Mech. Eng. 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 two two-hour laboratories per week.

400.
Mechanical Engineering Analysis

Prerequisite: Mech. Eng. 211, Mech. Eng. 240 and Math. 216. I. (3 credits)
Exact and approximate techniques for analysis of problems in Mechanical Engineering including structures, vibrations, control systems, fluids, and design. Emphasis is on applications.

401. (Appl. Mech. 401)
Engineering Statistics for Manufacturing Systems

Prerequisites: 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.

404. (Appl. Mech. 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. (Appl. Mech. 412)
Advanced Strength of Materials
Prerequisite: Mech. Eng. 311. II. (3 credits)
Review of energy methods, Betti's reciprocal theorem; elastic, thermo-elastic 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.

420.
Fluid Mechanics II
Prerequisite: Mech. Eng. 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 and 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
Prerequisite: Mech. Eng. 336, preceded or accompanied by Mech. Eng. 370. I. (3 credits)
Introduction to combustion processes, reaction kinetics, ignition, and flame propagation. Combustion of sprays. Detonation, temperature, and radiation. Spectrographic analysis. Optical methods for combustion studies. Otto, diesel, gas turbine, and rocket combustion.

435.
Design of Thermal-Fluid Systems
Prerequisite: Mech. Eng. 336 and Mech. Eng. 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: Mech. Eng. 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: Mech. Eng. 336. I. (3 credits)
Quantitative treatment of energy resources, conversion processes, and energy economics. Consideration of fuel supplies, thermodynam-

ics, environmental impact, capital and operating costs. Emphasis is placed on conversion of natural energy sources to electric, treating both the technical and economic aspects of fossil, nuclear, solar, and geothermal power production.

438.
Internal-Combustion Engines I

Prerequisite: Mech. Eng. 336. I and II. (3 credits)

Performance, economy and emission characteristics of spark ignited and Diesel engines. Thermodynamics of engine cycles. Fuels, fuel systems, combustion and combustion problems, friction. Valving and manifold considerations. Comparison of alternate engine design advantages and disadvantages including supercharging, turbocharging, and compounding.

439.
Automotive Laboratory

Prerequisite: preceded or accompanied by Mech. Eng. 438. I. (3 credits)

Experimental study of spark ignited and Diesel engines, including power, economy, thermal efficiency, mechanical efficiency, energy balance, cycle analysis, fuel systems, and emissions. Introduction to design of experiments as well as computerized data acquisition and analysis. One four-hour laboratory emphasizing hands-on participation and test report preparation.

441. (Appl. Mech. 441)
Intermediate Vibrations

Prerequisite: Mech. Eng. 240. I, II, and 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. Continuous systems, modal summation.

442. (Appl. Mech. 442)
Analysis & Synthesis of Motion

Prerequisite: Mech. Eng. 240. II. (3 credits)

Particle and rigid body kinematics in 3D 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. (Appl. Mech. 443)
Intermediate Dynamics

Prerequisites: Mech. Eng. 240. I and II. (3 credits).

Vector kinematics in 3D, 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

Prerequisite: Mech. Eng. 350 and Mech. Eng. 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 four-hour design periods.

451.
Properties of Advanced Materials for Design Engineers

Prerequisites: Mech Eng. 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.
Design for Manufacturability

Prerequisites: Mech. Eng. 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.

454.
Computer Aided Mechanical Design

Prerequisite: Eng. 103, Mech. Eng. 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. (Bioeng. 456) (Appl. Mech. 456) Biomechanics

Prerequisite: Mech. Eng. 211 and 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: Mech. Eng. 350. I and 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: Mech. Eng. 360. I, II, and IIIa. (4 credits). No credit for graduate students in M.E.

Linear feed-back control theory with emphasis on mechanical systems; transient and frequency response; stability; system performance; control modes; compensation methods; analysis of hydraulic, pneumatic, inertial components and systems. Three one-hour lectures and one three-hour laboratory.

465.
Real Time Microcomputer Applications

Prerequisite: Eng. 103, Mech. Eng. 461. I and II. (3 credits)

Real time applications of microcomputers to problems in mechanical engineering. Covers hardware and software aspects of microcomputers for data acquisition, data processing and control. Case studies of current interest to mechanical engineers. Two one-hour lectures and one three-hour lab.

467. (EECS 467) Robotics: Theory, Design and Application

Prerequisites: Mech. Eng. 360 or EECS 360 and senior standing. I and 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: Mech. Eng. 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.

474.
Phase Change Dynamics in Energy Systems
Prerequisite: Mech. Eng. 336 and Mech. Eng. 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, 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.

476. (Bioeng. 476)
Thermal-Fluid Sciences in Bioengineering
Prerequisites: None. Credit restrictions: not open to Mech. Engr. 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.

478.
Dynamics and Control of Thermal-Fluid Systems
Prerequisite: Mech. Eng. 370. I. (3 credits)
Application of fluid dynamics, heat transfer, and control theory to thermal-fluid equipment and processes in the mechanical engineering field. Methods for determination of dynamic characterization, controller types and applications of techniques of regulation.

480.
Manufacturing Processes Laboratory
Prerequisite: Mat. Sci. & Eng. 250. I and II. (1 credit). P/F only. Not for graduate credit.
Laboratory experience with basic machine tools to illustrate the geometric configurations, tolerances and surface finishes each can produce. Relationship of the manufacturing processes to design features and the design process. One three-hour period per week.

482.
Machining Processes
Prerequisite: Mech. Eng. 381 II. (4 credits)
Application of engineering fundamentals to design and analysis of machining operations. Special consideration is given to those facets of machine tool, cutting tool, and work material behavior which must be controlled in the use of computers, new electrical processes, and other modern and future facilities and techniques in manufacturing. Two recitations and two three-hour laboratories.

487.
Welding
I. (3 credits)
Study of mechanism of surface bonding, welding metallurgy, effect of rate of heat input on resulting micro-structures, residual stresses and distortion, economics and capabilities of the various processes.

490.
Experimental Research in Mechanical Engineering
Prerequisite: Senior Standing. I, II, IIa, IIb. (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: Mech. Eng. 490 and Permission of Instructor. I. II. III. IIa. 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, and IIIb. (To be arranged.)

Selected topics pertinent to mechanical engineering.

501. (Appl. Mech. 501) Analytical Methods in Mechanics

Prerequisites: Mech. Eng. 211, Mech. Eng. 240 and 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. (Appl. Mech. 502) Methods of Differential Equations in Mechanics

Prerequisites: 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. (Appl. Mech. 503) Numerical Methods in 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. (Appl. Mech. 504)

Prerequisite: ME/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. (Appl. Mech. 505) Finite Element Methods in Mechanical Engineering and Applied Mechanics

Prerequisite: ME/AM 501, Mech. Eng. 311, or Mech. Eng. 320, or Mech. Eng. 370. I and 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.

512. (Appl. Mech. 512) Theory of Elasticity

Prerequisite: Appl. Mech. 407 or ME/AM 412. II. (3 credits)

Stress, strain and displacement, equilibrium and compatibility. Use of airy stress function in rectangular and polar co-ordinates, 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. (Appl. Mech. 514) Nonlinear Fracture Mechanics

Prerequisite: ME/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. (Appl. Mech. 515) Contact Mechanics

Prerequisite: Mech. Eng. 350 or ME/AM 412 I. Alternate and even 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. (Appl. Mech. 517) (Macro. Science and Engineering 517) Theory of Linear Viscoelasticity I

Prerequisites: Appl. Mech. 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.

520. (Appl. Mech. 520) Advanced Fluid Mechanics I

Prerequisite: Mech. Eng. 320. I and 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. (Appl. Mech. 521) Advanced Fluid Mechanics II

Prerequisite: ME/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.

524. (AM 524) (NA 524) Wave Motion in Fluids

Prerequisite: ME 320. I. (3 credits)

Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to a moving body; Kortweg-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.

525. (Appl. Mech. 525) Computational Fluid Dynamics

Prerequisite: ME/AM 520. I. (3 credits)

Finite difference and finite

volume methods for incompressible, viscous flows, in two and three diminutions, complex geometries and coordinate mapping, methods for stratified flows. Special methods for inviscid flows, panel methods for flow around bodies, vortex methods for unsteady flows and free surface flows. Visualization of flow fields.

527. (Appl. Mech. 527) Multiphase Flow

Prerequisite: ME/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

Prerequisites: Mech. Eng. 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.
Internal Combustion Engines II

Prerequisite: Mech. Eng. 438. I. (3 credits)

Engine balancing and torque reaction considerations. Thermal efficiency, heat transfer, and thermodynamic modeling of both spark ignited and Diesel engines. Design of catalytic and noncatalytic exhaust treatment devices. Principles underlying recent advances in power development systems.

535.
Thermodynamics III

Prerequisite: Mech. Eng. 336. I. (3 credits)

Definitions and scope of thermodynamics; first and second laws. Maxwell's relations. Capeyron relations, equations of state, thermodynamics of chemical reactions, availability.

539.
Cryogenics and Refrigeration

Prerequisite: Mech. Eng. 336 and preceded or accompanied by Mech. Eng. 370. II. (3 credits)

Vapor compression refrigeration systems, properties of refrigerants, design of low temperature systems. Liquefaction, storage and handling of cryogenic fluids, including liquid natural gas, oxygen, nitrogen, hydrogen, and helium. Insulation problems. Applications of superconductivity. Emphasis placed on engineering practice, safety, and economics rather than low temperature physics.

541. (Appl. Mech. 541) Mechanical Vibrations

Prerequisite: ME/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. (Appl. Mech. 543) Analytical and Computational Dynamics I

Prerequisite: ME/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 stimulation.

548. (Appl. Mech. 548) Nonlinear Oscillations and Dynamic Stability of Mechanical Systems.

Prerequisites: ME/AM 443. II. (3 credits)

Large-amplitude vibrations of mechanical systems; dynamic instability theory of rods, plates, and shells; methods of Liapunov; asymptotic approaches of Krylov, Bogoliubov, and Mitropolosky; perturbation methods; Floquet theory.

551. (EECS 588) (CS 588) (IOE 578) Geometric Modeling

Prerequisites: 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. Management of Product and Manufacturing System Design

Prerequisites: 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) Computer Aided Design Methods

Prerequisite: Mech. Eng. 454 or ME/AM 501 or I.&O.E. 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; non-linear 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. Engineering Design Optimization

Prerequisite: Graduate standing. II. (3 credits)

Mathematical modeling of design problems for optimization. Emphasis on analytical techniques, monotonicity analysis, bounding functions, geometric programming, and extensions. Students propose a design term project from various engineering disciplines and apply the theory to analyze their individual problem.

556. Fatigue in Mechanical Design

Prerequisite: Stress-based finite element course recommended. I and 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.

557. Materials in Manufacturing and Design

Prerequisite: Mech. Eng. 381. I and II. (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 producibility and reliability.

558.
Vehicle Dynamics
Prerequisites: ME/AM 441 or ME/AM 443. 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.
Modeling Dynamic Systems
Prerequisite: Mech. Eng. 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.
Design of Automatic Control Systems
Prerequisite: Mech. Eng. 461 and Mech. Eng. 560. II. (3 credits)
Topics from control theory are introduced in the context of control systems design. Topics such as state variable feedback, modal control, optimal control, and adaptive control are introduced for both continuous and discrete systems. Design application is emphasized through the use of selected case studies.

562.
Dynamic Behavior of Thermal-Fluid Processes
Prerequisite: Mech. Eng. 478. II. (3 credits)
Principles of transport processes and automatic control. Techniques for dynamic analysis; dynamic behavior of lumped- and distributed-parameter systems, non-linear 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.
Time Series Analysis for Manufacturing Systems
Prerequisite: Mech. Eng. 461, plus one from Stat. 402, Stat. 310, 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.

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). Also human 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 and II. (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: Mech. Eng. 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: Mech. Eng. 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.

575.
Heat Transfer in Porous Media
Prerequisite: Mech. Eng. 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.
Rheology and Fracture
Prerequisite: Mech. Eng. 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.
Friction and Wear
Prerequisite: Mech. Eng. 580 or Mat. Sci. & Eng. 350 and 356. 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. (Mat Sci. & Eng. 523)
Metal-forming Plasticity
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.
Sensing and Modeling for Manufacturing Control
Prerequisite: Mech. Eng. 381; preceded or accompanied by Mech. Eng. 461 or 483. 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.
Control of Machining Systems
Prerequisites: 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.

585.
Mechanics of Manufacturing

Prerequisite: Mech. Eng. 381. I. (3 credits)

Development and evaluation of models for forming and machining processes. Applications to understanding causes of product defects, establishing conditions for quality, die/tool designs, and adding to the knowledge base of CAD/CAM systems.

589.
Failure Analysis Case Studies

Prerequisite: preceded or accompanied by Mech. Eng. 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

Prerequisite: graduate standing: permission of the instructor who will guide the work. I and II. (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".

595.
Master's Thesis Proposal

Prerequisite: graduate standing in Mechanical Engineering. I, II, IIIa, IIIb, and III. (3 credits) (Not for credit until 6 hrs of Mech. Eng. 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, and IIIb. (To be arranged)

Selected topics pertinent to mechanical engineering.

605. (Appl. Mech. 605)
Advanced Finite Element Methods in Mechanics

Prerequisite: ME/AM 505 or CEE 510/Nav. Arch. 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.

622. (Appl. Mech. 622)
Inviscid Fluids

Prerequisite: ME/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. (Appl. Mech. 623) Hydrodynamic Stability

Prerequisite: ME/AM 520. I. (3 credits)

An introduction to the theory of hydrodynamic stability with applications to stability of thermal flows, rotating and curved flows, wall-bounded 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. (Appl. Mech. 624) Turbulent Flow

Prerequisite: ME/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. (Appl. Mech. 625) Nonhomogenous Fluids

Prerequisites: ME/AM 520. I and 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. (Appl. Mech. 626) Pertubation Methods for Fluids

Prerequisite: ME/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. (Appl. Mech. 627) (NAME 627) Wave Motion in Fluids

Prerequisite: ME 520 or NA 520 or equivalent. I. (3 credits)

Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to a moving body; Korteweg de Vries equation; conoidal and solitary waves in water; wave reflection and diffraction; shallow-water waves by the method of characteristics; statistical approach and spectral analysis; wave generation.

631. Statistical Thermodynamics

Prerequisite: Mech. Eng. 235 or 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: Mech. Eng. 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. (Appl. Mech. 641). Advanced Vibrations of Structures

Prerequisite: ME/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. (Appl. Mech. 643) Analytical and Computational Dynamics II

Prerequisite: ME/AM 543 II. (4 credits)

Kinematical and dynamical equation formulation for rigid and flexible mechanical multibody systems undergoing large overall motion and small elastic deformation. Energy principles, higher and lower pair joint parameterizations, sparse and dense equation formulation and solution techniques, numerical integration, generalized impulse and momentum, collisions, and computational elastodynamics. Course project.

648. (Appl. Mech. 648) Nonlinear Oscillations and Stability of Mechanical Systems

Prerequisite: ME/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. (Appl. Mech. 649) (Aero. Eng. 615) (CEE 615) Random Vibrations

Prerequisite: CEE 513 or ME/AM 541 or Aero. Eng. 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: Mech. Eng. 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 non-linear systems, adaptation laws, and design and application of adaptive control systems.

663. Estimation of Stochastic Signals and Systems

Prerequisite: Mech. Eng. 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 framework, prediction, prediction-error and correlation-type estimation methods, recursive estimation methods, asymptotic properties, model validation.

672. Turbulent Transport of Momentum, Heat and Mass

Prerequisite: Mech. Eng. 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.

674.
Special Topics in Phase Change Dynamics

Prerequisite: Mech. Eng. 474. II. (3 credits)

Advanced topics in mechanisms and dynamics of phase change: nucleation, bubble dynamics, cavitation, flow boiling heat transfer, condensation, hydrodynamics of two-phase flow.

695.
Master's Thesis Research

Prerequisite: Mech. Eng. 595. I, II, and III, IIIa, IIIb. (3 credits) (Student must elect 2 terms of 3 hrs/term. No credit without Mech. Eng. 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

Prerequisites: Permission of instructor. I, II, III, IIIa, IIIb. (Arr.)

Advanced selected topics pertinent to mechanical engineering.

790. (Appl. Mech. 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 that discusses the future trends in his/her field. Graded S-U.

990.
Dissertation/ Pre-Candidate

I, II, and III. (1-8 credits); IIIa and IIIb. (1-4 credits)

Election for dissertation work by doctoral student not yet admitted to status as candidate.

995.
Dissertation/Candidate

Prerequisite: Graduate School authorization for admission as a doctoral Candidate. I, II, and III. (8 credits); IIIa and 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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Robert F. Beck, Ph.D., *Professor and Chair*

Professor

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Associate Dean for Undergraduate Education
William S. Vorus, Ph.D.
Director, Michigan Sea Grant College Program
John B. Woodward, Ph.D.
Raymond A. Yagle, M.S.E.

Professor Emeritus

Harry Benford, B.S.E.
Richard Couch, Ae.E.
Amelio M. D'Arcangelo, M.S.

Associate Professor

Howard M. Bunch, M.B.A., C.M.A., *Transportation Management*
Dale G. Karr, Ph.D.
Guy A. Meadows, Ph.D., *Physical Oceanography*
Anastassios N. Perakis, S.M. (M.B.A.), Ph.D.
Armin W. Troesch, Ph.D., P.E.

Assistant Professor

Marc Perlin, Ph.D., *Ocean Engineering*
David T. Walker, Ph.D.

Adjunct Associate Professor

Klaus-Peter Beier, Dr. Ing.

Adjunct Assistant Professor

Zissimos P. Mourelatos, Ph.D.

Adjunct Lecturer

Randel H. Visintainer, M.S.E.

Assistant Research Scientist

Stuart B. Cohen, Ph.D.

See Page 205 for statement on Course Equivalence.

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
Prerequisites: None. I. II. (3 credits)
Overall view of the ship and marine system design process. Weights, buoyancy, stability, powering, and economics. Each student designs an offshore vessel to satisfy a set of performance specifications. Hull lines are created and faired.

302.
Static Stability of Marine Vehicles
Prerequisite: Nav. Arch. 270., Eng. 103. II. (3 credits)
Calculation of areas, volumes, centers, statical

stability, damaged stability, launching. Use of digital computer is emphasized in all problems.

310.
Marine Structures I

Prerequisite: Mech. Eng. 210. 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: Nav. Arch. 270 and CEE 325. II. (4 credits)

Water waves. Ship resistance components: skin friction, form drag, wave resistance. Resistance prediction from standard series. Propeller geometry and design. Hull-propeller interaction, propeller charts, powering prediction. Model testing in the towing tank: wave loads, hull resistance, open water propeller test, shaft horsepower.

330.
Marine Power Systems I

Prerequisites: CEE 235; preceded or accompanied by CEE 325. 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: Nav. Arch. 302; preceded or accompanied by CEE 325. 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.

350.
Ocean Engineering Systems

Prerequisite: CEE 325. II. (3 credits).

Engineering analysis of work systems for operation in and on the ocean, offshore drilling platforms, submersibles and semi-submersibles, cables and moorings, buoy systems, pipe-laying, salvage and rescue systems, ocean mining. Selected aspects of physical oceanography, underwater acoustics and instrumentation.

381.
Probabilistic Methods in Marine Systems

Prerequisites: Math 350; preceded or accompanied by Nav. Arch. 340. II. (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.

385.
Ship Production and Shipping Management

Prerequisite: Nav. Arch. 270. I. (2 credits)

Techniques for performing economic evaluations of maritime management decisions; basic ship production technology; shipping economics; planning and scheduling concepts.

401.
Small Craft Design
Prerequisite: preceded or accompanied by Nav. Arch. 320. (3 credits)
Design of planing craft, hydrofoils, and other small high performance craft.

403.
Sailing Craft Design Principles
Prerequisite: preceded or accompanied by Nav. Arch. 320. (3 credits)
Application of hydrodynamic and aerodynamic principles to the design of sailing craft.

410.
Marine Structures II
Prerequisites: Nav. Arch. 310; preceded or accompanied by Nav. Arch. 340. I and II. (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. Eng. 411) (CEE 411)
Finite Element Applications
Prerequisites: Eng. 103, Mech. Eng. 211 or Mech. Eng 210. 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.

420.
Marine Hydrodynamics II
Prerequisites: Math 350, Nav. Arch. 320. I. (3 credits)
Viscous fluid theory applied to ships. Navier-Stokes equations, boundary layer theory, separation, form drag. Ideal fluid theory, Laplace and Bernoulli equations, method of singularities, numerical hydrodynamics. Two-dimensional and three-dimensional airfoil theory. Theoretical propeller design.

421.
Ship Model Testing
Prerequisites: Undergraduates only and permission of instructor. I, II, and IIIa, (To be arranged.) Undergraduates only
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: 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: Nav. Arch. 330. II. (3 credits)
Alignment analyses of marine gears and shafting systems. Characteristics of electrical generators, motors, and distribution systems. Electrical load analysis. Transients and faults in electrical systems. Applications of thermodynamics to diesel turbocompounding, turbocharging, and bottoming cycles. Choice of working fluid for bottoming cycles.

440.
Marine Dynamics II
Prerequisites: Nav. Arch. 340, Math 350. I. (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.

450.
Offshore Engineering Analysis I

Prerequisite: CEE 325. I. (3 credits).

Loading and motions of offshore structures. Morison's equation. Current and wind loads. Wave loading. Towing, mooring, oil drilling, production, pipelaying, etc. Design methodologies for offshore structures. Students will do two computer design mini-projects on risers, towing, cables, mooring, pipelines, redesign or tower dynamics.

455.
Environmental Nearshore Dynamics

Prerequisites: Nav. Arch. 425 or A.O.&S.S. 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 are examined. Environmentally conscious coastal design is emphasized.

460. (ME 460)
Ship Production Planning and Control

Prerequisites: Nav. Arch. 385; preceded or accompanied by Nav. Arch. 470. II. (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. (A.O. & S.S. 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: Nav. Arch. 320, Nav. Arch. 330, Nav. Arch. 381. I and II. (3 credits)

Preliminary design methods for sizing and form, powering, maneuvering, seakeeping, 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: Nav. Arch. 320, Nav. Arch. 381. II. (3 credits). Only one of Nav. Arch. 470 and Nav. Arch 471 may be taken for credit.

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

Prerequisites: Nav. Arch. 470 or Nav. Arch. 471. I, II, and 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.

490.
Directed Study, Research and Special Problems

Prerequisite: undergraduate only and permission. I, II and 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: Nav. Arch. 310 or CEE 312 or ME 311 or AE 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: Nav. Arch. 410, Aero. Eng. 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: Nav. Arch. 420 or CEE 325 or ME 320 or AE 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 ship hydrodynamics. Primarily for graduate students.

524. (ME 524) (AM 524)
Wave Motion in Fluids

Prerequisite: ME 320. I. (3 credits)

Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to a moving body; Kortweg-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.

528.
Remote Sensing of Ocean Dynamics

Prerequisite: NAME/AOSS 425 or permission of instructor. I. (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: Nav. Arch. 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: Nav. Arch. 340 or Mech. Eng. 441. I. (3 credits)

The human perception of sound and vibrations. Plane and spherical wave equations derivations. Interior acoustics. Diesel engine noise sources. Noise control techniques including materials and isolation systems.

540.
Marine Dynamical Systems

Prerequisite: Nav. Arch. 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, bilinear stiff moored systems, propeller-induced vibrations, and ship maneuvering. Extensive computer usage.

550. (AOSS 550)
Offshore Engineering Analysis II

Prerequisites: Nav. Arch. 420 and Nav. Arch. 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.

560.
Ship Production

Prerequisite: Nav. Arch. 460. I. (3 credits)

Selected areas of ship production, including group technology, welding processes, accuracy control, production planning and control, human resource development. Specialized production; naval vessels, workboats, recreational boats.

571.
Ship Design Project

Prerequisite: prior arrangement with instructor (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.
Computer-Aided Hull Design and Production

Prerequisite: graduate standing or permission. II. (3 credits)

Hull surface representation, creation, distortion, fairing. Computer-aided arrangement, piping, structures. Computer systems for structural detailing, production, manufacturing.

575.
Computer-Aided Marine Design Project

Prerequisite: Nav. Arch. 574. I, II, IIIa, IIIb, and III. (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.

582.
Reliability and Safety of Marine Systems
Prerequisite: EECS 401 or Math 425 or Stats 412. II. (3 credits)
Brief review of probability, statistics, trade-off analysis, and elements of financial management. Thorough presentation of the methods and techniques of reliability analysis. Marine reliability, availability, maintenance, replacement, and repair decisions. Safety and risk analysis. FMEA, fault tree and event tree analysis. Marine applications.

585.
Optimization and Management of Marine Systems
Prerequisite: NA 385 or equivalent. IIIa. (4 credits)
Optimization methods applied to marine systems design, production, and operations (linear, non-linear, integer, sequential). Marine decisions under uncertainty; utility theory. Fleet deployment optimization. International trade and shipping. Cartels, OPEC, and tanker shipping. Liner conference, rate formation elements of Maritime policy and law.

590.
Reading and Seminar
Prerequisite: permission. I, II, IIIa and 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: Nav. Arch. 510 and 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.

621.
Experimental Marine Hydrodynamics
Prerequisites: Nav. Arch. 520 and 540. IIIa. (3 credits)
Non-steady state ship model testing to compare hydrodynamic theory to experimental results, to develop experimental techniques, and to illustrate advanced applications. Propellers, seakeeping, vibrations, waves, resistance, etc.

622.
Real Flows of Marine Hydrodynamics
Prerequisite: Nav. Arch. 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: Nav. Arch. 520 or ME 520. (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: Nav. Arch. 420, Nav. Arch. 520, and 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 and II. (To be arranged)
Advances in specific areas of marine hydrodynamics as revealed by recent research.

627. (MEAM 627)
Wave Motion in Fluids
Prerequisite: ME 520 or Nav. Arch. 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 and 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: Nav. Arch. 410, Nav. Arch. 420, Nav. Arch. 440, Nav. Arch. 450. 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: Nav. Arch. 410, Nav. Arch 420, Nav. Arch. 440, Nav. Arch. 550 or Nav. Arch 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 and 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 and III. (2-8 credits) IIIa and IIIb. (1-6 credits)

990.
Dissertation/ Pre-Candidate
I, II, and III. (2-8 credits); IIIa and 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, and III. (8 credits) IIIa and 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 (Division 288)

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James P. Holloway, Ph.D.

See Page 205 for statement on Course Equivalence.

100.
Nuclear Energy in Modern Society
I and II (2 credits)
Nuclear power, as an example of introducing new technology for societal use. Human energy needs vs. consumption, alternative energy technologies (solar, fossil, and nuclear), natural and man-made radiation environment, nuclear medicine, nuclear energy, and the Green Revolution. Guest lecturers.

311.
Elements of Nuclear Engineering I
Prerequisites: Physics 242; preceded or accompanied by Math. 450. I. (3 credits)
Properties and structure of nuclei. Radioactivity; alpha-, beta-, and gamma-decay. Nuclear reaction. Interaction of neutron, gamma rays, and charged particles with matter. Nuclear fission.

312.
Elements of Nuclear Engineering II
Prerequisite: Nuc. Eng. 311. II. (3 credits)
Neutron physics; the four-factor formula for the multiplication constant for the infinite reactor; neutron generation time; one-speed neutron diffusion with elementary solutions; space-independent slowing down theory. Nuclear fusion.

315.
Nuclear Instrumentation Laboratory
Prerequisite: preceded or accompanied by Nuc. Eng. 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 and 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: Nuc. Eng. 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: Nuc. Eng. 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: Nuc. Eng. 312 and 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, multigroup diffusion theory and criticality calculations, and neutron slowing down and thermalization.

442.
Nuclear Power Reactors
Prerequisite: Nuc. Eng. 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: Nuc. Eng. 315 and Nuc. Eng. 441. II and 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 Nuc. Eng. 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 and Fusion
Prerequisite: Nuc. Eng. 312. I. (3 credits).
Introduction to the requirements and operation of fusion systems. Reaction cross sections. Plasmas and plasma containment. Wave phenomena in plasmas. Analysis of simple laboratory plasmas and devices, including glow discharges, probes and simple pinches.

472.
Fusion Reactor Technology
Prerequisite: Nuc. Eng. 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.

481. (Bioeng. 481)
Engineering Aspects of Radiology and Nuclear Medicine

II. (2 credits)

An introduction to the physical principles, instrument systems, and analytical methods of importance in radiation-related medical procedures. Topics are drawn from research and clinical activities in diagnostic radiology, nuclear medicine, and radiation therapy.

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 Department.

511.
Quantum Mechanics in Neutron-Nuclear Reactions

Prerequisites: Nuc. Eng. 312 and 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: Nuc. Eng. 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 455 and Nuc. Eng. 312 or Nuc. Eng. 511 concurrently. I. (3 credits)

A graduate level course on the principles of nuclear fission reactors including neutron transport theory, the P_n 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: Nuc. Eng. 541. II. (3 credits)

A continuation of Nuc. Eng. 541 including neutron resonance absorption and thermalization, perturbation and variational methods, flux synthesis, and numerical methods for solving the neutron transport equation including S_n and B_n methods, collision probabilities, and Monte Carlo methods.

551.
Nuclear Reactor Kinetics

Prerequisite: preceded or accompanied by Nuc. Eng. 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 Nuc. Eng. 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 Nuc. Eng. 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, thermalhydraulic, 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: Nuc. Eng. 561. IIIa. (3 credits)

Continuation of subject matter covered under Nuc. Eng. 561 with emphasis on applications of analytical models to the solution of current problems in reactor technology.

571.
Plasmas and Controlled Fusion I

Prerequisite: permission of instructor. I. (3 credits)

Fundamentals of the physics of fusion and of ionized gases. The basic equations describing the collective behavior of charged particles are formulated. General physical implications of these equations are examined.

572.
Plasmas and Controlled Fusion II

Prerequisite: Nuc. Eng. 571. II. (3 credits)

Investigations in plasma dynamics based on the Boltzmann and Fokker-Planck equations of magneto-hydrodynamics. Study of problems of containment, pinch effect, plasma oscillation, diffusion.

575. (EECS 519)
Plasma Dynamics and Particle Optics Laboratory

Prerequisite: preceded or accompanied by a course in plasmas or physical electronics. II (3 credits)

Experimental techniques for plasma dynamics, electron and ion beam technology, and vacuum technology. Experiments will be on microwave and probe diagnostics of plasmas, plasma instabilities, vacuum systems, plasma generation, electron and ion beam generation and optics, and other topics of current interest. Lectures will be given for background material.

576.
Principles of Charged Particle Accelerators

Prerequisites: Phys. 242 and 405 or permission of instructor, EECS 314 and 315. I, alternate years. (3 credits)

Study of electrostatic and electrodynamic accelerator principles and technology. Magnetic and electrostatic focusing of relativistic charged particles. Transient analysis of pulsed accelerators. Poisson/ Laplace analysis of accelerator systems and components. Electron beam cathodes. Ion beam sources. Engineering aspects of field emission, insulator flashover, and vacuum arc phenomena.

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.

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. (MSE 622)
Ion Beam Modification and Analysis of Materials

Prerequisites: Nucl. Eng. 421/521 or Mat. Sci. Eng. 351 or Permission of instructor. I. (3 credits)

Ion-solid interactions, ion beam mixing, compositional changes, phase changes, microstructural 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: Nuc. Eng. 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 microinstabilities; classical and anomalous diffusion of particles and energy, and scaling laws.

672.
Theory of Plasma Confinement in Fusion Systems I
Prerequisite: Nuc. Eng. 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. (Aero. Eng. 673) (EECS 617)
Topics in Theoretical Plasma Physics
Prerequisites: Nuc. Eng. 571 or EECS 517 or Aero. Eng. 726. I and II. (3 credits) This course may be taken for credit more than once.
An advanced course in theoretical plasma physics covering topics of current research interest. Specific content will vary from year to year. Representative topics include: studies of weakly ionized plasmas with applications to gas lasers; space plasmas; laser fusion plasmas; and non-linear plasma dynamics and plasma turbulence.

674. (Appl. Phys. 674)
High Intensity Laser-Plasma Interactions
Prerequisites: Nuc. Eng. 471, 571. I, 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.

676.
Physics of Intense Charged-Particle Beams
Prerequisite: Nuc. Eng. 572. I, alternate years. (3 credits)
Generation of intense electron and ion beams, dynamics and transport of such beams in vacuum, neutral and ionized gases. Stability and erosion of intense beams with applications to inertial confinement fusion and high-power coherent radiation.

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

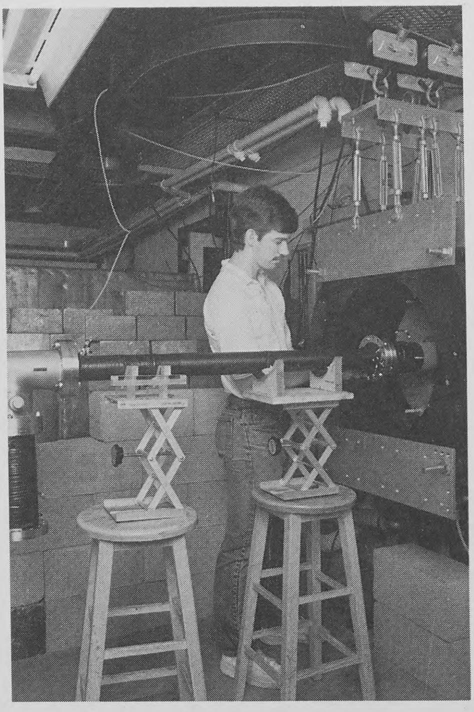
I, II, and III. (2-8 credits); IIIa and IIIb. (1-4 credits)

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 and III. (8 credits); IIIa and 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 H. A. Neal, *Chair*

Professors Akerlof, Allen, Axelrod, Becchetti, Bretz, Bucksbaum, Chapman, Clarke, Coffin, Donahue, Einhorn, Ford, Hecht, Hegyi, Jaklevic, Janecke, Jones, Kane, Kopelman, Krimm, A. Krisch, Longo, Merlin, Meyer, Neal, Roe, Ross, Sander, Sanders, Sands, Savit, Sinclair, Smith, Steel, Thun, Tickle, Tomozawa, Uher, van der Velde, Veltman, Wang, Ward, Weinreich, Williams, A. Wu, Yao, Zorn; **Associate Professors** Akhoury, Campbell, Chupp, Dierker, Freese, Gidley, Gray, J. Krisch, Rand, Tarlé, Weber; **Assistant Professors** Adams, Amidei, Antonuk, Aronson, Evrard, Fahy, Field, Hearshen, Hoogerbeets, MacKintosh, Nori, Orr, Rasul, Riles, Schmidt, Snow, Stuart, D. Wu; **Instructor**, Dershem.

140.
General Physics I
Prerequisite: Calculus and Physics 141 to be taken concurrently. I, II, IIIa. (3 credits)
The normal course consists of two lectures and two discussions per week. However, there are Keller sections available that meet four hours per week in two-hour sessions. This is the first of a three-term sequence in general physics for scientists and engineers, and the following topics are covered: Classical Mechanics: Vectors, motion in one dimension, circular motion, projectile motion, relative velocity and acceleration, Newton's Laws, particle dynamics, work and energy, linear momentum, torque, angular momentum of a particle, simple harmonic motion, gravitation, planetary motion, pressure and density of fluids, Archimedes Principle.

141.
Elementary Laboratory I
To be taken concurrently with Physics 140. I, II, IIIa. (1 credit)
One two-hour period of laboratory per week, designed to accompany Physics 140.

160.
Honors Physics I
Prerequisites: Math. 115 or equivalent, or permission of instructor. No credit granted to those who have completed or are enrolled in Phys. 140. I and II. (4 credits)
Physics 160 is a rigorous introduction to particle mechanics and the motion of extended objects. Particular topics include vectors, one- and two-dimensional motion, conservation of laws, linear and rotational dynamics, gravitation, fluid mechanics and thermodynamics. Students should also elect a Physics 141 laboratory. Interested students should get information from the departmental Office of Student Services.

240.
General Physics II
Prerequisite: Physics 140 or equivalent: Physics 241 to be taken concurrently. I, II, IIIa. (3 credits)
The normal course consists of two lectures and two discussions per week. However, there are Keller sections available that meet four hours per week in two-hour sessions. This is the second of a three-term

sequence in general physics for scientists and engineers, and the following topics are covered: Electricity and Magnetism: Charge, Coulombs's Law, electric field, Gauss's Law, electric potential, capacitors and dielectrics, current and resistance, EMF and circuits, magnetic field, Biot-Savart Law, Amperes' Law, Faraday's Law of Induction. Waves: Traveling wave equation, light waves, interference.

241.
Elementary Laboratory II

To be taken concurrently with Physics 240. I, II, IIIa.
(1 credit)

One two-hour period of laboratory per week, designed to accompany Physics 240.

242.
General Physics III

Prerequisite: Physics 240-241 or equivalent. I, II.
(3 credits)

This is the third of a three-term sequence in general physics for scientists and engineers, and the following topics are covered:

Relativity: Review of spacetime, energy-momentum transformation, invariant mass, mass-energy equivalence, energy-momentum conservation, and applications. Atomic Physics and Quantum Effects: Rutherford scattering, atomic structure (Bohr, Sommerfeld, Goudsmit-Uhlenbeck), electron spin, Zeeman effect. Waves, Schrödinger equation and its application to free particles, bound states of square well potential, harmonic oscillator and the Hydrogen atom. Rotational spectrum, Band theory of solids, Fermi energy, etc.

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)

A course to develop some techniques and concepts of physics, such as the first and second laws of thermodynamics, in order to understand some environmental problems and their possible solutions.

260.
Honors Physics II

Prerequisite: Phys. 140 or Math. 115, or equivalent, or permission of instructor. No credit granted to those who have completed or are enrolled in Phys. 240. I and II. (4 credits)

Physics 260 is a rigorous introduction to the theory of electromagnetic phenomena. Topics include electric and magnetic fields and potentials, DC and AC circuits, inductance and Maxwell's equations. Students should elect Physics 241 laboratory. Interested students should get information from the departmental Office of Student Services.

262.
Honors Physics III

Prerequisite: Phys. 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 Phys. 242. I.
(4 credits).

Physics 262 is an introduction to the ideas of modern physics with emphasis on the development of basic Quantum Mechanics. Topics covered include special relativity, particle in a box, quantum oscillators, the hydrogen atom and its spectra, spin and statistics, nuclear and particle physics. Interested students should get information from the departmental Office of Student Services.

288.
Physics of Music

II. (3 credits)

Lectures, demonstrations, and laboratory designed to acquaint the student with the physical basis of music. Distribution of time between laboratory and demonstrations would depend on enrollment. While no prior formal knowledge of either physics or music theory is required, a reasonably strong interest in music is assumed, as well as a willingness to combine ear and mind in an attempt to analyze the phenomena involved. Topics to be covered include: nature of sound; properties of musical tones; dynamics of vibrating bodies, dynamics of continuous systems; harmonic series; pitch relationships; temperaments and their role as expressions of style; survey of musical instruments.

333.
Keller Tutor 140

Prerequisite: permission of instructor. I and II. (1-3 credits)

Student works as a tutor in Keller Physics 140.

334.
Keller Tutor 240

Prerequisite: permission of instructor. I and II. (1-3 credits)

Student works as a tutor in Keller Physics 240.

401.
Intermediate Mechanics

Prerequisites: Physics 126 or 240-241 and Math. 216 or equivalent. I and II. (3 credits)

The methods of Lagrange are introduced and compared with the Newtonian approach to solving problems. Simple problems are introduced using the new methods: Simple harmonic motion, problems with springs and pulleys, projectile motion, spherical pendulum.

The theory of small oscillations for two or more dimensions: Secular determinant, eigen frequencies, normal modes, normal coordinates, the double pendulum, resonance, CO_2-like molecules, etc.

Problems with three or more dimensions: Central and planetary motions; the laws of Kepler; Newton's Law of universal gravitation, the theory of the motion of a rigid body, instantaneous angular velocity, the center of mass, the theory of moments of inertia, the theory of the motion of a free rigid body, and the symmetric top.

402.
Light

Prerequisites: Physics 126 or 240-241 and Math. 216 or equivalent. I. (3 credits)

The phenomena of physical optics, reflection, refraction, dispersion, interference, diffraction, polarization, etc., interpreted in terms of the wave theory of light.

403.
Optics Laboratory

Prerequisite: Physics 242 or permission of instructor. I and II. (2 credits)

Laboratory course covering geometrical and physical optics. It is intended for physics and other science majors. Lab experiments cover the following topics: lens equations, lens aberrations, light sources and detectors, polarization, interferometry, diffraction, electro-optical effects, light scattering, spatial filtering, holography, and spectroscopy. Although no formal optics course is required, students are encouraged to take Physics 402 (Light).

405.
Intermediate Electricity and Magnetism

Prerequisites: Physics 126 or 240-241 and Math. 216 or equivalent. I and II. (3 credits)

The laws and principles of electrostatics, moving electric charges and electromagnetism; introduction to Maxwell's equation.

406.
Statistical and Thermal Physics

Prerequisites: Physics 126 or 240-241 and Math. 216. I and II. (3 credits)

Introduction to thermal processes, including the classical laws of thermodynamics and their statistical foundations: Basic probability concepts, statistical description of systems and particles, thermal interaction, microscopic basis of macroscopic concepts such as temperature and entropy, laws of thermodynamics, elementary kinetic theory of transport processes.

407.
Thermodynamics Laboratory

Prerequisite: Physics 126 or 240-241. I and II. (2 credits)

Laboratory course meeting four hours per week. Normally taken concurrently with Physics 406. Experiments in thermodynamics and heat transport.

409.
Modern Physics Laboratory

Prerequisite: admission primarily to science majors in the junior year. I and II. (2 credits)

Develops experimental skills as well as acquaints the students with some of the subject matter of modern physics. Experiments available include: electron charge to mass ratio, electron charge, photoelectric effect, optical interferometer, microwaves, velocity of light, and others.

411.
Introduction to Computational Physics

Prerequisites: Physics 242, Calculus, some knowledgeof BASIC, FORTRAN or PASCAL. I. (3 credits)

Introduction to techniques of computational Physics with applications in optics, atomic, solid-state, nuclear and particle physics.

413.
Physics of Complexities

Prerequisites: Physics 401 or equivalent and familiarity with programming in BASIC. II. (3 credits)

This course is intended to introduce some concepts of non-linear dynamics, chaos, fractals, and disorderly growth at an undergraduate level. It should be useful to students in physics, chemistry, biological sciences, engineering, medical sciences, and, in some cases, social sciences. The prerequisites are Physics 401 (undergraduate mechanics) or the equivalent, or permission of the instructor.

415.
Special Problems

Prerequisite: permission of instructor. I, II, III, IIIa and IIIb. (Arranged)

417.
Dynamical Processes in Biophysics

Prerequisites: Math. 216 and Physics 242, Chem. 468 or by permission of instructor. II. (3 credits)

Introduction to physics techniques to study the ultrastructure of macromolecules and biomolecules: characterization of macromolecular structure; factors influencing conformational stability; an elementary study of structural techniques; scattering theory (x-ray diffraction, light scattering, etc.) and spectroscopic methods (infrared, Raman, UV, NMR, etc.) with application to macromolecules.

418.
Structural Macromolecular Physics

Prerequisite: Math. 216 and 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 transitions; denaturation; statistical nature of physical properties; nature of general organization and folding in macromolecules; case studies of structural problems in bio-and macromolecules.

435.
Gravitational Physics

Prerequisites: Physics 242, 401 and 405 or equivalent. I. (3 credits)

The Einstein theory of general relativity provides the foundation of gravitational physics, astrophysics, and cosmology. After an introduction to the theory, experimental tests of general relativity which were performed in the past, the implications of pulsars, black holes, supernova, and cosmic background radiation as well as the ongoing experimental detection of gravitational waves are discussed. This is an elective course for concentrators in physical sciences and the prerequisites for the course are Physics 242, 401 and 405.

438.
Electromagnetic Radiation

Prerequisite: Physics 405. II. (3 credits)

Electromagnetic waves in free space; propagation of electromagnetic waves in matter; reflection and refraction by dielectrics, conductors and ionized gases; dispersion ; wave guides, cavity resonators, and transmission lines; absorption and scattering of light; radiation by dipoles and antennas; radiation by moving charges: bremmstrahlung; synchrotron radiation and Cerenkov radiation.

451, 452.
Methods of Theoretical Physics

Prerequisites: Physics 401 and Math. 450 or equivalent. 451, I; 452, II. (3 each)

Applications of matrix theory, vector and tensor analysis, boundary value problems approximation and variational methods, applications from theory of analytic functions. Fourier series and integrals, eigenvalue problems, spherical harmonics, Bessel functions and other special functions of mathematical physics. Green's functions. Other topics may include an introduction to integral equations or group theory with applications to physical problems.

453.
Quantum Mechanics

Prerequisites: Physics 242 ; Physics 401 or 405 recommended. I and II.

(3 credits)

The course in an introduction to quantum mechanics.

Introduction: Bohr model, breakdown of classical mechanics, Stern-Gerlach experiment, probability amplitudes.

Schrödinger Equation: Application to a free particle, reflection at a potential discontinuity, barrier penetration, bound states of a square well, harmonic oscillation, qualitative discussions of solutions of the Schrödinger Equation for the hydrogen atom.

Electron spin and fine structure (hydrogen atom): The Stern-Gerlach experiment, angular momentum coupling for the one-electron atom; semi-quantitative (non relativistic) treatment of spin-orbit coupling and fine structure.

The many electron-atom: Pauli Principle, the periodic table, X-rays, Moseley's Law.

454.
Electronic Acquisition and Processing of Physics Data

Prerequisite: basic knowledge of computer structure helpful. I. (3 credits)

Open to students at the junior, senior, and graduate level. The external characteristics of analog and digital electronic elements are reviewed prior to their use in specific circuits for monitoring and collecting from physics experiments.

455.
Electronic Devices and Circuits

Prerequisites: Phys. 240 and 241. I. (5 credits).

An introduction to DC and AC circuits; j-notation, circuit theorems; semiconductors (primarily qualitative) and introduction to diodes and bipolar (junction) transistors; four-terminal networks; transistor characteristics and biasing, equivalent circuits, transistor amplifiers and their frequency and pulse response; unipolar transistors (J-FET, MOSFET, IGFET); resonant circuits, oscillators, inductive coupling; transistors as switches, the multivibrator family including the Schmitt trigger circuit; integrated circuits; operational amplifiers and logic gates; pulse shaping; modulation and detection; noise; and power supplies.

457.
Nuclear Physics
Prerequisite: Physics 453. II. (3 credits)

The course is an introduction to nuclear physics. The basic elements of quantum mechanics are used.
Nuclear Structure: binding energies, size and shape, angular momentum, parity, isospin, magnetic moments, electric quadrupole moments; statistical, shell, and collective models for the nucleus.

Nuclear Decays: radioactivity, barrier penetration and alpha-particle decay, the weak interaction and beta-decay, electro-magnetic transitions in nuclei.
Nuclear Interactions: Basic properties of the nuclear force, nucleon-nucleon scattering, the deuteron, nuclear reactions, and reaction models.
Nuclear Radiation: Interaction of charged particles, gamma rays and neutrons with matter, nuclear radiation detectors.

459.
Nuclear Laboratory
Prerequisites: Physics 242 and one 400-level physics laboratory course, or by permission. I and II. (2 credits)

Study of nuclear phenomena and instrumentation. Experiments available include: radioactivity; scintillation counter, angular correlation, Compton effect, Rutherford scattering, cosmic-ray muon lifetime, nuclear magnetic resonance, nuclear fission, neutron diffusion, and others.

460.
Atomic Physics
Prerequisite: Physics 453. II (2 credits)

This is the second of a two-course sequence on quantum mechanics and atomic physics. The topics covered are:

The two-electron atom: The Pauli exclusion principle, energy levels of the helium atom.

Structure and spectroscopy of many-electron atoms: L-S land j-j coupling, the Zeeman, Stark, and Paschen-Bach effects, hyperfine structure; elementary treatment of transition probabilities and selection rules, line widths and broadening.

Lasers: Stimulated emission, pumping, output characteristics.

Interaction of light micro-waves with atoms: Nuclear magnetic resonance, optical pumping, level-crossing spectroscopy.

461.
Atomic Laboratory
Prerequisites: Physics 242 and one 400-level physics laboratory course or by permission. I and II. (2 credits)

Intended for science majors. Covers atomic phenomena. Zeeman Effect, Faraday Effect, optical pumping and mass spectrometer, diffraction of electrons, atomic spectroscopy.

463.
Introduction to Solid State Physics
Prerequisite: Physics 453 or permission of instructor. II. (3 credits)

Structure and physical properties of crystalline solids. Ionic crystals; free electron theory of metals; band theory of solids; effects of impurities and imperfections; theories of magnetism. Introduction to the concepts of phonons, polarons, plasmons, etc. Interaction of radiation with crystalline materials.

464.
Solid State Laboratory
Prerequisites: Physics 242 and Physics 406. Physics 463 to be taken concurrently or previously, or permission of instructor. I. (2 credits)

Experimental work in x-ray diffraction from solids, electron transport in solids, phase transitions, the use of the electron microscopes and thermal mechanism in solids.

468.
Elementary Particles
Prerequisite: Physics 453, or Physics 453 taken concurrently. I. (3 credits)

A survey course, emphasizing the systematics of elementary particles, basic theory, and current experimental problems.

505, 506.
Electricity and Magnetism

Prerequisites: Physics 405 and Math. 450. 505, I. (2 credits); 506, II. (3 credits)

Electromagnetic theory; Maxwell's equations and the radiation from a Hertzian oscillator; connections with special relativity theory.

507.
Theoretical Mechanics

Prerequisite: an adequate knowledge of differential equations: an introductory course in mechanics is desirable. I. (3 credits)

Lagrange equations of motion; the principle of least action. Hamilton's principle, the Hamilton-Jacobi equations; Poisson brackets.

510.
Statistical Physics I

I. (3 credits)

Kinetic and statistical methods of Boltzmann, and explanation of the second law; extension to the quantum theory; nonideal gases and the theory of the solid body; theory of radiation; fluctuation phenomena.

511, 512.
Quantum Mechanics I and II

Prerequisite: Physics 453. Physics 511 is a prerequisite for Physics 512. 511, I ; 512, II. (3 credits each)

Physics 511 and 512 make up a two-term sequence on the quantum theory and its applications to the solution of problems in atomic physics.

513.
Advanced Quantum Mechanics

I and II. (3 credits)

A review of time dependent perturbation theory, creation and destruction operator formalism, second quantization of the photon field, scattering of photons and atoms, and the Klein-Gordon and Dirac equations.

515, 516.
Supervised Research

Prerequisite: permission. I and II. (4-6 credits each term).

517.
Graduate Physics Laboratory

Prerequisite: graduate standing. I. (3 credits)

Experiments in atomic, optical, nuclear, condensed matter, and low temperature physics for the graduate student with limited experimental experience.

518.
Microcomputers in Experimental Research

Prerequisite: graduate standing. II. (3 credits)

A laboratory course in the application of microcomputers to experimental research: data acquisition, handling, analysis, and geographical presentation.

520.
Condensed Matter Physics

Prerequisite: Physics 510, 511 or equivalent. II. (3 credits)

Modern theory of solids with emphasis on electron states, band theory, electron-electron interactions, phonons, electron-phonon interactions, transport theory, semiconductor physics and superconductors.

521.
Elementary Particle Physics

Prerequisite: Physics 506, 512, or equivalent. II. (3 credits)

Experimental aspects of the following topics will be covered in depth; particles and their quantum numbers; measurement techniques; basic symmetries, e.g., parity, charge conjugation, etc.; weak interactions; electromagnetic interactions; strong interactions.

523.
Advanced Quantum Mechanics II

Prerequisite: Relativistic Quantum Mechanics at the level of Physics 513. II. (3 credits)

This course will assume a background of Relativistic Quantum Mechanics at the level of Physics 513 (Advanced Quantum Mechanics I). Among the topics explored will be: Group theory, spin, isospin, SU_2 and higher groups, the application of the Dirac equation to High Energy Physics, hyperfine splitting, etc. Topics in field theory will include Feynman diagrams and calculations of cross sections for simple processes.

540.
Advanced Condensed Matter

Prerequisite: Phys. 520 or equivalent. (3 credits)

Use and development of Green's function techniques to study the many body aspects of electron-electron interactions, electron-phonon interactions, magnetic and superconducting instabilities of a Fermi liquid, formulation and application of the renormalization group to critical phenomena and Anderson localization.

601, 602.
Particles and Fields

603, 604.
Magnetic Monopoles

605, 606.
Applied Group Theory

609. (EECS 638) (Phys 609)
Quantum Theory of Light

Prerequisite: one graduate level course in quantum mechanics (3 credits)

The atomfield 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)
Nonlinear Optics

Prerequisites: 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.

613, 614.
Advanced Quantum Theory

615, 616.
Advanced Classical Mechanics

617, 618.
Physics of Continuous Media

619, 620.
Solid State

621, 622.
Quantum 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. (EECS 538)
(Appli. Phys. 550)
Propagation of Laser Beams
Prerequisite: EECS 434. I. (3 credits)
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.

651. (EECS 539)
(Appli. Phys. 551)
Lasers and Electro-Optics II
Prerequisite: EECS 538. II. (3 credits)
Laser resonators, eigenmodes, and stability analysis; rate equation analysis; homogeneous and inhomogeneous broadening mechanisms; laser gain and gain saturation; O-switching and mode locking. Special topics: laser pulse compression; Raman and Brillouin scattering; phase conjugation.

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

800.
Physics Technology

990.
Dissertation/ Pre-Candidacy

995.
Dissertation/Candidacy

Statistics* (Division 489)

Department Office
1444 Mason Hall
(313) 763-3519

**College of Literature, Science, and the Arts*

Professor Muirhead, *Chair*

Professors Csorgo, Ericson, Hill, Howrey, Hymans, Keever, Nair, Rothman, Smith, Woodroofe and Wu; **Associate Professors** Jeganathan and Keener; **Assistant Professors** Faraway, Hardwick, and Sun

Other courses in 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, and IIIa. (4 credits)

Course is designed to expose a student to the basic ideas underlying statistical reasoning and modern statistical methodology. Topics covered include: rudiments of probability theory; critical discussion of alternative interpretations of probability; statistics as inference and/or decision making; basics of decision theory; the fundamental ideas underlying hypothesis testing and estimation; classical versus Bayesian ideas.

170.
The Art of Scientific Investigation

Prerequisite: none. II. (4 credits)

The course will explore the critical thought processes involved in a scientific investigation. Concepts covered will include: the role of empiricism, modelling, the nature of variability, the design of scientific experiments (advantages and disadvantages), the role of randomization, the measurement process, possible biases, the use of controls, and the evaluation of final results. Examples from the history of science will be used to illustrate successes and failures in science. Various ethical issues will be considered.

290.
The History of Chance

Prerequisites: None. II. (3 credits)

This course will acquaint students with the evolution of some of the main ideas of probability in an historical context. This evolution will be depicted from the earliest evidence of chance in ancient cultures and continue with the description of problems appearing in the Renaissance that prompted leading mathematical thinkers to attempt the measurement of uncertainty.

301.
Introduction to Decision Theory

Prerequisite: None. II. (3 credits)

Models for decision making, including actions, states of nature, and consequences; using probability to measure uncertainty; the subjective and objective views of probability; Bayes and minimax solutions to decision problems with data; admissible and inadmissible strategies; relation to game theory; solutions to decision problems with data; quantifying the value of information; choosing among alternative experiments; special topics such as group and multi-purpose decision making.

310.
Elements of Probability
Prerequisite: taken concurrently with Math. 215. I and II. (3 credits)
Basic concepts of probability; expectation and variance, covariance; distribution functions; bivariate marginal and conditional distributions. The binomial and related distributions, the Poisson process, the exponential and gamma distributions, the normal distribution, the distributions of sample statistics, the law of large numbers and the central limit theorem.

311. (I.&O.E. 365)
Engineering Statistics
Prerequisites: Eng. 103, Math. 215, and I.O.E. 315 or Statistics 310. I and 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.

402.
Introduction to Statistics and Data Analysis
Prerequisites: None. I, II, IIIb. (4 credits) (NS) No credit granted to those who have completed or enrolled in Economics 404 or Statistics 311, 405 or 412.
A one-term course in applied statistical methodology from an analysis-of-data viewpoint. Frequency distributions; measures of location; mean, median, mode; measures of dispersion; variance; graphic presentation; elementary probability; populations and samples; sampling distributions; one-sample univariate inference problems, and two-sample problems; categorical data; regression and correlation; and analysis of variance. Use of computers in data analysis. Three hours of lecture and one and one-half hour lab session each week.

403.
Introduction to Statistics and Data Analysis II
Prerequisite: Statistics 402. II. (4 credits). (Excl).
Continuation of Statistics 402. Additional topics in the design and analysis of experiments (partially hierarchical, Latin squares, split plot; fixed, random, and mixed models, both parametric and non-parametric techniques); multiple regression including some discussion of model choice and evaluation, partial correlations, multicollinearity; analysis of covariance; and analysis of categorical data from both a classical chi square perspective and via linear models. Each techniques presented with assumptions and illustrative examples.

404.
Problem Solving in Medical Statistics
Prerequisite: Enrollment in Inteflex or permission of instructor. I. (3 credits) (Excl).
Intended to introduce students in the medical sciences to the measurement and interpretation of clinically relevant variables. Applications to the design and analysis of clinical trials and diagnosis are presented. The methodology includes some probability theory, classical inference, and curve fitting. Many of the topics are illustrated through current problems in medicine.

405. (Econ. 405)
Introduction to Statistics
Prerequisite: Math. 115 or permission of instructor. Juniors and seniors may elect concurrently with Economics 201 and 202. I and II. (4 credits). (Excl). No credit granted to those who have completed or are enrolled in Statistics 311 or 412. Students with credit for Economics 404 can only elect Statistics 405 for 2 credits and must have permission of instructor.
The purpose of this course is to provide students with an understanding of the principles of statistical inference.

Topics include probability, experimental, and theoretical derivation of sampling distributions, hypothesis testing, estimation, and sample regression. (Students are advised to elect the sequel, Economics 406).

406.
Introduction to Statistical Computing

Prerequisites: Statistics 402 and Math./Statistics 425. II. (4 credits). (Excl).

Acquaints students with selected topics in statistical computing, including basic numerical aspects, iterative statistical methods, principles of graphical analysis, simulation and Monte Carlo methods, generation of random variables, stochastic modeling, importance sampling, numerical and Monte Carlo integration. Three hours lecture and one-and-one-half hour lab session each week.

412.
Introduction to Probability and Statistics

Prerequisite: taken concurrently with Math. 215 and either EECS 283 or Eng. 103. I, II and IIIa. (3 credits)

An introduction to probability theory; statistical models, especially sampling models; estimation and confidence intervals; testing statistical hypotheses; important applications, including the analysis of variance and regression.

413.
The General Linear Model and Its Applications

Prerequisites: Statistics 402, Math. 217, co-registration in Math./Stat 425 (or concurrent enrollment in Math./Statistics 425). I. (4 credits). (Excl). Only two credits if student has taken Statistics 403.

Course will introduce students to the general linear model and its assumptions, and will cover topics such as the geometry of the model, projections, least squares estimation, residuals, normal distribution theory results, inference on parameters, diagnostic tools, and applications in analysis of variance, design, and time series. Three hours lecture and one-and-one-half hour lab session each week.

414.
Topics in Applied Statistics

Prerequisites: Statistics 413 or Statistics 403 and permission and concurrent or previous enrollment in Statistics 426. II. (4 credits) (Excl).

Topics in applied statistics, including random and mixed effects ANOVA models, analysis of covariance and repeated measure designs, ridge regression, splines, logit-probit analysis, log-linear models, topics in multivariate analysis (MANOVA, discriminant analysis, profile analysis), topics in time series analysis, and basics of survival analysis. Three hours lecture and one and one-half hour lab session each week.

425. (Math. 425)
Introduction to Probability

Prerequisite: Math. 215. I, II and IIIb. (3 credits) (N. Excl).

Basic concepts of probability; expectation, variance, covariance; distribution functions; and bivariate, marginal and conditional distributions.

426.
Introduction to Mathematical Statistics

Prerequisite: Statistics 425. I and II. (3 credits) (NS)

Treatment of experimental data, normal sampling theory, confidence intervals, and tests of hypotheses, and intro-duction to regression and to analysis of variance. This course serves as a prerequisite for many 500-level statistics courses.

466.
Statistical Quality Control

Prerequisite: Statistics 311 or I.O.E. 365. I and II. (3 credits) (Excl).

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.

470.
Experimental Design

Prerequisite: Statistics 402. I. (4 credits) (Excl).

Course will introduce students to basic principles in classical experimental design, including randomization, replication, confounding, interaction, covariates, use of the general linear model. Students will be introduced to the following designs: completely randomized, randomized blocks, Latin squares, incomplete blocks, factorial, split plot, Taguchi, response surface, optimal. Three hours lecture and one and one-half hour lab session each week.

480.
Survey Sampling Techniques

Prerequisite: Statistics 402. I. (4 credits). (Excl).

Course will introduce students to basic ideas in survey sampling, moving from motivating examples to abstraction to populations, variables, parameters, samples and sample design, statistics, sampling distributions, Horvitz-Thompson estimators, basic sample designs (simple random, cluster, systematic, stratified, multiple state), various errors and biases, special topics. Three hours lecture and one and one-half hour lab session each week.

499.
Honors Seminar

Prerequisite: permission of departmental honors adviser. I, II, IIIa, and IIIb. (2-3 credits)

Advanced topics, reading and/or research in applied or theoretical statistics.

500.
Applied Statistics I

Prerequisites: Math. 417 and a course in statistics (402 or 426 or permission of instructor). I. (3 credits)

Review of matrices, multivariate normal and related distributions. Regression and general least squares theory, Gauss-Markov Theorem, estimation of regression coefficients, polynomial regression, stepwise regression, residuals. ANOVA models, multiple comparisons, analysis of covariance, Latin squares, and other designs, random and mixed-effects models. Applications and real data analysis will be stressed, with students using the computer to perform statistical analysis.

501.
Applied Statistics II

Prerequisite: Statistics 500 or permission of the instructor. II. (3 credits)

A variety of topics in applied statistics will be covered in the course. The main topics are survey sampling methods including: simple random sampling, stratification, cluster sampling, systematic sampling and multistage sampling methods. Survival analysis including: hazard and survival functions, censoring, Kaplan-Meier estimation, graphical methods and proportional hazards models. Bootstrap and jackknife methods and their uses. Topics in time series analysis including: autocorrelation functions, stationarity, identification, estimation and forecasting with ARIMA models and spectra. Non-parametric density estimation including: kernels, cross validation, stationarity and the penalized maximum likelihood estimators. Discriminant analysis including: linear and quadratic discriminators, relation to regression and non-parametric approaches.

502.
Analysis of Categorical Data

Prerequisite: Statistics 426. I, II. (3 credits)

Models of contingency tables, including the Poisson, multinomial, and hypergeometric models; additive and log linear models for cell probabilities; estimation of parameters, exact and asymptotic sampling distributions, and sufficient statistics; tests of hypotheses, including likelihood ratio tests, chi-square tests, and Fisher's exact test; special topics, such as quantal response problems, incomplete tables, tests for trend, and/or measures of association.

503. Applied Multivariate Analysis

Prerequisite: Statistics 500 or permission. I. (3 credits)

Topics in applied multivariate analysis including Hotelling's T2, multivariate ANOVA, discriminant functions, factor analysis, principal components, canonical correlations, and cluster analysis. Selected topics from: maximum likelihood and Bayesian methods, robust estimation and survey sampling. Applications and data analysis using the computer will be stressed.

504. Seminar on Statistical Consulting

Prerequisite: Statistics 403 or 500. I, II. (1-4 credits)

Applications of statistics to problems in the sciences and social sciences; students will be expected to analyze data and write reports.

505. (Econ. 673) Econometric Analysis

Prerequisite: permission of instructor. (3 credits)

Theory and practice of hypothesis testing, statistical estimation, and the basic statistical theory underlying the linear model.

506. Statistical Computing

Prerequisites: Statistics 426 or Statistics 500 and Computer Science 380 or Computer Science 383 or permission of instructor. II. (3 credits)

Monte Carlo procedures, generation of random numbers, computation of estimators, linear and nonlinear problems, resampling algorithms, structural algorithms, splines, and other topics.

510. Mathematical Statistics I

Prerequisites: Math 450 or 451 and a course in probability or statistics, or permission. I. (3 credits)

Review or probability theory including: probability, conditioning, independence, random variables, standard distributions, exponential families, inequalities and central limit theorem. Introduction to decision theory including: models, parameter spaces, decision rules, risk functions, Bayes versus classical approaches, admissibility, minimax rules, likelihood functions and sufficiency. Estimation theory including unbiasedness, complete sufficient statistics, Lehmann-Scheffe and Rao-Blackwell theorems, and various types of estimators.

511. Mathematical Statistics II

Prerequisite: Statistics 510. II. (3 credits)

More on the theory of estimation including: minimax, Bayes and James-Stein estimators. The theory of hypothesis testing including: tests significance levels, power, the Neyman-Person lemma, uniformly most powerful unbiased tests, monotone likelihood ratios, locally best tests, similar tests, likelihood ratio tests and the associated large sample theory, sequential tests, goodness of fit tests, and tests in contingency tables. Other topics include: confidence regions, introduction to the general linear model, and non-parametric methods.

525. (Math 525) Probability

Prerequisite: Math 450 or 451 or permission of the instructor. I an II. (3 credits)

Axiomatic treatment of probability, with emphasis on discrete sample spaces. Sums of independent random variables, random walks, limit theorems; Markov chains and other stochastic processes. Carries one credit for students with credit for Statistics/Math. 425.

526. (Math. 526)
Discrete State Stochastic Processes

Prerequisite: Math. 525 or Statistics 510. (3 credits)

Review of discrete distributions; generating functions; compound distributions; renewal theorem; systems as Markov chains. Properties of Markov chains: Chapman-Kolmogorov equations; return and first passage times; classification of states and periodicity; absorption probabilities; forward equation; stationary distributions; backward equation; ergodicity; limit properties. Branching and queueing processes, examples from engineering, biological and social sciences; continuous time Markov chains; embedded chains; the M/G/1 queue; Markovian decision processes; inventory problems.

531.
Statistical Analysis of Time Series

Prerequisite: Statistics 426. I and II. (3 credits)

Decomposition of series; trends and regression as a special case of time series; cyclic components; smoothing techniques; the variate difference method; representations including spectrogram, periodogram, etc.; stochastic difference equations, autoregressive schemes, moving averages; large sample inference and prediction; covariance structure and spectral densities; hypothesis testing and estimation; applications, and other topics.

550.
(Statistics & Mgt. Sci. 603) (I.&O.E. 560)
Bayesian Decision Analysis

Prerequisite: Statistics 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 land hypothesis tests; applications to a variety of decision-making situations.

551.
Bayesian Inference

Prerequisite: Statistics 550. II. (3 credits)

Foundations; likelihood principle, non-informative stopping; sequential analysis; choice of priors; stable estimation; conjugate priors; invariance; estimation; credible intervals; hypothesis testing, the Lindley-Jeffreys paradox, the meaning of significance levels; unidentifiability; Behrens-Fisher problem; regression and multivariate problems.

552.
Sequential Analysis and Design

Prerequisite: Statistics 426 or equivalent. I, II. (3 credits)

Models for sequential sampling and sequential design; potential advantages and disadvantages of sequential methods, including their increased efficiency, ethical considerations and the effect on significance levels; the insensitivity of the likelihood function and posterior distributions to sequential sampling; fixed width confidence intervals; the Robbins Munro and related processes; some common sequential tests, including the sequential probability ratio test and restricted sequential procedures; decision theoretic formulation of sequential problems; Bayesian solutions of sequential problems by dynamic programming; applications to quality control and clinical trial; special topics.

560. (Biostatistics 685) Introduction to Non-parametric Statistics

Prerequisites: Statistics 511 and permission of the instructor. I and II. (3 credits)

Confidence intervals and tests for quantiles, tolerance regions and coverages; estimation by U statistics and linear combination of order statistics; large sample theory for U statistics and order statistics; the sample distribution and its uses including goodness-of-fit tests; rank and permutation tests for several hypotheses including a discussion of locally most powerful rank and permutation tests; large sample and asymptotic efficiency for selected tests.

570. Experimental Design

Prerequisites: Statistics 426 and basic knowledge of matrix theory or permission of the instructor. I and II. (3 credits)

The course will cover the basic topics and ideas in the design of experiments. That is, randomization and randomization tests, the validity and analysis of randomized experiments, randomized blocks, Latin and Graeco-Latin squares, and plot techniques; factorial experiments, the use of confounding, single and fractional replications, and other types of factorial arrangements; topics in split plot experiments, split plot confounding and response surface methodology; weighing designs, lattice and incomplete block and partially balanced incomplete block designs.

575. (Econ. 775) Econometric Theory

Prerequisite: Statistics 425, Math 417; or Economics 673 and 653 or equivalent. (3 credits)

A course in econometric theory stressing the statistical foundation of the general linear model. The course involves a development of the required theory in mathematical statistics and of derivations and proofs of main results associated with statistical inference in the general linear model.

576. (Econ. 776) Econometric Theory

Prerequisite: Economics 775 or the equivalent. II. (3 credits)

Generalized least squares, multivariate multiple regression, simultaneous equation models (including problems of identification, estimation by equation and system methods, and forecasting), introduction to asymptotic theory, estimation problems in time series models.

580. Theory of Sampling

Prerequisites: Statistics 426 and permission of instructor., II. (3 credits)

Mathematical foundations of sampling finite populations. Simple random sampling; stratification; ratio and regression estimates; systematic sampling, subsampling; cost functions and choice of optimal designs, estimation procedures.

581. Topics in Nonparametric Modeling

Prerequisites: Statistics 510, 511 or permission. I or II. (3 credits)

This course introduces computer-intensive nonparametric statistical methodology. Topics to be covered include: density estimation (incorporating such topics as kernel density estimates, nearest neighbor methods, variable kernel methods, orthogonal series estimates, maximum penalized likelihood estimates, bandwidth choice), nonparametric regression (incorporating kernel methods, spline methods, penalized likelihood, bandwidth choice, generalized additive models), and bootstrapping.

600, 601.
Advanced Topics in Applied Statistics, I and II

Prerequisite: Statistics 501 or permission. 600, I; 601, II. (3 credits each)

Advanced topics in applied statistics, such as cluster analysis, analysis of qualitative data, ranking and selection methods, sequential methods, etc. The course will study one or two advanced topics in detail with case studies.

610, 611.
Mathematical Statistics, I and II

Prerequisite: Math. 601 and 625. 610, I; 611, II. (3 credits each)

Decision theory, including: an introduction to subjective probability and utility, and finite decision problems, Bayes and minimax procedures, admissibility and completeness, exponential families, and the role of sufficiency. Point and interval estimation, including unbiasedness, invariance, large sample theory, maximum likelihood, Bayes, and empirical Bayes methods, and multiple comparisons. Hypothesis testing, including power, uniformly most powerful tests, Bayes tests, best invariant tests, best unbiased test, likelihood ratio tests. Special topics.

620.
Theory of Probability I

Prerequisite: Math 451 or the equivalent. I. (3 credits)

The course covers the basics of probability at an advanced level. Specific topics will include the following: Discrete probability spaces, the weak law of large numbers, the DeMoivre-Laplace theorems, classes of sets, algebras, measures, extension of measures, countable additivity and Lebesque and product measures. Also: measurable functions, random variables, conditional probability, independence, the Borel-Cantelli lemmas and the zero-one law. The course will additionally cover: integration, convergence theorems, inequalities, Fubini's theorem, the Radon Nikodym theorem, distribution functions, expectations and the strong law of large numbers.

621.
Theory of Probability II

Prerequisite: Statistics 620. II. (3 credits)

The course is a continuation of Statistics 620. The topics covered will include: weak convergence, characteristic functions, inversion, unicity and continuity, the central limit theorem for sequences, extensions to higher dimensions, and the Cramer-Wold theorem. Also: the renewal theorem, conditional probability and expectation, regular conditional distributions, the Ergodic theorem, martingales, and the optional stopping theorem. The course will also cover: the Poisson process, Brownian motion, the strong Markov property and the invariance principle.

625, 626.
(Math. 625, 626)
Probability and Random Processes I and II

Prerequisite: Math 601 for I; Statistics 624 for II. (3 credits each)

Advanced introduction assuming knowledge of measure theory. Conditional expectation, characteristic functions, stochastic processes, limit theorems, selected topics.

630.
Topics in Applied Probability

Prerequisite: Statistics 526 or Math. 626. I. (3 credits)

Advanced topics in applied probability, such as queueing theory, inventory problems, branching processes, stochastic difference and differential equations, etc. The course will study one or two advanced topics in detail rather than attempting to study several in a (necessarily) superficial manner.

Technical Communication

(Division 291)

Department Office
111 Technical Information Design and Analysis (TIDAL) Laboratory
(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.,
Assistant Dean for Continuing Engineering Education

Associate Professor

David E. Kieras, Ph.D.
Peter R. Klaver, Ph.D.

Lecturer

Marthalee S. Barton, Ph.D.
Rodney C. Johnson, Ph.D.
Fred C. Ward, Jr., M.S.

Professor Emeritus

Webster E. Britton, Ph.D.
Thomas M. Sawyer, Ph.D.

Usually, Engineering College students 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 advisers and technical communication or humanities faculty representatives, may prescribe additional study.

The following courses provide senior 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: 486, 492, or 498.

400.
Technical Information and Communication Resources
I and 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 and 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 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.
Visual 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. I and II. (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 and 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)

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.

Directed Study Courses in Technical Communication

Prerequisite: permission of Technical Communication faculty. (elective credit only).

Conferences and tutorial sessions that provide opportunities for students with special interests to work on a tutorial basis with a member of the Technical Communication faculty. 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 and 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 and 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

Prerequisite: graduate standing and permission of instructor. I, II, IIIa and 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.

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.

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 which 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 499 and permission of instructor. I, II, IIIa and 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 and II. (1-3 credits)

Intended for American and foreign students writing their dissertations, dissertation proposals, or theses. Writing guidelines and their scientific base for problem definition and literature review; argument structures for the discussion of problems, criteria, methodology, results, and conclusions; selection and ordering of information; editing visual aids; and special grammatical problems.

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 and II. (To be arranged)

Study of selected topics. May be taken for 1-4 credit hours as arranged by the instructor.

501.
Selected Topics

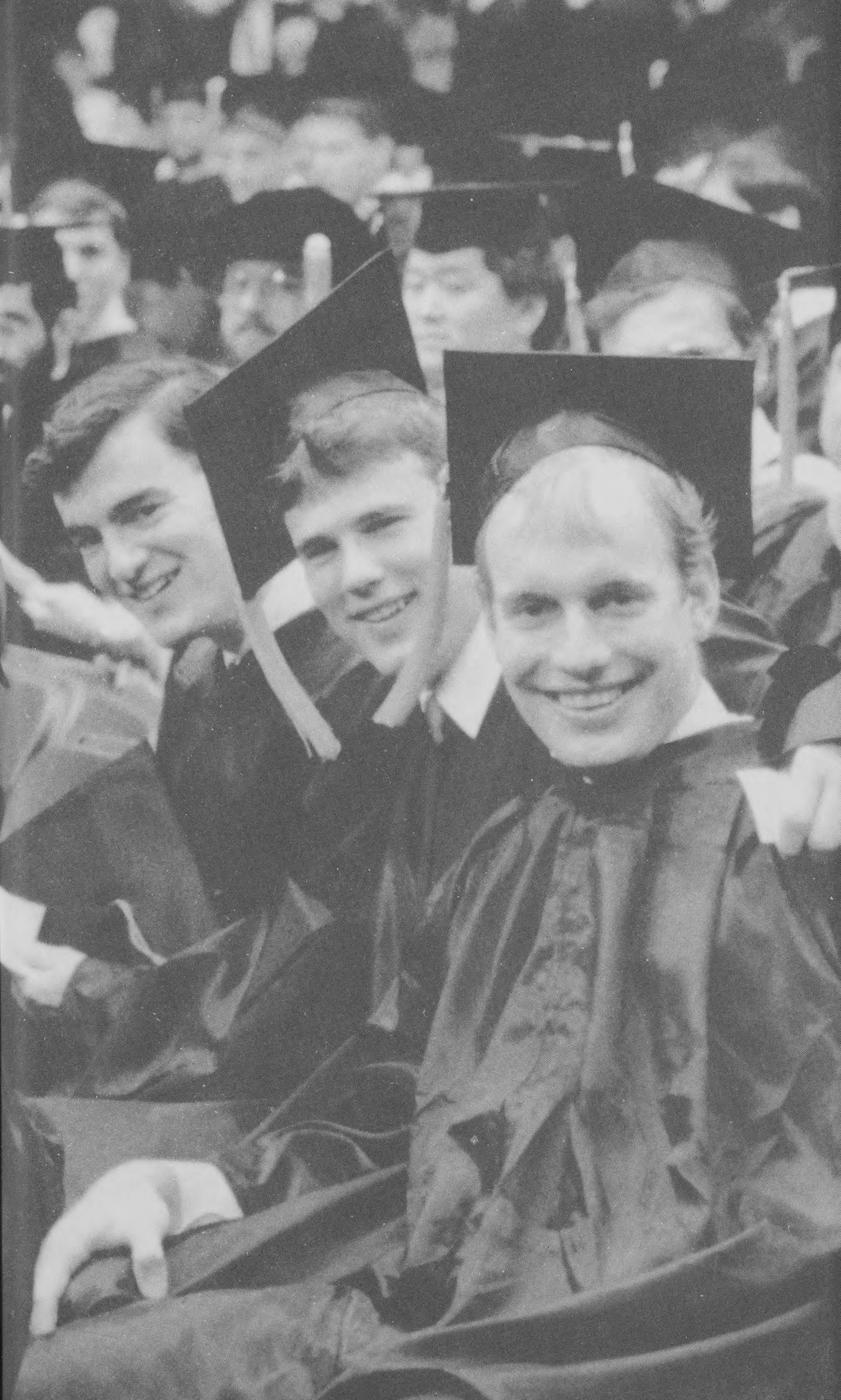
Prerequisite: graduate standing. (To be arranged)

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.



Committees of the College

Executive Committee

Dean P.M. Banks, Chair
G. Knoll
A. Nagy
S. Pollock
A. Schultz

Committee on Combined Degrees

with the College of Literature, Science, and the Arts
G. Smith, Chair
J. Wilkes

Committee on Curriculum

C. Pierre, Chair
M. Brake
J. Miller
K. Powell
P. Savage
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Committee on Discipline

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J. Linderman
J. Stein

Committee on Faculty Rules

R. Carr, Chair
E. Kannatey-Asibu
P. Roe

Committee on Freshman Counseling

G.E. Smith, Chair
T. England
J. Meyer
A. Yagle

Committee on Program Counseling

G.E. Smith, Chair
all undergraduate program advisors

Committee on Scholarships and Loans

S.J. Wright, Chair
W. Monroe Keyserling
P. Klaver
D. Pavlidis
J. Taylor
D. Wehe

Committee on Scholastic Standing

W.H. Yang, Chair
T. Birdsall
R. Curl
S. Jacobs
D. Martin
L. McAfee
A. Perakis
K. Powell
R. Saigal
D. Wehe
A. Yee

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The University of Michigan College of Engineering

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