UNIVERSITY of MINNESOTA BULLETIN 1975 1977

APRIL 30, 1975

Institute of Technology

UNIVERSITY OF MINNESOTA

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Institute of Technology

UNIVERSITY OF MINNESOTA

To New and Prospective IT Students. . .

The Institute of Technology includes the general areas of architecture, physical science, mathematics, and engineering. This broad spectrum under a single administrative umbrella is virtually unique in American universities, and students are thereby afforded an unusual opportunity for study in a wide spectrum of related fields.

Science and technology, we believe, offer unusual opportunities to motivated men and women. People seeking cures for many of the ills of society, such as urban blight, inadequate transportation, shortage of energy sources, and pollution of the environment, will need help and advice from those with a broad technical education. At the present time, many students and faculty members in IT are working on socially oriented programs such as the experimental city, development of solar energy sources, personalized rapid transit development, solid waste disposal, and studies of air and water pollution, to name only a few. In many cases these programs offer work experience as well as more formal classroom contact by means of topical courses, seminars, or talks. The problems to be solved are large, but the potential for contribution from IT graduates is great.

In IT you will be joining a group of motivated, talented men and women who have the common goal of obtaining a high quality education. The programs of study which are available to IT students have recently been restructured in order to provide a high degree of flexibility so that an individual may tailor a program to fit his or her special interests. Each student has a faculty adviser to help in the development of an academic program which is responsive to the student's personal interests and fulfills the requirements of both IT and the various accrediting agencies. These faculty advisers are helped and their work supplemented by advising and counseling services in the Office of the Dean.

The interests and fields of activity of recent IT graduates are diverse. IT has prepared a booklet, Careers in Engineering and Science, *which provides case studies of the present professional activities of 16 recent graduates. If you would be interested in receiving a copy of this informative booklet, please inform me and I shall send you a copy.*

Richard A. Swalin
Dean, Institute of Technology

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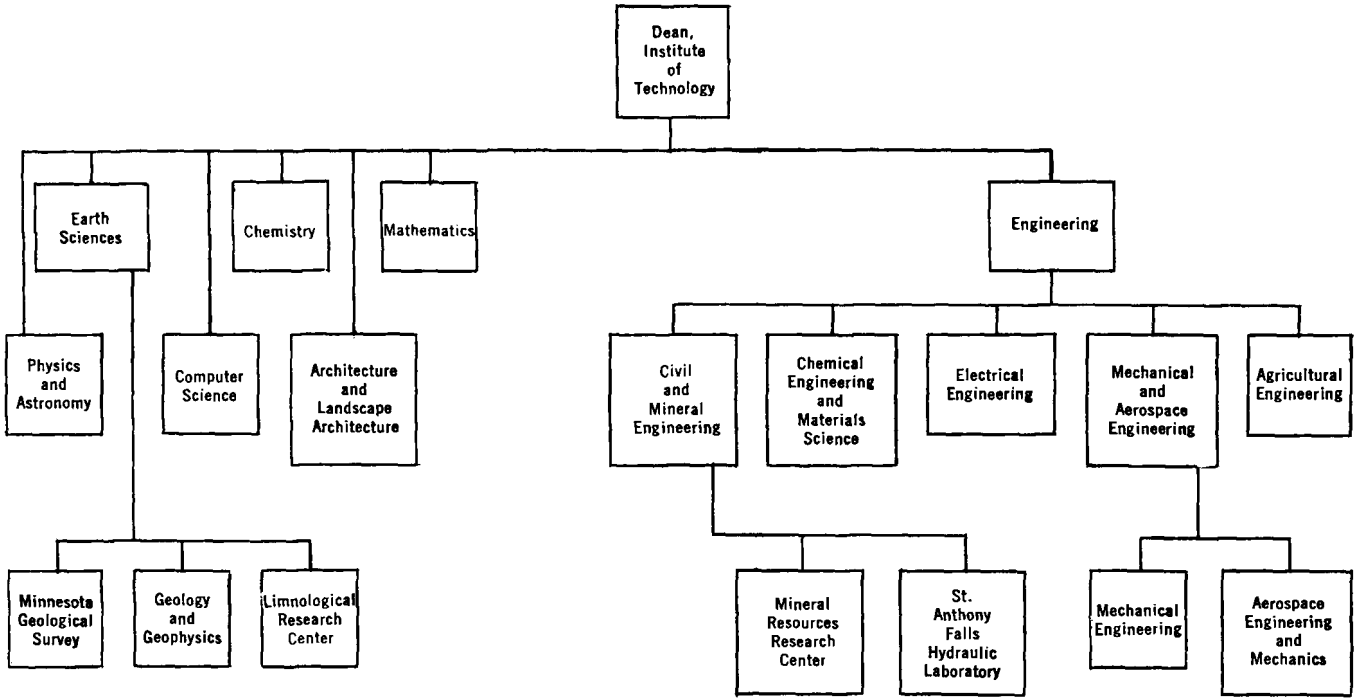
OF THE
INSTITUTE OF TECHNOLOGY



Institute of Technology

I. GENERAL INFORMATION

Degrees Offered

The Institute of Technology awards both undergrduate and graduate degrees. Bachelor's degrees are offered in architecture and landscape architecture, various branches of science, and major engineering fields. The specific undergraduate degrees are:

Bachelor of Architecture
Bachelor of Landscape Architecture
Bachelor of Environmental Design
Bachelor of Chemistry
Bachelor of Computer Science
Bachelor of Science in Geology
Bachelor of Science in Geophysics
Bachelor of Mathematics
Bachelor of Physics
Bachelor of Aerospace Engineering and Mechanics
Bachelor of Agricultural Engineering
Bachelor of Chemical Engineering
Bachelor of Civil Engineering
Bachelor of Electrical Engineering
Bachelor of Geo-Engineering
Bachelor of Mechanical Engineering
Bachelor of Metallurgical Engineering
Bachelor of Mineral Engineering

On the graduate level, IT offers a program leading to the master of engineering (M.E.) degree in any of the engineering curricula. This program provides advanced preparation in specialized design work for recent graduates in engineering as well as for working engineers who wish to improve their technical capabilities.

The objectives of the M.E. program are completely different from those of the research-oriented M.S. program. Design study leading to the M.E. degree focuses upon applying knowledge of engineering, physical, and social sciences to adapt materials and sources of power for human uses.

The curriculum, one calendar year long, includes up to six courses of a design nature plus several courses in a minor field (related to the student's undergraduate specialty) such as busines, economics, statistics, geography, political science, etc. In addition, students complete a design project equivalent to 4 or 5 months' total effort under faculty supervision and often with the assistance of a working engineer.

Applicants are considered according to the following criteria:

—Interest in and aptitude for creative, design-oriented programs, as shown by performance in relevant undergraduate courses.

—Industrial design work, including technical reports and reports on undergraduate projects.

—An undergraduate GPA of 2.50 or better, with greatest consideration given to upper division work.

Students who do not meet the above criteria may also be considered, upon recommendations from faculty or practicing engineers. Prospective students should contact the departmental office in their area of specialization for more information and necessary forms.

Special Programs

Interdisciplinary Programs—Any IT student may plan an interdisciplinary program tailored to his or her specific interests. Although only one department confers the degree, students may combine course work from several departments. Here are a few examples of such programs:

Acoustics—Noise, its sources, its abatement, and its environmental impact are considered.

Bioengineering—Study in biology, physiology, and chemistry, along with related engineering courses and project work provides background for this field.

Business Minor—Qualified students, after having earned the Bachelor's degree in engineering and having taken electives such as accounting, economics, management, etc., may enter the Graduate School of Business Administration to earn the Master's degree in business administration.

Environmental Engineering—Topics such as air and noise pollution, solid waste disposal, water resources and quality, and environmental design are studied.

Nuclear Engineering—This field combines upper division course work in mechanical and chemical engineering with physics.

Transportation—Project work includes system planning, vehicle design, personalized rapid transit, community impact studies, and other related problems.

Numerous other interdisciplinary programs are possible. Students should contact their departmental office or visit 105 Main Engineering for more information.

Engineering Internships—Applied engineering training is available during alternate quarters of work experience in selected industries. Students are registered and considered to be in full-time attendance during the work periods. Internships are usually completed during the last 2 years of study. Application to an internship program must be made before January 1 of the sophomore year. Students should contact the departmental office for more information.

Premedical Programs—Because there is no prescribed premedical major, some students plan their IT programs as preparation for medical school. The three Minnesota medical schools, in Duluth, Minneapolis, and Rochester, give strong preference to applicants who are state residents.

The Admissions Committee for the Minneapolis Campus Medical School has approved the following courses to fulfill its premedical requirements:

Biol 1011 plus 5 cr in biology, zoology, or genetics (10 cr)

Chem 1004-1005 or 1031-1032, 3100, 3101, 3301, 3302 or 1034, 3034, 3201, 5126 (25 cr)

Engl 1001-1002, Comm 1001-1002, literature, or humanities (12 cr)

Math 1211, 1221—mathematics through calculus (10 cr)

Phys 1271-1275-1281-1285-1291-1295 (15 cr)

plus at least 27 cr graded A-N in humanities, social science, foreign language, or other liberal arts areas (literature and humanities recommended)

Students considering career work in medical research or academic medicine should choose electives in these fields beyond the basic requirements listed above. Although reading knowledge of a foreign language is not an admission requirement, it is recommended for students interested in medical research or postdoctoral study in medicine.

Following is a list of faculty members who will assist students in planning premedical programs in the IT departments identified and in applying to medical schools:

Prof. R. Forstrom (154 Mechanical Engineering): Mechanical Engineering

Prof. R. Hobbie (233 Physics): Computer, Information, and Control Sciences, Geology, Geophysics, Mathematics, Physics

Prof. K. Keller (151r Chemical Engineering): Chemical Engineering, Chemistry

Prof. T. A. Wilson (107 Aeronautical Engineering): Aeronautics, Agricultural Engineering, Architecture, Civil Engineering

Prof. F. Waltz (257 Electrical Engineering): Electrical Engineering

The Pre-Health Science Library, 30 Johnston Hall, contains bulletins for all U. S. and Canadian medical schools and other sources of career information about medical and paramedical fields.

For details about application procedures, students should consult the premedical adviser for their IT department.

Reserve Officers' Training Corps—Qualified men and women students may combine work toward an IT degree with participation in an ROTC program. The Departments of Military Science (Army ROTC), Naval Science (Navy/Marine ROTC), and Aerospace Studies (Air Force ROTC) each offer 2- and 4-year programs. Participating students earn elective credits, and those who complete one of the training programs qualify for a commission as an officer in one of the four military services. The ROTC curricula are designed to provide instruction and practice in leadership skills as well as in military subjects. Scholarships providing up to 4 years of subsidized education are available also.

Students interested in the specific qualifications, curriculum, benefits, and obligations of each ROTC program should consult the *Army, Navy, Air Force ROTC Bulletin*. Inquiries may also be made at the following offices in the University Armory on the Minneapolis Campus: Military Science, room 108, phone 373-2212; Naval Science, room 203, phone 373-2230; and Aerospace Studies, room 3, phone 373-2205.

Continuing Education

To enhance their professional competence, practicing engineers and scientists must regularly acquire new knowledge—both of basic science and of technology—in fields beyond their undergraduate area of specialization. Although on-the-job experience, technical reading, and attending professional

meetings are readily available opportunities for continuing one's education, University resources offer an additional dimension that augments these opportunities.

Because of the interest of members of the technical community in postgraduate course work, IT and the Division of Continuing Education and Extension jointly established the Office of Continuing Education in Engineering and Science. This office surveys the needs of technical specialists and responds to them by arranging quarter-length courses, special conferences, short courses, and workshops.

This office maintains an *Engineers Information Registry* which lists names of professionals and their company, job classification, and areas of interest for further study. The registry, along with input from advisory committees, companies, and professional societies, is used to determine what areas of study would be most beneficial to practicing engineers. It also identifies locations outside the metropolitan area where courses might be given.

Professional Development Recognition Program—This is a joint program of the Institute of Technology and Continuing Education and Extension for engineers and scientists who have already earned a Bachelor's degree and who wish to pursue a personalized program of continuing professional education. Participants prepare a statement of specific educational objectives related to their professional goals and then meet with an IT faculty member to plan a program that will meet these objectives. Upon completion of the program, PDR participants receive a citation which states their self-chosen objectives and steps taken to achieve them.

The minimum number of credits required to complete a PDR program is 18. Up to 50 percent of this total may be devoted to external work such as in-plant company programs and conferences and seminars offered by other institutions. For an expenditure of about 10 hours per week, a PDR program normally requires 2 calendar years to complete.

Because professional development is a lifelong process, it is hoped that those in technical careers will pursue a series of PDR programs.

Unite Instructional Television—Approximately 20 courses are offered each quarter through UNITE (UNiversity-Industry Television for Education), an instructional television system for in-plant continuing education. These include regular upper division and graduate courses as well as specially developed courses and seminars. Classes originate in specially equipped studio classrooms with on-campus students present. The system is interactive, i.e., students at all sites talk to the classroom instructor and participate in class discussion. Each participating company helps support the system through a special fee based on the number of credit hours for which its employees are enrolled. This surcharge is separate from tuition which is paid by the student or by the company, depending on individual company policy. The growing list of participating organizations includes Honeywell, Inc., IBM Corporation, 3M Company, Northern States Power Company, Sperry Univac, U.S. Bureau of Mines, Donaldson Company, and Thermo King.

For further information about continuing education for engineers and scientists, contact the Director, Continuing Education in Engineering and Science, 11 Mines and Metallurgy, phone: (612) 373-3132.

Admission Information

Equal Opportunity—The Board of Regents has committed itself and the University of Minnesota to the policy that there shall be no discrimination in

the treatment of persons because of race, creed, color, sex, or national origin. This is a guiding policy in the admission of students in all colleges and in their academic pursuits. It is also to be a governing principle in University-owned and University-approved housing, in food services, student unions, extracurricular activities, and all other student and staff services. This policy must also be adhered to in the employment of students either by the University or by outsiders through the University and in the employment of faculty and civil service staff.

Project Technology Power—In our increasingly technological society, not all the groups actually and potentially affected by changes are involved in the decision-making and production stages of those changes. In particular, only 1 percent of engineers are members of minority or low-income groups, yet almost 13 percent of the nation's population belongs to those groups.

In order to correct this imbalance, IT is making a vigorous effort to attract and train more minority and low-income students through recruitment and retention programs collectively called Project Technology Power. Academic aids for IT students served by this program include special tutorial assistance, dormitory residence scholarships, and, when possible, part-time employment in a technological environment. The project also runs motivational programs for inner-city secondary school students, in which all IT students are invited to serve.

For More Information—Detailed admission criteria and information about University-wide application procedures are available in the *General Information Bulletin*. Students should consult that bulletin in their school's counseling office or may request their own copy from the Service Bureau, B-3 Morrill Hall.

Advisers—Any student who wants to discuss his/her individual admission situation is welcome to do so by arranging an interview through the Office of the Assistant Dean, 105 Main Engineering. Students should bring transcripts of high school and college work, test results, and any other pertinent information.

Early Admission—Outstanding high school students who have not yet graduated may be admitted to the University, usually after the junior year. Such students must be sufficiently mature to adjust to University life and work. Personal interviews, comprehensive testing, and letters of recommendation from the high school principal or counselor and the parents are required. Fall quarter applicants should apply during the preceding winter or spring. A student admitted under this plan normally would not receive a high school diploma.

Admission as a Freshman—In order to be admitted as a freshman to IT, the student must complete courses in high school mathematics, including beginning and intermediate algebra, geometry of two and three dimensions, and trigonometry. Physics and chemistry are highly recommended also.

In addition, admission to IT is based on high school rank and a combination of either the mathematics and natural science scores of the American College Testing Program (ACT), the mathematics score on the Preliminary Scholastic Aptitude Test (PSAT), or the mathematics and verbal scores on the Scholastic Aptitude Test (SAT).

Admission with Advanced Standing—Students transferring from other accredited colleges or universities may enter IT with advanced standing—that is, IT accepts credits earned for appropriate courses satisfactorily completed elsewhere. However, students with less than 1 year of advanced work must meet regular freshman admission requirements.

Transfer students should apply and submit transcripts to the Office of Admissions and Records more than a month before the beginning of the quarter they wish to enter. July 15 is the deadline for fall quarter. Transcripts must include all college work attempted, whether satisfactorily completed or not, all extension and independent study courses, as well as any previous work at the University of Minnesota.

Admission as an Adult Special—Persons interested in individual courses or groups of courses to meet their own needs, rather than in a degree program, may be admitted as "adult special" students to individual IT departments. Applicants are usually required to have already earned the Bachelor's degree. Although adult special students are not considered degree candidates, they may subsequently begin degree work when recommended by the department in which they have studied. In this case, credit earned as an adult special is accepted as degree credit when possible.

Students seeking admission under adult special status should apply and submit transcripts of all college work to the Office of Admissions and Records well in advance of the quarter they wish to begin. Restrictions on admission of nonresident undergraduate students apply also to adult special students. Once accepted, adult special students complete a One-Year Plan with a departmental adviser.

Financial Aids

The University offers financial aid to undergraduates in three general categories: scholarships and grants, student loans, and college work-study. A student employment service is also available. These options are fully described in the *General Information Bulletin.* Students should consult this bulletin in their school's counseling office or may obtain the information from the Office of Student Financial Aid, 107 Armory.

Various IT research facilities offer research and part-time job opportunities for qualified undergraduate and graduate students. Because a complete listing of facilities and positions is not possible, students should contact individual departments for more information.

Scholarships restricted to IT students are listed below, under individual department and "all departments" headings. Unless otherwise noted, one award is made each year. Students should read the Official Daily Bulletin the first week of winter quarter each year for application information. Applications received by March 1 are given priority consideration.

ALL DEPARTMENTS

Alcoa Foundation Scholarships: For engineering undergraduates who have shown exceptional promise. Preference given to students majoring in electrical, mechanical, and metallurgical engineering. Four $750 awards.

Boeing Company Scholarships: For aeronautical, electrical, mechanical, and civil engineering students for use in the third year (may be renewed for fourth-year undergraduates). Three $500 awards annually.

J. Miller Brown Scholarship: Awarded annually to one of the five top students of the freshman class based upon merit without regard to financial need. Amount is tuition for 1 quarter.

IT Alumni Association Scholarship: For undergraduates in any department of the Institute of Technology. Amount is $200-400.

Minneapolis-Honeywell Award in Engineering and Science: For distinguished performance of third- and fourth-year students in engineering and science. Amount is $250-300.

Minnegasco Engineering Scholarship: To aid and encourage students in engineering, especially chemical and mechanical. Qualified transfer students and students with advanced standing are eligible. Usually covers tuition for at least 1 quarter.

Otto John Pfeifer Scholarship: To an IT student who has completed at least 1 year in engineering studies.

Harlow C. Richardson Scholarship: For undergraduates in the Institute of Technology who have demonstrated interest in the humanities. Amount minimum is tuition and student services fee. Six or more awards annually.

Sigma Xi Scholarship (Minnesota Chapter, University of Minnesota): For an undergraduate with aptitude and proficiency in some field of scientific endeavor. Amount is $500.

Sundstrand Foundation Scholarship Fund: For students in mechanical engineering, electrical engineering, metallurgical engineering, industrial engineering, or any other technical curricula approved by the board of directors of the Sundstrand Foundation. A scholarship awarded to a freshman shall be renewable for 3 additional years.

Nellie S. Trufant Memorial Scholarship in Engineering: For the use of any qualified student in the Institute of Technology in his third or fourth year.

Twin Lakes Auxiliary M.S.P.E. Scholarship Fund: An initial gift of $100 from the Minnesota Society of Professional Engineers Twin Lakes Chapter Auxiliary established a scholarship fund to provide assistance to a promising engineering student with preference to women.

AEROSPACE ENGINEERING AND MECHANICS

Aero-Alumni Scholarship: For students majoring in aerospace engineering and mechanics. Amount is tuition and fees.

Irvin M. Nestigen Memorial Loan Fund: Loans may be made to aerospace engineering students without interest until graduation, and at 3 percent thereafter.

Rosemount Engineering Company Instrumentation Award: To the graduate or undergraduate student in aerospace engineering and mechanics or mechanical engineering judged by the departments to have the greatest potential for the design and development of industrial aircraft and/or space instrumentation. Award is $400.

AGRICULTURAL ENGINEERING

William Boss Agricultural Engineering Scholarship (Specialty Manufacturing Company, St. Paul): For an entering freshman in agricultural engineering. Amount is $500.

Farmhand Agricultural Engineering Scholarship: For an entering freshman or undergraduate in agricultural engineering. Amount is $300.

Minnesota Concrete Drain Tile Manufacturers' Association Scholarship: For a student in agricultural engineering or mechanized agriculture with preference given to freshmen. Amount is $300.

Northern States Power Company Agricultural Engineering Scholarship: For an entering freshman or undergraduate in agricultural engineering. Amount is $300.

Northwest Farm Equipment Association Agricultural Engineering Scholarship: For academically qualified students in the College of Agriculture or the Institute of Technology. Amount is $300.

Other: Students enrolling in agricultural engineering should inquire through the department for information about scholarships administered under the jurisdiction of the St. Paul Campus Scholarship Committee.

ARCHITECTURE

American Institute of Architects and American Institute of Architects Foundation, Inc., Scholarship Program: For undergraduate and graduate students in architecture.

Flour City Architectural Education Fund (Flour City Architectural Metals Division, Hupp Corporation, Minneapolis): For educational programs and scholarship aid for architecture students. Amount varies.

Horty, Elving Architectural Fund: For educational programs and scholarship aid for architecture students. Amount varies.

Roy Childs Jones Architectural Education Fund: For advanced students in architecture. Amount varies.

Minneapolis Gas Company Total Energy Fund: For student who designs, in competition with other students, the best project which would be heated, cooled, and powered via gas total energy. Amount is $250.

Minnesota Society of Architects Scholarship Fund: For students in the School of Architecture and Landscape Architecture. Amount varies.

Northern States Power Scholarship: For undergraduates with advanced standing in architecture. Amount is $250.

Ochs Brick and Tile Company Prize in Architecture: For educational programs and scholarship aid for architecture students. Amount varies.

Betty Poole Architectural Education Fund: For educational programs and scholarship aid to students enrolled in the School of Architecture and Landscape Architecture who show exceptional creative ability and financial need. Amount varies.

Ralph Rapson F.A.I.A. and Assoc. Architectural Education Fund: To aid deserving students with architectural ability, talent, and promise to carry on their professional studies, and to aid and contribute to the educational programs of the school. Amount varies.

Rhodes Robertson Educational Fund in Architecture: For educational programs and scholarship aid for architecture students. Amount varies.

Setter, Leach, and Lindstrom, Inc., Scholarship: For advanced students in architecture. Amount varies.

Alpha Rho Chi Medal: For architectural ability and student leadership.

American Institute of Architects Medal: For highest scholastic standing in graduating class during academic year.

CHEMICAL ENGINEERING AND MATERIALS SCIENCE

American Institute of Chemical Engineers Scholarship: To a chemical engineering student who is active in the A.I.Ch.E.

John P. Fridley Foundation Scholarship: For undergraduate students in chemical engineering.

Minnesota Mining and Manufacturing Company Scholarship: For one or more scholarships in chemical engineering. Amount is tuition plus student services fee.

Minnegasco Engineering Scholarship: To aid and encourage students in engineering, especially chemical and mechanical. Entering freshmen, qualified transfer students, and students with advanced standing are eligible. Usually covers tuition for at least 1 quarter.

Pillsbury Scholarship: One junior and one senior in chemical engineering. Amount is $500 each.

Standard Oil Company of California Scholarship: For an advanced student in chemical engineering. Amount is $750.

CHEMISTRY

Peteris Auzins Scholarship: To a promising physics or chemistry student.

I. M. Kolthoff Scholarship in Analytical Chemistry Fund

M. Cannon Sneed Memorial Scholarship in Chemistry: To provide assistance to students in the field of inorganic chemistry who demonstrate great promise for future achievement and who are in need.

John Torrence Tate Memorial Scholarship (memorial gifts from friends of the late Professor John T. Tate): For students with advanced standing in astronomy; chemisry, mathematics, or physics. Amount is $200-250. Two awards annually.

George T. Walker Fund: To aid deserving students in the Department of Chemistry. Amount varies.

CIVIL ENGINEERING

Minnesota Surveyors and Engineers Society Highway Engineering Scholarships: For undergraduates in civil engineering with emphasis on highway engineering. Students must be enrolled in the Institute of Technology. Students may apply to Personnel Office, State Highway Department, for summer employment. Amount is $400-600.

Adolph A. Sommerfeld Scholarship Fund in Civil Engineering: For students planning to major in civil engineering. Awarded on the basis of academic ability, professional promise, and financial need.

ELECTRICAL ENGINEERING

Litton Microwave Cooking Scholarships: One or more scholarships for Minnesota residents who are juniors or seniors in electrical or mechanical engineering with a grade point average of 3.00 or above, based on grades earned at the University of Minnesota.

Pillsbury Company Scholarships: For junior or senior students in mechanical or electrical engineering on the basis of academic ability and record, vocational promise, leadership potential, personal attributes, and financial need.

GEOLOGY AND GEOPHYSICS

Geology Service Fund: Special grants to students of the Department of Geology and Geophysics.

David K. Jensen Memorial Scholarship: To undergraduate students planning to continue with graduate work (or to graduate students) in geology or geophysics.

American Metal Climax Foundation: For fieldwork.

William A. King Fund: To assist undergraduate students in meeting the expenses of field camp or field-related studies.

Longyear Fellowship: Given in alternate years for undergraduate students.

MATHEMATICS

Dr. Halbert C. and Mrs. C. Christofferson Scholarship: To a promising student in mathematics.

John Torrence Tate Memorial Scholarship: See description under Chemistry scholarships.

MECHANICAL ENGINEERING

Adolph O. Lee Scholarship: To one or more needy mechanical or industrial engineering students.

Litton Microwave Cooking Scholarships: see description under Electrical Engineering scholarships.

Pillsbury Company Scholarships: See description under Electrical Engineering scholarships.

Rosemount Engineering Company Instrumentation Award: See description under Aerospace Engineering and Mechanics scholarships.

METALLURGY/MATERIALS SCIENCE

International Nickel Company Scholarship: For entering freshmen in engineering with preference to mineral, geological, and metallurgical engineering. Renewable annually. Amount is $300 plus tuition and fees.

MINERAL RESOURCES AND GEO-ENGINEERING

M. A. Hanna Company Scholarships: For Hanna Company employees, their sons and daughters, or their relatives who wish to attend the University on the Minneapolis Campus, or Michigan College of Technology, Houghton, Michigan. Preference given to those enrolled in mineral technology (mineral and metallurgical engineering), but other students in IT may also be eligible. Amount is $500. Entering students apply through their high school by January 1 each year; University students follow regular procedure. Two awards each year, renewable if student maintains at least a 2.80 grade point average.

Mineral Industry Education Fund Sponsored by the Minnesota Section, American Institute of Mining, Metallurgical, and Petroleum Engineers: For graduate and undergraduate students pursuing degrees in mineral and geological engineering. Grants from $500 to $1,500 per year. The Mineral Industry Education Fund includes the Cleveland-Cliffs Iron Company, E. J. Longyear Memorial, and Mesabi Tire Co., Inc., Scholarship.

PHYSICS

John Torrence Tate Memorial Scholarship: See description under Chemistry scholarships.

Student Services

Faculty Advisers—At the time of registration, each new IT student is assigned a faculty adviser from the department in which he/she seeks a degree.

During fall quarter, students consult with their advisers to plan their schedule for the rest of the year. During spring quarter, students meet again with their advisers to plan a program of studies for the following year. All students must have their adviser's approval of their program before they are allowed to register, as well as for any changes after registering. Students who wish to change advisers within the same department should go to their departmental office. (See index for Directory of Departmental Offices.)

Students undecided about a specific major in engineering or science are titled "IT Unclassified." Students in this category may include freshmen, new advanced standing students, transfers to IT from other collegiate units within the University, and students changing majors within IT. Unclassified students are assigned an adviser in the Central Advising Office, 104 Main Engineering. Thus, the Central Advising Office serves as the departmental office for unclassified students.

Faculty selected from various IT departments serve as advisers for unclassified students. They are available at regularly scheduled times to meet with students. In addition to helping students prepare their programs, advisers also provide special career counseling, including arranging visits to IT laboratories and local industries, and referrals to other faculty members.

IT Unclassified students follow first-year programs the same as those followed by IT students with declared majors. (A listing of the common elements in all IT lower division curricula is found on page 19.) Unclassified students are usually able to choose a major by the end of a year of study.

Two counselors are available to discuss questions about IT, choice of major, career plans, or any personal problems students may have. Counseling appointments are scheduled in 104 Main Engineering.

Tutoring Programs—To help all students perform to the best of their abilities, IT provides peer tutorial assistance for its students in chemistry, mathematics, physics, and other IT courses. Tutors are selected from junior and senior IT honor students who are willing and able to work with other students. Tutoring services are provided in various locations—on campus, in residence halls, and at selected metropolitan high schools.

Tutors are available during regular office hours Monday through Friday in 104 Main Engineering. Two or three tutors hold regularly scheduled hours, usually from 7 p.m. to 10 p.m. Sunday through Thursday, in Comstock, Frontier, Sanford, and Territorial Halls. Tutors staff several metropolitan high schools, including Coon Rapids, Edina East, Minneapolis Washburn, Mounds View, Robbinsdale, and St. Paul Johnson. The schedule in these locations is usually 7 p.m. to 9 p.m. on Tuesday and Wednesday.

In addition, graduate teaching assistants staff designated study rooms in the Departments of Chemistry; Computer, Information, and Control Sciences; Mathematics; and Physics. Teaching assistants help with course work taught by the department with which they are associated and are available during office hours, usually 9 a.m. to 4 p.m.

Inquiries about tutorial programs should be made to the Director of Lower Division Programs, 104 Main Engineering.

IT Placement Service—The Placement Service, located in 15 Experimental Engineering, is available to assist graduating seniors, advanced degree candidates, or alumni in career choices and career development.

A wide variety of companies, representing local, state, and national organizations, visit the Placement Office each year. The Placement Service schedules interviews and maintains a library of information on companies and government agencies who are prospective employers. Assistance is also available to undergraduate and graduate students seeking summer employment.

The Placement Service also coordinates and supplies information and applications for the Engineer In Training (EIT) Examinations.

Computer Facilities

Digital computers have become common working tools for most people in the areas of science and technology. In recognition of this, the Institute of Technology, in cooperation with the University Computer Service, has established a number of laboratories for student use. The laboratories are of two types. The time-sharing laboratories allow interactive computing, using a terminal to communicate with a central time-sharing computer system. The batch laboratories allow the student to submit a punched card deck containing program and data, which is transmitted to a general purpose batch computer. After the program has been executed, the output is returned and printed on a line printer at the laboratory where the job was submitted. Both types of laboratories are available to any IT student at any time during the working day and during evening and weekend hours, depending upon demand. These laboratories are used for class assignments or special projects under faculty supervision.

In addition to these general purpose computers, students have access to a large number of special purpose ones, ranging in size from small tabletop units for data reduction in laboratories to larger models reserved for special projects in computer sciences and electrical engineering.

While many entering students have learned programming and computer use in high school, it is usually at the elementary level (BASIC language). A series of graded courses which may be entered at different levels is offered in the freshmen year, both for those students and for those who have no prior training, by the Department of Computer, Information, and Control Sciences (CICS). These courses bring the student to the level of more sophisticated programming, using both the interactive and batch systems, and introduce other languages such as FORTRAN, Assembly Language, and SNOBOL. All students are thus prepared to use digital computers in their subsequent course work.

Although digital computers are the most widely used computational aid in engineering work, analog computers also are used for a number of applications. Each engineering department in IT has one or more analog computers for instructional use, in addition to those reserved for research projects. They are used for such diverse student projects as the investigation of aircraft, spacecraft, and rapid transit dynamics, transients in chemical process industry, flow-in hydraulic systems, and feedback control stability.

University Computer Services also administers a hybrid computer system, consisting of two EAI-680 analog computers interacting with a CDC 1700 digital system. While there are a number of applications of this system of interest to undergraduates, perhaps the most important is in the field of computer graphics. This enables the fledgling architect to see in animation on a special TV screen how the roof of this design shades the house at different seasons of the year. It lets civil engineering students examine the influence of new dams and channels on the flow patterns of a town, a county, or an entire state, using the same equipment. It is hoped that in the future, students will be able to use this or similar equipment to study graphics in its most general form.

The use of computers of all sizes and types is developing so rapidly that it is difficult to predict all applications even a few years ahead. It is the stated purpose of IT to make sure that all of its graduates have experience with enough different computers during their undergraduate education that they will be thoroughly familiar with their use on the job.

Student Activities

Architects, scientists, and engineers find that membership in technical or professional societies usually helps their career development. Many of these societies have student chapters at the University. Through them students have the opportunity to participate in activities of the parent society, to gain experience in the conduct of technical meetings, and to meet senior members of the societies. In addition, regular membership in the society is facilitated upon graduation, and any entrance fee is reduced or waived for former student members.

Professional Societies—Branches of the following national professional societies are maintained at the University of Minnesota by students and faculty members: American Chemical Society, American Institute of Chemical Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Physics, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society of Agricultural Engineers, American Institute of Aeronautics and Astronautics, and the Institute of Electrical and Electronic Engineers. Additional professional societies include the Architectural Society, the School of Mineral and Metallurgical Engineering Society, the University of Minnesota Flying Club, the Geology Club, and the Minnesota Society of Professional Engineers.

Honorary Scholastic Fraternities—The honorary scholastic fraternities in IT promote the high standards of the engineering profession by conferring memberships, awards, and other honors on undergraduates distinguished for scholastic achievement and for character. These fraternities normally elect members from the junior and senior classes, considering scholarship, as measured by class rank, and character, as judged by peers and faculty. Of these honorary fraternities, only Tau Beta Pi selects its members from students in all undergraduate departments of the Institute of Technology. The others confine their membership to students from a single department: Chi Epsilon (Civil Engineering), Eta Kappa Nu (Electrical Engineering), Phi Lambda Upsilon (Chemistry), Pi Tau Sigma (Mechanical Engneering), Sigma Gamma Tau (Aerospace Engineering and Mechanics).

Plumb Bob—Plumb Bob is a senior honorary leadership and service fraternity. Its 12 members serve during their senior year, but their names are not announced until Engineers' Day (IT Week). Plumb Bob works to create and maintain a spirit of fellowship and cooperation among the students of the Institute of Technology and to further the interests of the institute and the University. Its members are chosen for their character, leadership, and service by a committee composed of students and faculty.

IT Student Board—The IT Student Board is the executive body of the students in the Institute of Technology. The board enables the students to act as a unit in matters affecting the general interests of the institute and the University. The Student Board is responsible for general supervision of Engineers' Day (IT Week) and other student activities in the Institute of Technology.

***Technolog* and Technolog Board**—The *Technolog* is the undergraduate technical magazine of the Institute of Technology. The publication is produced by the students under the direction of an editorial and business staff selected by the student body. The policies of the magazine are determined by the Technolog Board. The Technolog Board selects the editor-in-chief and business manager and assists them in their work.

Professional Registration

Registration as an engineer is a legal requirement for certain kinds of practice. A professional license is a requirement before anyone may use the designation of engineer in any legal connection. There is an increasing interest in industry for engineers to be registered as an indication of professional competency, even though they have no legal obligation to be registered. Many engineers have obtained licenses to show their support for the concept of a legal recognition of the professional standing of the engineer. Many also obtain licenses because professional registration may be useful or required in future employment.

The license is awarded in most states to those graduates of an accredited engineering curriculum who have passed an examination in the fundamentals of engineering and who have demonstrated their competence by a number of years of appropriate experience. The examination covers materials studied in undergraduate curricula. For the convenience of students, this examination is given at the University in the spring of every year and may be taken by students in their senior year. Further information and application forms may be obtained from:

Executive Secretary
Minnesota State Board of Registration for Architects, Engineers, and Land Surveyors
1512 Pioneer Building
St. Paul, Minnesota 55101

II. CURRICULAR REQUIREMENTS

First-Year Programs

Lower division curricula are similar in many IT departments, because all degree programs require a solid foundation in chemistry, mathematics, and physics. For the benefit of freshmen, transfer students, and students changing majors, the common elements of first-year programs in all IT departments are listed below. IT Unclassified students usually follow the program for the department most closely related to their major interest.

Note that students majoring in chemistry, chemical engineering, and metallurgy/materials science, unlike majors in other IT departments, begin chemistry courses their freshman year.

Also, in fulfilling the mathematics requirements, all students have the option of taking either Math 1211-1221-1231 (Analysis I, II, III) or Math 1311-1321-1331 (Computer Calculus).

CORE A

Agricultural Engineering, Aerospace Engineering, Civil Engineering, Computer Science, Electrical Engineering, Geological Engineering, Geology, Geophysics, Mathematics, Mechanical Engineering, Mineral Engineering, Physics

	Credits—f,w,s		
Math 1211, 1221, 1231—Analysis I, II, III (or) Math 1311, 1321, 1331—Computer Calculus	5	5	5
Comp 1001, 1002—Introductory Composition (or) Comm 1001, 1002—Communications	4	4	..
Phys 1271, 1281—General Physics	..	4	4
Phys 1275, 1285—Physics Lab	..	1	1
Elective**	4-5	..	4-5
	13-14	14	14-15

CORE B

Chemical Engineering, Chemistry, Materials Science

	Credits—f,w,s		
Math 1211, 1221, 1231—Analysis I, II, III (or) Math 1311, 1321, 1331—Computer Calculus	5	5	5
Chem 1031, 1032, 1034—General Principles	5	5	5
Comp 1001, 1002—Introductory Composition (or) Comm 1001, 1002—Communications	4	4	..
Nontechnical Elective	..	..	4
	14	14	14

CORE C

Architecture, Environmental Design

	Credits—f,w,s		
Math 1211, 1221, 1231—Analysis I, II, III (or) Math 1311, 1321, 1331—Computer Analysis	5	5	5
Comp 1001, 1002—Introductory Composition (or) Comm 1001, 1002—Communications	4	4	..
Arch 1021, 1022, 1023—History of Environmental Development	4	4	4
Phys 1121, 1122—Physics for Architects	..	4	4
Nontechnical Elective	..	..	4
	13	18	18

CORE D

Landscape Architecture

See department curriculum.

**Elective may be in computer science, introduction to engineering, or a nontechnical elective.

Aerospace Engineering and Mechanics

Aerospace engineering is a pioneering field which encompasses many areas of science and engineering and plays a major role in the technological advancement of our society. The aerospace industry embraces not only the design and development of conventional aircraft and spacecraft but also such areas as the development of suitable vehicles for high-speed ground transportation, the design of hydrofoil ships, and the design of deep-diving vessels for oceanographic research.

An aerospace engineer is in a professional field which is constantly changing and which involves a wide diversity of problems. For this reason the aerospace engineer must have a broad fundamental education in mathematics, the physical sciences, and the engineering sciences. The 4-year program leading to the bachelor of aerospace engineering and mechanics (B.A.E.M.) is designed to accomplish this objective. The required technical courses are designed to provide the student with a firm basic knowledge of engineering science, aerodynamics, mechanics, and dynamical systems. The elective portion of the curriculum is extremely flexible and allows the student to build on the fundamental work and to concentrate his study in some depth in an area of special interest. The available options are varied, permitting students to prepare for careers in many different fields such as oceanography, meteorology, environmental engineering, transportation systems, or noise reduction engineering.

The department offers an optional engineering intern program in the upper division. This program provides practical work experience in industry in alternate quarters (including summer) during the last 2 years of study. The program is run in conjunction with the intern program of the Department of Mechanical Engineering as a program of the School of Mechanical and Aerospace Engineering, and prospective candidates should contact the director of the program for information.

The department is very actively involved in transportation studies, and students with an interest in the problems of urban and interurban transportation can participate in this special program. The program includes a carefully selected group of elective courses from various departments which prepare the student for some of the problems encountered in the transportation field, particularly in the application of new technologies to transportation.

Students interested in the problems arising from noise pollution and the possible solutions to these problems can select special courses in acoustics, offered by this and other departments, to form a coherent program with emphasis on acoustical engineering.

A recommended program for students majoring in aerospace engineering and mechanics is presented below. The suggested lower division courses provide the necessary fundamental background for the more sophisticated upper division courses. The student has great flexibility in arranging the upper division program.

LOWER DIVISION

	Credits
Comp 1001, 1002—Introductory Composition (or) Comm 1001, 1002—Communication	8
Liberal Education Electives	10
Math 1311, 1321, 1331—Computer Calculus (or) Math 1211, 1221, 1231—Analysis I, II, III	15
Math 3211, 3221—Analysis IV, V	10
Phys 1271, 1281, 1291—General Physics	12
Phys 1275, 1285, 1295—Physics Laboratory	3
Chem 1014—General Principles	4

EG 1026—Engineering Graphics 2
CICS 1100, 1101—Introduction: FORTRAN Programming
(or) CICS 3101—Introduction: FORTRAN Programming 4
EE 3000—Circuits 4
ME 3301—Thermodynamics 4
Phys 3501—Modern Physics 4
(or) Biol 1101—General Biology
(or) EBB 3101—Ecology
(or) Geol 1601—Oceanography
(or) Geol 5601—Limnology
(or) Phsl 3055—Principles of Physiology
(or) equivalent
AEM 1001, 1005, 1006—Aerospace Engineering Orientation and Survey 3
AEM 3016—Deformable Body Mechanics 4
AEM 3036—Dynamics 4
Total Credits 91

UPPER DIVISION

Credits

Liberal Education Electives 18

Required Technical Courses 42
AEM 3401—Introduction: Dynamical Systems (4)
AEM 5200, 5201, 5202—Fluid Mechanics I, II, III (12)
AEM 5206—Lifting Surfaces (4)
AEM 5300—Flight Mechanics (4)
AEM 5515—Aerospace Structures I (4)
AEM 5645, 5646—Laboratory I, II (6)
ME 5342, 3305—Heat Transfer, Propulsion (8)

Selected Required Technical Courses (select 3 of the 7 listed) 12
AEM 5319—Dynamic Stability of Aerospace Craft (4)
AEM 5330—Design I (4)
AEM 5435—Introduction: Random Vibrations (4)
AEM 5438—Intermediate Dynamics (4)
AEM 5580—Mechanics of Elastic Solids I (4)
EE 3001—Electronics (4)
MatS 3400—Mechanical Properties of Materials (4)

Technical Option 12
Technical elective courses to be selected from a coherent group of recommended courses for one of several options—see option program information in the departmental office.

Electives 10

Total Credits 92

Agricultural Engineering

Agricultural engineering is the application of engineering principles to food and fiber production, rural living, and management of our land and water resources. Agricultural engineers utilize their skills to increase production of crops and livestock, to improve the quality of agricultural products, to reduce the dependence of agriculture on human labor, and to use our soil, water, and energy resources wisely. These objectives are accomplished by developing and applying new and improved processes, machines, structures, and systems that not only achieve economic goals but also give full consideration to human and environmental factors.

Agricultural engineers serve not only the agricultural industry but also the general public, through their role in producing food efficiently and in protecting our soil and water resources. They provide an essential link between the science of agriculture, which is largely biological, and engineering, which

utilizes physical science to solve everyday problems. As world population moves ahead of world food production, the work of agricultural engineers becomes more and more important both at home and abroad.

The Agricultural Engineering curriculum can be completed in 4 years with a minimum of 183 credits. Emphasis is on the physical sciences and on engineering design. However, a general knowledge of biology, agricultural science, communications, social science, and the humanities is required as well, since the agricultural engineer must be able to communicate and work with various professional people. In total, the program provides a fundamental background for continued professional growth and an ability to contribute to the needs of an ever-changing society.

Each student, with the assistance of an adviser, plans a curriculum tailored to his or her individual interests. The principal fields of specialization within Agricultural Engineering are: design of agricultural power and machinery, soil management and water control, building design and environmental control, food engineering, and agricultural waste management. In addition, students select special courses from a number of other subject areas to give them a broad background in other topics related to their specialization.

An engineering intern program, providing practical training and experience with an employer in addition to the formalized training, is available to a limited number of students. Students may begin their work assignments in industry in the summer following either the first or the second year. Transfer students can be accommodated in this program also.

The first 2 years of the program provide the background necessary to enable the student to master the material offered in the junior and senior years. They also provide a portion of the general education experience essential to an engineering education.

GENERAL PROGRAM REQUIREMENTS

	Credits
Mathematics	
Math 1211, 1221, 1231—Analysis I, II, III	15
Math 3211, 3221—Analysis IV, Linear Algebra and Differential Equations	10
Physical Sciences	
Phys 1271, 1281, 1291—General Physics	12
Phys 1275, 1285, 1295—General Physics Laboratory	3
Chem 1014—General Principles of Chemistry plus Natural Science Elective or Chem 1004, 1005—General Principles	8-10
Agricultural and Biological Science	
Electives	8
Engineering Science	
EG 1025—Engineering Graphics	4
AEM 1015—Statics	4
AEM 3016, 3036—Deformable Body Mechanics, Dynamics	8
AEM 1031—Computations in Agricultural Engineering	2
AgEn 3050—Soil-Plant Relations in Agricultural Engineering	4
AgEn 3060—Analysis in Agricultural Engineering	4
CE 3400—Fluid Mechanics	4
EE 3000—Circuits	4
ME 3301, 5342—Thermodynamics, Heat Transfer	8
Electives	4
Engineering Design	
AgEn 1071—Introduction to Agricultural Engineering	2
AgEn 5081, 5082, 5083, or 5084—Design	4
Agricultural Engineering Electives: AgEn 5060, 5070, 5130, 5140, 5330, 5340, 5540, 5550, 5730, 5740, 5910, 5920	16
Approved Engineering Design Elective	4

English Composition, Humanities, and Social Science	
English Composition or Communications	8
Electives to satisfy liberal education requirement (see page 57)	28
Technical or Professional Writing	4
Other Courses	
AgEn 1060—Agricutural Engineering Orientation (to be taken by freshman students only)	1
AgEn 1030—Introduction to Computer Programming (CICS 1100 may be substituted for this requirement)	2
Electives as needed to meet graduation requirement of 183 cr	

Electives are usually chosen to develop professional competency in a given area of specialization, but can be used to prepare oneself for professional service on a broader scale. Sample programs and lists of suggested electives are available at the department office or from individual advisers.

Architecture

(School of Architecture and Landscape Architecture)

The environment in which we live and work exerts physical, emotional, and psychological influence on us and our society. Unplanned and uncontrolled growth produces visual chaos, misuse of natural and man-made resources, and pollution; it has a detrimental effect on our quality of life.

Dramatic technological and scientific changes and the accelerated growth of population in urban conglomerates are having a direct impact on the tasks of the architectural and environmental design professions. Many of the problems facing the world today find their physical manifestation in the areas of the architect's or designer's concern: inadequacy of housing, misuse of land and water, obsolescence of transportation systems, unplanned suburban sprawl, urban decay, wasteful use of energy and materials. The urgency and critical nature of these problems demand a far broader, far more comprehensive approach to the education of architects, landscape architects, and environmental designers than only a decade ago.

The spaces in which we live, move, work, and play are largely the product of our own devising. The process of this devising and shaping of the physical environment is the very essence of the art and science of architecture. Its greatest challenge is not the design of individual and isolated projects but the blending of many varied factors into a total cohesive and sensitive physical environment, providing a full and rich life for all members of the community.

The design and planning process demands that the architect be trained in a wide variety of technical skills, and that he also possess a thorough understanding of social, political, and economic issues. In its educational philosophy the School of Architecture and Landscape Architecture is concerned with the design of the total environment and with the education of the total human being.

The Architecture program offers three undergraduate curricula:

Bachelor of Architecture Curriculum (B.Arch.) (5 years in Institute of Technology)—This program normally requires 1 year of pre-architecture work followed by 4 years in the School of Architecture and Landscape Architecture. Required couses plus electives must equal at least 250 credits. The curriculum is intended for students who expect to enter the practice of architecture in any of its recognized phases. Upon completion, students may apply for admission to graduate study in architecture leading to the M.Arch. degree. When supplemented by practical experience the B.Arch. degree qualifies graduates for admission to registration examinations as required by laws of the various states.

Before enrolling in Arch 5123, each student is required to present evidence of a minimum of 800 hours of practical experience. Preferably, such experience would be in an architect's office.

Bachelor of Environmental Design Curriculum (B.E.D.) (4 years in Institute of Technology)—This program normally requires 1 year of pre-environmental design work followed by 3 additional years in the School of Architecture and Landscape Architecture. Required courses plus approved electives must equal at least 192 credits.

This curriculum prepares students for (a) continuation toward the B.Arch degree, (b) application for graduate study in architecture leading to the M.Arch. degree, or (c) transfer into other disciplines such as city design, city and regional planning, product design, or, in some cases, the social or natural sciences.

Bachelor of Arts Curriculum (B.A. with major in architecture) (4 years in College of Liberal Arts)—This program normally requires 2 years of pre-architecture work followed by 2 years of work in the School of Architecture and Landscape Architecture. Required courses plus approved electives must equal 180 credits in the major.

Upon completion of the B.A. degree students may (a) transfer to the Institute of Technology and after 2 additional years of study in the School of Architecture and Landscape Architecture earn the B.Arch. degree, or (b) apply for admission to graduate study in architecture leading to the master of architecture degree.

This curriculum is intended for students who wish to combine the study of architecture with a liberal education. It provides an advantageous approach to professional training in the fields of architecture, landscape architecture, urban design, urban and regional planning, and decorative, industrial, or interior design.

SPECIAL PROGRAMS

The School of Architecture and Landscape Architecture participates in the following special programs:

Combined Degree Programs—In architecture, landscape architecture, and planning.

MXC—Preliminary exploration into alternatives in experimental city design.

Computer Application—(In collaboration with the University Computer Sciences) Students carry out projects in computer programming and computer graphics as these areas might apply to architecture and landscape architecture and planning.

Community Advocacy Design—(In collaboration with the Urban Education Center) Students work with urban and rural communities on a variety of design projects.

Built Environment Communication Center—A program employing various forms of audiovisual media for educational and documentary use. It is anticipated this program will be the nucleus of graphic communication instruction and laboratory experience.

Foreign Study Program—Qualified students in the spring quarter of their third year of architecture or landscape architecture carry out their studies in various countries abroad.

Educational Exchange Program—An exchange program with the School of Environmental Design, University of Lagos, Nigeria.

Project Ouroboros—Studies of architecture's role in energy conservation through research, design, and construction of full-scale residences.

COURSE REQUIREMENTS

ARCHITECTURE

The pre-architecture program, common for all students, is 1 year in length. It provides the background necessary to prepare students for the required course work in the School of Architecture and Landscape Architecture.

Pre-Architecture

	Credits
Comp 1001-1002—Introductory Composition or Communications	8
Math 1211-1221-1231—Analysis I, II, III	15
Phys 1121-1122—Physics for Architects	10
Arch 1021-1022-1023—History of Environmental Development	12
Liberal Education Electives	4
Total Credits, Pre-Architecture	49

After substantial completion of the above work with a superior grade point average, students must apply for admission to the School of Architecture and Landscape Architecture on Form AR 110 before May 1 of the year for which admission is sought.

B.Arch. Program

Arch 3081 through Arch 5123—Architectural Design	84
ArtS 1107-1108-1109**—3140—Drawing and Painting	12
AEM 3092-3093—Statics and Mechanics of Materials	8
Arch 3061-3062-3064-3065—Architecture Technology	24
Arch 3067—Integrated Design Systems	4
CE 3600-3601—Structural Design	8
Arch 5051 through Arch 5056—Architectural History (any three)	12
Arch 5115-5116—Structure and Form in Architecture	8
Arch 5126—Professional Practice	4
Arch 5137-5138—Planning	8
Recommended Professional Electives:	
Arch 1001-1002-1003—Environmental Design	12
Liberal Education Electives	21
Total Credits Required for B.Arch. Degree	250

(See Architecture Department for yearly handout which may indicate changes or additions.)

ENVIRONMENTAL DESIGN

The pre-environmental design curriculum provides fundamental courses which prepare the student for subsequent courses leading to the B.E.D. degree.

Pre-Environmental Design

	Credits
Comp 1001-1002—Introductory Composition or Communications	8
Math 1211-1221-1231—Analysis I, II, III	15
Phys 1121-1122—Physics for Architects	10
Arch 1021-1022-1023—History of Environmental Development	12
Liberal Education Electives	4
Total Credits, Pre-Environmental Design	49

**Offered only after admission to School of Architecture and Landscape Architecture.

B.E.D. Program

Arch 1001-1002-1003-3140—Environmental Design	12
ArtS 1107-1108-1109-3140††—Drawing and Painting	12
Arch 3061-3062-3064-3065—Architectural Technology	20
AEM 3092-3093—Statics and Mechanics of Materials	8
Arch 3081 through 5113—Architectural Design	54
Arch 3067—Integrated Design Systems	4
CE 3600-3601—Structural Design	8
Arch 5051 through 5056—Architectural History (any three)	12
Liberal Education Electives	13
Total Credits Required for B.E.D. Degree	192

Astronomy

(School of Physics and Astronomy)

An undergraduate program is offered leading to the B.S. in astrophysics. The English composition and foreign language requirements are identical to those in the Physics program.

GRADUATION REQUIREMENTS

(Based on 180 credits)	Credits
Liberal Education (same as Physics)	36
Mathematics (same as Physics)	32-39
Required Astrophysics and Physics Courses	
Ast 3051-5161-5162—Astrophysics	12
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
Phys 3011-3012-3015—Waves and Optics, Laboratory	9
Phys 3511-3512-3513—Modern Physics	12
Phys 5021-5022—Mechanics	8
Phys 5023-5024—Electricity and Magnetism	8
Electives to total 180 credits	41-48
Subtotal	180
English and/or Foreign Language as required	0-17
Total Credits	180-197

Electives—The curriculum above is a minimum program. The courses below provide a stronger program, particularly for those who intend to pursue graduate study.

Recommended Physics and Astrophysics Courses

Ast 1021-1025-1201—Introductory Astronomy
Phys 5101-5102—Quantum Mechanics
Phys 5201-5202—Thermodynamics, Statistical Mechanics
Phys 5804—Optics Laboratory

Suggested Technical Electives

Statistics, Computer Programming
Geology
Chemistry
Meteorology
Cloud Physics
Cosmic Ray and Space Physics
History of Physics
Electronics

††Offered only after admission to Environmental Design degree program in School of Architecture and Landscape Architecture.

Chemical Engineering

(Department of Chemical Engineering and Materials Science)

The chemical engineer is primarily a producer whose special province is to develop a process from its laboratory beginnings, through semiworks equipment, to full-scale production. Chemical engineering is based upon applications of chemistry, physics, mathematics, economics, and occasionally ecology as well as other aspects of biology. The Chemical Engineering curriculum includes study of applied mathematics; material and energy balances; properties and physics of gases, liquids, and solids; fluid mechanics; heat and mass transfer; thermodynamics; reaction kinetics; and process design, control, and optimization. Because of this broad-based foundation which emphasizes basic and engineering sciences, the chemical engineer is most nearly the universal engineer.

Chemical engineers work on a wide variety of projects: basic and applied research, development work, design and modifications of processes and equipment, and plant operation. Some enter sales engineering, marketing, and management. Because of the span and flexibility of the Chemical Engineering curriculum, it is chosen by some students who plan graduate study in medical sciences, business administration, or patent law.

Chemical engineering deals with unit operations such as materials handling, mixing, fluid flow and metering, heat exchange, filtration, drying, evaporation, distillation, absorption, extraction, crystallization, ion exchange, and processing in chemical reactors. These operations are vital to the commercial success of industries based on chemical or physical transformation of matter. A chemist uses these operations qualitatively in a laboratory; but to apply them to a large-scale industrial process requires a chemical engineer who has a complete and quantitative understanding of the engineering as well as the scientific principles on which the operations rest.

Because many industries are based on some chemical or physical transformation of matter, the chemical engineer is much in demand. He may be engaged in the manufacture of inorganic products—acids, alkalies, ammonia, paint pigments, fertilizers; in the manufacture of organic products—dyes, explosives, textiles, polymer fibers, rubber, rocket propellants, solvents, plastics, agricultural chemicals, pharmaceuticals, coal-based fuels, petroleum derivatives; in the manufacture of graphite, calcium carbide, abrasives, wet and dry batteries, fuel cells, electroplating; in the metallurgical industries; in the food processing industries; and in the fermentation industry for production of chemicals such as antibiotics and feed supplements. Many other products such as hydrocarbon fuels, nuclear materials, paper, glass, ceramics and cement concern the chemical engineer, as do problems of waste disposal and environmental protection.

Chemical engineering underlies most of the energy field, including utilization of coal, petroleum, natural gas, tar sand, oil shale, geothermal deposits, solar radiation, and nuclear energy. The chemical engineer entering the nuclear industry may deal with materials for nuclear reactors and with design and operation of reactors for research, isotope production, heat and power production, and utilization as well as storage of radionuclides and fission products.

The chemical engineer may also enter the field of bioengineering, where problems range from utilization of the activities of microorganisms, to manufacture of foods to design of prosthetic devices and artificial human organs.

Degree Requirements—To receive the bachelor of chemical engineering degree, required courses plus electives normally total 200 credits (although the

minimum in special cases is 191 credits). Students must satisfy the IT minimum liberal education requirements (a total of 36 credits including at least 7 in biological science; other categories are explained on pages 57-59) as parts of a pre-chemical engineering program (96-105 credits) and a coherent degree program of science and technical courses (86-104 credits). Both pre-degree and degree curricula are outlined below.

The student, together with her or his adviser, plans the degree program in two stages: a 1-year plan is submitted at the start of the third year, and, ordinarily, a complete 4-year program is submitted for certification by the department by the beginning of the fourth year. By selecting appropriate technical electives and, in certain cases, substituting courses with approval of the adviser and department, students can emphasize various special interest areas in their upper division curriculum. Coherent programs which illustrate these possibilities are available from the departmental office, 151 Chemical Engineering Building. Advisers and the department's director of undergraduate studies can be contacted through the same office.

Transfer Students—Students intending to transfer from another campus or school should take the most nearly equivalent courses available to them. Students with questions about a proposed transfer are encouraged to write or visit the Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, Minnesota 55455.

NORMAL PRE-CHEMICAL ENGINEERING PROGRAM ON TWIN CITIES CAMPUS (LOWER DIVISION)

First Year

	Credits	f	w	s
Comp 1001, 1002—Introductory Composition	4	4	..	
Math 1311, 1321,1331—Computer Calculus I, II, III (or) Math 1211, 1221, 1231—Analysis I, II, III	5	5	5	
Chem 1031, 1032, 1034—General Principles I, II, Synthesis I**	5	5	5	
Electives (quarters of registration may be rearranged with Comp 1001, 1002)	....	0-4	4-8	

Second Year

Chem 3034, 3201, 5126—Synthesis II, Rates and Mechanisms, Modern Analytical Chemistry**	5	5	5	
Phys 1271, 1281, 1291—Mechanics, Heat and Electricity, Magnetism and Optics	4	4	4	
Phys 1275, 1285, 1295—General Physics Laboratory	1	1	1	
Math 3211, 3221—Analysis IV, Linear Algebra and Differential Equations	5	5	..	
AEM 3016—Deformable Body Mechanics (or) EE 3000—Electrical Circuits (or) Math 3231—Vector Analysis	....	..	4	
EBB 3101—Ecology for Engineers and Physical Scientists	....	4	..	
GCB 3201—Molecular Biology (or approved biology alternatives)	....	..	3-4	
Elective (quarter of registration may be rearranged with EBB 3101)	0-4	..	..	

Note that the lower division curriculum in chemical engineering is the same as the lower division curriculum in chemistry, except that courses in biology and ecology are included. The lower division curriculum in chemical engineering differs from those in other engineering fields because chemical engineering requires more study of chemistry.

Also note that the lower division courses EBB 3101 and GCB 3201 (or approved substitutes) fill both chemical engineering and liberal education requirements.

**Check with adviser about current chemistry courses.

BASIC UPPER DIVISION PROGRAM IN CHEMICAL ENGINEERING

Third Year

	Credits—f,w,s		
ChEn 5101, 5102, 5103—Principles: Stoichiometry and Balances, Fluid Mechanics, Heat and Mass Transfer	4	4	4
ChEn 5001—Mathematical Methods in Chemical Engineering and Materials Science	2	..	..
ChEn 5401—Chemical Engineering Laboratory	..	..	2
Chem 5505—Statistical Thermodynamics	4	..	..
ChEn 5201—Thermodynamics and Materials State	..	4	..
ChEn 5202—Chemical Engineering Thermodynamics and Kinetics	..	..	4
MatS 5011—Introduction to Science of Materials	4	..	..
Phys 3501, 3505—Modern Physics and Laboratory (or) Chem 5502—Quantum Mechanics with Laboratory	..	5	..
Electives	0-4	3-5	4-8

Fourth Year

ChEn 5104—Separation Processes	4	..	..
ChEn 5501, 5502—Process Evaluation and Design	..	4	2
ChEn 5301—Chemical Reactor Analysis	4	..	..
ChEn 5601, 5604—Process Control, Laboratory**	..	4	2
ChEn 5402, 5403—Chemical Engineering Laboratory**	2	2	..
ChEn 5901—Chemical Process Laboratory**	2	..	..
Technical Electives	3-4	3-4	6-8
Electives	3-4	3-4	6-8

Students interested in bioengineering should contact Professor Tsuchiya in fall quarter of their third year in order to reserve places in Biol 3021, 3025 for winter or spring quarter. Enrollment in these courses, as in some other biology courses, is severely limited.

Chemistry

Note: At the time this bulletin went to press, the faculty of the Department of Chemistry was considering possible revisions of the present curriculum. For more up-to-date information, please contact the Chemistry Advising Office, 147b Smith Hall.

The Chemistry curriculum begins with a set of courses called the "core program in chemistry," which contains the background prerequisite to a successful study of the diverse, higher-level courses to be taken later in the various tracks leading to the 4-year bachelor of chemistry degree.

The first 7 quarters constitute the core program: two courses on general principles of chemistry with analytical laboratory work, two courses which examine the synthesis and chemical properties of compounds, one course on rates and mechanisms of chemical reactions, one course on modern analytical chemistry, and one course on statistical thermodynamics, taken in the above-listed order. The philosophy behind the core courses is the elimination of artificial boundaries between the various areas of chemistry in order to present chemistry as an interrelated whole. After completion of the core courses, a student may choose one of the seven tracks to develop expertise in that area of chemistry best suited to his/her individual interests and professional goals.

**Normal programs include at least three of these four laboratory courses.

Curricular Requirements

A minimum of 180 credits is required for graduation. All required courses, including freshman English and German, must be taken A-N.

1. Minimum Liberal Education Requirements—36 credits, as listed on page 57.
2. A minimum of 20 credits (in addition to the required chemistry, physics, and mathematics courses) from the technical elective courses listed below:

Astronomy	Microbiology
Biochemistry	Mineralogy
Biology	Physical geology
Botany	Physics
Computer, information, control sciences	Physiological chemistry
Geology	Physiology
Geophysics	Plant physiology
Mathematics	Zoology

3. A minimum of 20 credits in other electives chosen from courses not listed in paragraph two above. In certain instances where specialization in an area such as microbiology, biochemistry, or geology is desired, the student may obtain permission by petition to use a smaller number of electives in this category and to substitute additional courses in areas from paragraph two. To use more than one nonrequired 5000-level chemistry course, the student must petition. Petition forms are to be submitted in the IT office, 105 Main Engineering.

First Year

	Credits—f, w,s		
Chem 1031, 1032, 1034—General Principles I, II, Synthesis I	5	5	5
Math 1311, 1321, 1331—Computer Calculus I, II, II (or) Math 1211, 1221, 1231—Analysis I, II, III	5	5	5
Comp 1001, 1002—Introductory Composition	4	4	..
Electives (quarters of registration may be rearranged with Comp 1001, 1002)	..	0-4	4-8

Second Year

Chem 3034, 3201, 5126—Synthesis II, Rates and Mechanisms, Modern Analytical Chemistry	5	5	5
Phys 1271, 1281, 1291—Mechanics, Heat and Electricity, Magnetism and Optics	4	4	4
Phys 1275, 1285, 1295—General Physics Laboratory	1	1	1
Math 3211, 3221—Analysis IV, Linear Algebra and Differential Equations	5	5	..
Electives	..	..	4-8

Third Year

Chem 5505—Statistical Thermodynamics	4	..	..
Ger 1101, 1102, 1103 (or) 1001, 1002, 1003—Beginning German	5	5	5
"Track" Courses	4-10	4-10	4-10
Electives	4-5	4-5	4-5

Fourth Year

"Track" Courses
Electives

Track Program

*Basic Track***:* Chem 5502, 5703 plus at least 11 cr of elective chemistry courses chosen in consultation with the student's adviser from the following: Chem 3499, 5125, 5302, 5305, 5309, 5365, 5503, 5705.

Biophysical Chemistry Track: Chem 5522, 5523, 5524 plus at least 12 cr chosen in consultation with the student's adviser from the following: BioC 5741, 5742, 5745, 5746; Chem 5125, 5342, 5580; MicB 3103; ChEn 5751, 5752, 5753; GCB 3022, 5082; BPhy 5126, 5157.

Chemical Instrumentation Track: Chem 5127, 5128 plus at least 10 cr chosen in consultation with the student's adviser.

Materials Science Track: At least 20 cr chosen in consultation with the student's adviser.

Eco-Chemistry Track: Chem 5310, 5704 plus at least 12 cr chosen in consultation with the student's adviser.

Open Track: At least 20 cr of 5000-level courses chosen in consultation with the student's adviser and approved by the director of undergraduate studies. (The Open Track provides an avenue for individual students to innovate and formulate special programs tailor-made for their special education goals. In all cases, these special programs must be approved on an individual basis by the director of undergraduate studies, using a petition form available in 105 Main Engineering.)

Civil Engineering

(Department of Civil and Mineral Engineering)

Students interested in keeping pace with scientific and technological innovations, as well as in providing service to others, will find a strong appeal in civil engineering. This field requires the highest order of technological competence coupled with an understanding of social goals and government structures in order to meet the challenge of adapting the environment for the health and benefit of human beings.

There are ample opportunities for civil engineers in both private practice and public service. Graduates may pursue careers in design, construction, maintenance, management, or research and development. Many find employment in federal, state, and municipal agencies; in the construction industry; and in aiding the development of emerging nations. Whether the setting is a complex urban area or a developing population and industrial center, civil engineers serve the public as planners, designers, and supervisors of transportation systems, structures, pollution control facilities, water resource projects, private and public utility enterprises, and other civil works.

Three interdisciplinary programs of current national interest are offered through the cooperation of Civil Engineering and other IT departments:

Environmental Engineering—The systematic control of air, water, and land pollution to protect the public health and enhance environmental quality by providing for safe and adequate water supplies, treatment and disposal of waste water, and solid waste management systems.

Transportation Engineering—The economics, planning, design, construction, maintenance, and administration of highways, railroads, airways, pipelines, and transmission lines for the conveyance of passengers, materials, or energy.

Water Resources Engineering—The application of hydrology, meteorology, fluid mechanics, and other basic knowledge in the design and operation of water resources systems; irrigation and drainage; hydropower development; flood control; coastal engineering and harbor de-

**The Basic Track is recommended for those students planning to attend graduate school in chemistry. Chem 5703 is required of those students who desire to be certified by the American Chemistry Society.

velopment for a more effective and humane utilization of our water resources. The St. Anthony Falls Hydraulic Laboratory, a part of the Department of Civil and Mineral Engineering, is the site of much water resources research.

In addition to these interdisciplinary options, Civil Engineering students may enter an engineering intern program after completing approximately 5 quarters of study. Participants alternate study quarters with two 6-month work periods, for which they earn 4 credits each period.

The bachelor of civil engineering degree (B.C.E.) requires a minimum of 184 credits. The first 2 years of study are similar to lower division curricula in several IT departments. The preprofessional requirements are deliberately general so that students may transfer from one branch of engineering to another, or from a liberal arts or junior college to IT, without loss of credits. The last 2 years provide training in engineering science and engineering practice.

Principal fields of upper division specialization within Civil Engineering are: environmental engineering; water resources engineering; transportation engineering; structural engineering; soil mechanics and geo-mechanics; construction materials; and land use planning, including surveying and mapping. By selecting appropriate elective courses, students may develop a strong "minor," such as business administration, or attain legitimate specialized professional objectives.

General requirements are listed below, followed by three sample curricula illustrating how these required courses plus appropriate electives can be combined into an area of specialization within civil engineering. Other sample programs are available from the Director of Undergraduate Studies, Department of Civil and Mineral Engineering, 112 Mines and Metallurgy.

GENERAL REQUIREMENTS

	Credits
Mathematics	
Calculus and analytic geometry	15
Linear algebra and linear differential equations	5
Advanced calculus (or) probability, statistics, and linear programming	4
Basic Science	
Physics (with laboratory); dynamics; heat, electricity, optics	15
Chemistry (with laboratory)	10
Elective chosen from geology, biology, ecology, chemistry, or physics	0-8
Engineering Science	
Statics	4
Fluid mechanics (with laboratory)	4
Introduction to structural analysis	4
Computer programming	4
Approved engineering science electives	8-16
Introduction to engineering in society and to graphical communication	4-6
Engineering Analysis, Design and Systems	
Minimum of five introductory courses from the seven professional areas: soil mechanics, structures, environmental engineering, water resources engineering, transportation, materials and surveying	20
Completion of an 8-credit sequence in three of the professional areas listed above (if all seven introductory courses are included in the program only two of the 8-credit sequences need be completed)	24
English Composition, Humanities, and Social Science (required and elective courses)	36
Elective Program	
Must be chosen so as to form part of a coherent program	18
Total Credits Required	184

ENVIRONMENTAL ENGINEERING—SAMPLE PROGRAM

LOWER DIVISION

(93 credits)

	Credits
English Composition or Communications	8
Math 1211, 1221, 1231, 3221, and CE 3010—Analysis I, II, III, Introduction to Linear Algebra and Linear Differential Equations, Data Analysis and Optimization in Civil Engineering	24
CICS 3101—A Fortran Introduction to Computer Programming	4
Phys 1271, 1275, 1281, 1285, 1291, 1295—General Physics (with laboratory)	15
Chem 1004, 1005—General Principles of Chemistry	10
AEM 1015—Statics	4
I of T 1010—Introduction to Engineering	4
CE 1001—Civil Engineering Orientation	1
CE 3400—Fluid Mechanics	4
CE 3605—Introduction to Structural Analysis	4
Geog 1301 and Soc 1505 (or LA 1031 or Pol 1001)	10
Biol 1011—General Biology	5

UPPER DIVISION

(92 credits minimum)

	Credits
Liberal Education Electives (see department for recommended list)	18
Recommended Civil Engineering Courses: CE 3200, 3500, 5500, 5501, 5505, 5510, 5401, 5405, 5420, 5210, 5201, 5600, 3700 (for course titles and descriptions, see Section IV)	53

OPTIONAL TECHNICAL COURSES

(20 credits minimum)

	Credits
EBB 5027—Human Population, Environment, Resources	4
Chem 3301, 3302—Elementary Organic Chemistry	(each) 5
Geo 5601—Limnology	3
Biol 3013—Microbiology	4
ME 3301—Thermodynamics	4
PubH 5151—Environmental Health	4
PubH 5181—Introduction to the Air Pollution Problem	3
ChE 5101, 5103—Principles of Chemical Engineering	(each) 4

TRANSPORTATION ENGINEERING—SAMPLE PROGRAM

LOWER DIVISION

Same as Environmental Engineering program, except substitute EBB 3101 for Biol 1011.

UPPER DIVISION

	Credits
Liberal Education Electives (see department for recommended list)	18
Recommended Civil Engineering Courses: CE 3100, 3102, 5100, 3200, 5200, 5201, 5202, 5210, 3300, 5304, 5401, 5600, 3700 (for course titles and descriptions, see Section IV)	53

OPTIONAL TECHNICAL COURSES

(21 credits minimum)

	Credits
Arch 5137, 5138—Planning: Urban Function, Structure, and Planning: Theory, Methodology	(each) 4
IEOR 5000, 5040—Introduction: Industrial Engineering Analysis, Introduction: Operations Research	(each) 4
SMAE 5711—Advanced Urban Transport Systems	4
EE 3460 (for CE)—Special Investigations	4
Geo 1111—Introductory Physical Geology	5
Tran 3054—Fundamentals of Transportation	4
Tran 5195—Government Economic Regulation: Transportation	4
Geog 5383—Transportation Geography	4

WATER RESOURCES ENGINEERING—SAMPLE PROGRAM

LOWER DIVISION

	Credits
(See Environmental Engineering) For non-IT electives, Geo 1401, Soc 1505, or Pol 1001 and EBB 3101 are suitable	14

UPPER DIVISION

Liberal Education Electives (see department for recommended list)	18
Recommended Civil Engineering Courses: CE 3100, 3300, 5310, 5401, 5402, 5405, 5410, 5420, 3500, 5500, 5501, 5505, 5600	53

OPTIONAL TECHNICAL COURSES

(21 credits minimum)

ME 3301—Thermodynamics	4
ME 3900—Introduction to Engineering Statistics	4
Geo 1001—Physical Geology	5
Geo 5611—Groundwater Geology	3
IEOR 5000—Introduction to Industrial Engineering Analysis	4
CICS 5301—Numerical Analysis	4
AgEn 5540—Erosion Control, Watershed Engineering	4
Geo 5601—Limnology	4

Computer, Information, and Control Sciences

Computer science is concerned with the study of the hardware and software (programming) aspects of high-speed computing devices and with the application of these devices to the solution of a broad spectrum of technological and business problems. A Bachelor's degree in computer science can be obtained in either the College of Liberal Arts or the Institute of Technology. Details of the former program can be found in the *CLA Bulletin*. Both curricula are designed to give the student a broad base in the foundation subjects of computer science. By means of the Upper Division Option and a choice of alternatives in the required courses, the curriculum is made flexible enough so that a student can build on the basic foundation with a concentration within computer science or in interdisciplinary areas involving the applications of computers. This should prepare the student for a variety of industrial and governmental positions involving computer usage, as well as provide the background necessary for pursuing graduate work.

The 4-year IT curriculum leads to the degree of bachelor of computer science, B.Comp.Sci.

In addition to the required courses, a student must satisfy the liberal education requirements for the Institute of Technology and have sufficient approved electives to complete a minimum of 180 credits for graduation.

All IT courses in the required program as well as the 28 credits which constitute the Upper Division Option must be taken on an A-N basis (unless particular courses are offered only on an S-N basis).

Transfer Students—After the sophomore year, a student with a calculus, elementary physics, and FORTRAN background will be able to enter the program as a junior, assuming that his liberal education courses are roughly equivalent to those required by the Institute of Technology. Most transfer students will not have had the material covered in CICS 3105-3106 (formerly 1105-1106) and 3107; however, a program can be worked out in which these courses are taken during the summer or during the junior year. All transfer students should go to the departmental office for advice.

LOWER DIVISION

	Credits
Freshman English or Communications	8
Math 1311, 1321, 1331—Analysis (with Computers)	15
Math 3211, 3221—Analysis; Linear Algebra and Differential Equations	10
Stat 3091—Probability, Statistics or Stat 5121**	4
Physics 1271, 1281, 1291—General Physics	12
Physics 1275, 1285, 1295—Physics Laboratory	3
CICS 3101††—A Fortran Introduction to Computer Programming	4
CICS 3001—Perspectives on Computers and Society	4
CICS 3105-3106 (formerly 1105-1106)—Fundamentals of Algorithms and Languages I-II	8
CICS 3107—Introduction to the Structures and Programming of Computer Systems	4
Liberal Education Electives	20
Lower Division Credit Minimum	92

UPPER DIVISION

	Credits
English 3085—Technical Writing	4
Liberal Education Electives	16
Free Electives	16
Required Technical Courses:	
At least one upper division math or statistics course (Math 5701—Combinatorics is recommended)	4
CICS 5102—Structure and Programming of Software Systems II	4
CICS 5121—Data Structures	4
CICS 5201—Fundamentals of Logic System Design	4
CICS 5301—Numerical Analysis	4
CICS 5400—Introduction to Automata Theory	4
CICS 5501—Artificial Intelligence and Heuristic Programming	4
Upper Division Option	
Elective courses which form a coherent program in CICS and applied areas; e.g., health sciences, transportation, biomedical engineering, environmental engineering, machine design, software systems, mathematics of computation, theory of computation, etc. These courses are to be selected from additional 5000-level CICS courses and adviser-approved courses from other departments. See option program information available in departmental office	28
Upper Division Credit Minimum	92

Electrical Engineering

Many of today's electrical engineers encounter assignments in fields that developed after their formal education was completed. Indeed, some electrical engineers find themselves applying their expertise in these new areas to problems that are far afield from the traditional boundaries of electrical engineering; examples include the urban economic system, transportation, computer-aided education, and monitoring systems for hospital patients. New technologies will surely continue to emerge from results of basic scientific discoveries. Likewise, we can expect the search to broaden for technological solutions to the countless complex problems that arise from the concentration of population in urban centers and from the conflicting needs both to utilize and to conserve our resources and environment. In the face of such a challenge, the Electrical Engineering curriculum seeks to prepare its graduates to cope with their first assignments, but probably more importantly, to provide a fundamental background for continued professional development.

**Students intending to take additional work in statistics must take Stat 5121 not Stat 3091.
††Optional—intended for people without previous programming experience.

The required curriculum provides essential scientific and engineering background. Elective freedom, primarily in the senior year, allows for some concentration in specialized areas or in related interdisciplinary studies. The available senior elective courses within electrical engineering range from biomedical instrumentation to computer engineering, control or communication systems, power and electromechanics, microwave applications, and electronic devices and circuits. Supporting courses from other areas are broadly available.

An honors program is also offered within the Electrical Engineering Department which features special recitation sections, individual projects under faculty guidance, and increased elective freedom. A cooperative work-study program is available which offers a measure of industrial experience through alternate quarters on campus and on industrial assignment during the last 2 years of the curriculum.

The 4-year curriculum includes a minimum of 189 quarter credits and leads to the degree bachelor of electrical engineering, B.E.E. Curricular details, sample elective programs, and quarterly plans leading to the B.E.E. degree at the University of Minnesota can be obtained by writing to the Department of Electrical Engineering, University of Minnesota, Minneapolis, Minnesota 55455.

LOWER DIVISION

	Credits
Liberal Education Electives, including 8 cr Freshman Composition or Communication	18
Math 1211-1221-1231, 3211, 3221, 3231—Analysis I-IV, Introduction to Linear Algebra and Differential Equations, Vector Analysis	29
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—Physics Laboratory	3
Chem 1014—General Chemistry	4
Natural Science Elective (modern physics or chemistry recommended)	4
EE 1000—Introduction to Electrical Engineering	1
CICS 1100-1101—Fortran Programming	4
EE 1510—Elements of Electrical Engineering	5
Engineering Science Elective (AEM 3036 or Stat 3091 or ME 3301 recommended)	4
Electives	9
Total Credits	93

UPPER DIVISION

	Credits
EE 3010-3011-3012—Circuits, Signals, and Systems I-II-III	12
EE 3050-3051—Electronics I-II	8
EE 3100-3101—Electromagnetic Fields I-II	8
EE 3400-3401-3402—Junior EE Laboratory	8
EE 5050—Nonlinear Electronic Circuits	4
EE 5100—Electromagnetic Fields III	4
EE 5101—Electromagnetic Fields Laboratory	1
Comp 3085—Technical Writing	3
Senior Technical Elective Program	28
Electives (including liberal education courses to satisfy the CLE requirements for IT students)	20
Total Credits	96

Geo-Engineering

(Department of Civil and Mineral Engineering)

Geo-engineering concerns the application of engineering and geological principles to the problems of analysis and design in those engineering activities directly related to the earth, its material structure, forces, and economic products.

Geo-engineers carry on their professional work in many branches of industry and government, including:

The construction industry, involving problems of the behavior of rocks and soils such as dam site studies and selection, foundations, slope stability and design, erosion control, drainage, irrigation, highway subgrades, and tunneling and underground excavation.

The mineral industries, including metal and coal mining, petroleum, and industrial raw materials where the major concerns are analysis and design in the exploration and development of mineral economics, mineral valuations, and application of geochemical, geophysical, and geologic principles and techniques. The geo-engineer may also advise and assist mining engineers on problems of ore reserves, quality control, the effects of geologic factors on rock behavior, and other areas.

Government bureaus and other agencies involved in environmental studies, geothermal energy, water resources, underground transit systems, etc.

Depending on his or her interests, the geological engineer may work for mining or petroleum companies, consulting engineering groups, construction companies, research organizations, or government agencies. It should be recognized that a high degree of specialization within the broader professional field usually requires some postgraduate study.

The undergraduate curriculum provides training in engineering geology and related topics such as geomechanics, and has sufficient flexibility so that the student can obtain a limited degree of specialization in one of the fields with which geo-engineers are concerned. It also allows able and interested students to prepare for graduate study.

A 4-year degree program is offered that leads to the degree of bachelor of geo-engineering (B.Geo.E.). A minimum of 184 credits (or equivalent demonstrated competence), including field trips, is required for graduation.

Following is a recommended program which can be modified, in consultation with a faculty adviser, to better meet individual student interests.

LOWER DIVISION

	Credits
English Composition or Communications	8
Math 1211, 1221, 1231; 3221; and CE 3010 (or) ME 3900—Analysis I, II, III; Introduction to Linear Algebra and Differential Equations; Data Analysis and Optimization; Introduction to Engineering Statistics	24
Chem 1004, 1005, 1006—General and Solution Chemistry	14
Phys 1271, 1275, 1281, 1285, 1291, 1295—General Physics with Laboratory	15
I of T 1010 (or) EG 1025—Introduction to Engineering (or) Engineering Graphics	4
I of T 1003, 1004—Seminar: Freshman Engineers	2
AEM 1015—Statics	4
CE 3400—Fluid Mechanics	4
CICS 1100—Introduction to Fortran Programming I	2
AEM 3016 or 3017—Deformable Body Mechanics	4
Electives	10

UPPER DIVISION

Junior Year—All Options

	Credits
MinE 5611—Mineral Resources I: Exploration and Development	4
MinE 5612—Mineral Resources II: Development and Production Systems	4
MinE 5613—Mineral Resources III: Examination and Valuation of Mineral Property	4
Geo 1111—Introductory Physical Geology	5
Geo 3103—Structural Geology	5

Geo 3401—Introductory Mineralogy	5
CE 3300—Elements of Soil Mechanics	4
GeoE 5320—Fundamentals of Geomechanics	4
GeoE 5321—Slopes and Foundations I	4
CE 3100—Surveying	4
Electives (CLA)	7

Senior Year—Geomechanics Option

	Credits
GeoE 3012—Geo-Engineering and Mine Surveying	2
GeoE 5260, 5262—Geo-Engineering Analysis	5
GeoE 5322—Slopes and Foundations II	4
GeoE 5437—Computer Applications in Geo- and Mineral Engineering	4
Geo 5512—Principles of Seismic Exploration	3
Geo 5513—Principles of Electrical Exploration	3
CE 3605—Introduction to Structural Analysis	4
CE 5600—Linear Structural Systems	4
Technical Electives (geology or geo-engineering or mineral engineering)	7
Electives (CLA)	12
Geology Summer Field Trip (4 weeks or more)	

Senior Year—Exploration Option

	Credits
GeoE 5180—Geochemical Exploration	3
GeoE 5260, 5262—Geo-Engineering Analysis	5
GeoE 5437—Computer Applications in Geo- and Mineral Engineering	4
Geo 5351—Metal Sulphide Deposits	5
Geo 5451—Optical Mineralogy and Petrography	4
Geo 5512—Principles of Seismic Exploration	3
Geo 5513—Principles of Electrical Exploration	3
MinE 5830—Microscopy for Mineral Engineering	3
MinE 5800—Introduction to Mineral and Metal Extraction	4
Electives	12
Geology Summer Field Trip (4 weeks or more)	

Note: Students in the exploration option may take Geo 5216, Geo-Engineering and Rock Mechanics I, and a 4-credit geo-engineering or geology elective in place of GeoE 5320 and 5321.

Geology and Geophysics

The Department of Geology and Geophysics offers two programs in the undergraduate curriculum, one in geology and one in geophysics. A minimum of 189 credits is required for graduation with the degree of B.S.Geol. or B.S.Geophys.

Geologists and geophysicists are employed in a wide variety of fields. These include exploration for and development of natural resources such as petroleum, minerals, and groundwater. They also include urban planning, conservation, oceanography, and various branches of civil engineering. Potential employers are private industry, research institutions, universities, and many governmental agencies. An advanced degree is generally necessary for employment at a professional level in research and development work or in teaching.

The undergraduate curriculum is designed to provide a strong foundation in physics, mathematics, and chemistry. The Geophysics program emphasizes the first two. Some students select a geology or geophysics major simply to obtain this broad science base.

The Geology program is built around a core of seven basic courses taken during the second and third years.

Geophysics is the study of the physical structure and properties of the earth. The curriculum includes seismology applied to earthquakes and to petroleum exploration; gravity applied to internal structure and to mineral exploration; magnetic, thermal, and electrical properties applied to topics ranging from continental drift to mineral exploration.

Selection of an option should be made during the second year, although later transfers are possible. Both options will accommodate either students preparing for graduate work or those planning to terminate with a B.S.

GENERAL REQUIREMENTS

	Credits
CLE requirements or distribution requirements as defined by IT	36
Specific courses required of all students. These should be taken on an A-N grading basis, except Engl 3085.	
1. Core Geology Courses—Should be taken in order shown, if possible	39
Sophomore Year: fall Geo 1111—Introductory Physical Geology (5 cr) winter Geo 3401—Mineralogy (5 cr) spring Geo 3102—Petrology (5 cr)	
Junior Year: fall Geo 3101—Surficial Processes (5 cr) winter Geo 3112—Historical (5 cr) spring Geo 3103—Structure and field (5 cr)	
Summer After Junior Year: Geo 5110—Field Camp (9 cr)	
2. Math 1211, 1221, 1231, 3211 should be taken as early as possible, preferably beginning in the freshman year.	20
3. Phys 1271, 1275, 1281, 1285, 1291, 1295 should be taken early if possible.	15
4. Chem 1004, 1005 should be taken early, preferably in freshman year. (Chem 1004 is needed for Geo 3401—Mineralogy).	10
5. Engl 3085—Technical Writing should be taken late in junior or early in senior year. Required for those graduating after winter 1976.	4
Free Electives	20
Subtotal	144

ADDITIONAL REQUIREMENTS FOR IT GEOLOGY MAJORS

Courses in this category should be taken on an A-N grading basis, unless available only on S-N. Specific courses should be chosen in consultation with the adviser.

	Credits
Additional cognate sciences *to total at least 29 credits*, including:	
1. Math 3221 (recommended for most students) or Stat 3091	4-5
2. Chem 1006 and 5520 and Chem 5521 or Geo 5301 (or) Chem 3301 and 3302 (or) BioC 1301 and 1302	9-10
3. Additional other science credits chosen from: Physics (3000 level or above; 3501 recommended) Math (3000 level or above; 3231 recommended) Chemistry (3000 level or above) Biology (Biol 1011 is prerequisite for other biology courses; no more than one additional 1000-level course from the College of Biological Sciences can be applied) CE 3400 GeoE 5216 CICS (no more than 4 cr at 1000 level can be applied) Other science courses, as suitable, with departmental consent.	14-16
Minimum Additional Requirements	29
Additional geology or geophysics electives, to be chosen from 5000 level or above. Geo 3099, 3201 applicable; 8008 is not.	16
Subtotal	45
Total Credits Required for Geology Major	189

ADDITIONAL REQUIREMENTS FOR IT GEOPHYSICS MAJORS

	Credits
Phys 3501, 3505, 3011	9
Math 3221	5
Geophysics chosen from Geo 5500 series courses	9-12
Geology, math, physics, electrical engineering, chemistry, or computer science chosen, in consultation with the adviser, from:	
Geo 3099, 3201, 5351, 5401, 5611	
Math 3231, 3142, 5512, 5457-5458-5459, 5601-5602-5603	
Stat 3091 or 5131	
Phys 5011-5012-5013 or 5021-5022, 5023-5024-5025, 5851	
EE 3100-3101 may be substituted for Phys 5023-5024-5025; 3000-3001 may be substituted for Phys 5851	
Chem 5520 and: 5521 or Geo 5301	
CICS 1100-1101 or 3101	19-22
Subtotal	45
Total Credits Required for Geophysics Major	189

Industrial Engineering/Operations Research

(Department of Mechanical Engineering)

Professional training in industrial engineering is offered through an industrial engineering option in mechanical engineering.

Industrial engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, and equipment. It draws upon specialized knowledge and skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems. The industrial engineer studies product designs to adapt them for production, determines an optimal system of necessary operations, selects the most economical production equipment and tooling, and develops effective work methods and measurements.

LOWER DIVISION

(See Mechanical Engineering Lower Division requirements)

UPPER DIVISION

	Credits
Industrial Engineering Courses	20
IEOR 5000—Introduction to Industrial Engineering Analysis	
IEOR 5010—Introduction to Work Analysis	
IEOR 5020—Engineering Cost Accounting, Analysis and Control	
IEOR 5030—Quality Control and Reliability	
IEOR 5040—Introduction to Operations Research	
Mechanical Engineering Courses	30
ME 3201—Mechanical Engineering Systems Analysis	
ME 3203—Analysis of Mechanism Systems	
(or) ME 3205—Engineering Systems Design	
ME 3301—Thermodynamics	
ME 3303—Applied Thermodynamics	
(or) ME 5342—Heat Transfer	
ME 3701—Basic Measurements Laboratory I	
ME 3702—Basic Measurements Laboratory II	
ME 3703—Systems Laboratory	
ME 5260—Engineering Materials and Processing	
ME 5254—Design Morphology with Applications	
Liberal Education Electives	18
Coherent Elective Program**	24

**Detailed information on suggested coherent programs of study in the following areas of emphasis, as well as other combinations, is available in the Industrial Engineering Office, 113 Mechanical Engineering: operations research, quality control and reliability, production engineering, engineering statistics, engineering management.

GRADUATE STUDY IN INDUSTRIAL ENGINEERING AND OPERATIONS RESEARCH

Graduate programs in Operations Research and Industrial Engineering, leading to the M.S. and Ph.D. degrees, are available for those students meeting the entrance requirements of the Graduate School.

Landscape Architecture

(School of Architecture and Landscape Architecture)

Landscape architecture is concerned with the impact, disposition, and management of natural resources as well as the quality of experience which results through the development of land for specific human use.

The landscape architect concentrates on a wide range of involvement: large-scale regional landscape planning; design of exterior environments for working, living, and recreation; commercial, institutional, and industrial development; transportation systems; and multiple-use areas. Specifically, this range may vary in scale from single family residences to regional open space systems. Professional services include land use feasibility studies, site selection studies, site layout proposals, detail grading, and construction drawings and planting plans.

Regional resource planning and design, recreation planning and design, urban landscape design, and detail site planning projects involve interdisciplinary involvement between landscape architects, architects, planners, engineers, geographers, physical scientists, social scientists, etc. The relationship between regional or single site qualities of terrain, soil, climate, vegetation, orientation, visual quality, and the program for development are studied carefully to assure sound recommendation.

Bachelor of Landscape Architecture (B.L.A.)—This program is organized to provide the basic professional training for the practice of landscape architecture and to allow for specialization in one of the expanding areas of professional interest.

The program is offered jointly by the Institute of Technology and the Institute of Agriculture. Students may enroll in either institute.

There are 215 credits required for graduation: 179 credits in core area requirements, which include a sequential design-course program taking a minimum of 3 years, and 36 credits in specialized focus areas. Students, through consultation with their adviser during the second year, elect one of four areas of specialized focus options. They are:

Site Planning and Design—Students in this option will focus upon the art and science of developing small-size land areas for intense human usage. Studies are directed toward analyzing microscale environmental determinants as well as aspects of human interaction in detail environments by analyzing the potential subtleties of site organization. Projects will focus upon a range of intensely developed landscapes including those for housing, commercial, industrial, educational, and urban recreational development.

Urban Landscape Design—Students in this option will focus upon the organization of urban environments. Studies are directed toward exploring the potential input of a designer trained in the development of urban systems (such as open space, housing, commercial, industrial, transportation, historic preservation, etc.).

Regional Resource Planning and Design—Students in this option will focus on large-scale land areas to analyze their developmental potential and to differentiate land uses such as those for agricultural, residential, commercial, industrial, recreational, and preservation purposes. Students will prepare analyses and develop other special skills related to the planning process for large-scale areas. Specialized emphasis in the areas of computer-assisted approach to regional land analysis and recreational planning issues are a major part of the option.

Recreation Planning and Design—The recreation planning focus provides an area of specialization in the broad field of recreation. The student interested in this area will develop special capabilities in the design of parks, golf courses, ski areas, camping facilities, recreational streams and rivers, resort grounds, and county or large jurisdictional areas of recreation from both the resource and design capability points of view.

It is strongly recommended that all students show evidence of completing a minimum of 800 hours of practical work experience outside of classwork. At least 400 of these hours should be spent in landscape construction or in a landscape nursery and 400 hours in an office of a professional landscape architect.

ADMISSION PROCEDURES

Application is required to enter the Landscape Architecture program. The procedure is as follows:

1. Complete a minimum of 30 credit hours of acceptable college courses.
2. Complete Form LA 110b (available from the Department of Horticultural Science and Landscape Architecture, St. Paul, the School of Architecture and Landscape Architecture, Minneapolis, or the Office of Admissions and Records).
3. Submit this application form by May 1 of the year the student wishes to enroll.
4. Interview or correspond with a minimum of two members of the Landscape Architecture faculty prior to the May 1 application submission.

Approval of admission will be based on consideration of the following: (a) the student's scholastic standing in high school and on previous college work; (b) his or her maturity and experience; (c) a letter of intent, stating why the student wishes to become a landscape architect.

A student may apply for admission to the Landscape Architecture program at any point in his or her academic or professional career. However, past experience has indicated that application during the second year of college provides the best opportunity for the student to be admitted. All students will be considered on an equal basis except those applying for advanced standing. It is strongly recommended that after two rejections the student apply to another program.

Admission to Basic Design (LA 3081) is normally permitted only in the fall quarter. However, students who wish to apply for advanced standing within the program are requested to bring a portfolio of their work and a grade transcript to discussions with the advisers in Landscape Architecture.

Students are encouraged to visit the design studios and talk to students who are in the program, as well as enroll in the basic Introduction to Landscape Architecture course (LA 1031). Both of these experiences are intended to aid the student in his or her decision to select landscape architecture as a profession.

LOWER DIVISION (IT)

	Credits
Core Course Requirements	36
English Composition or Communications	
Three courses in mathematics, statistics, and computer information	
Chem 1004	
Soc 1001	
AgEc 1020	

LOWER DIVISION (IAg)

	Credits
Core Course Requirements	36
Rhet 1101, 1102, 1022	
Math 1008, 1111	
Chem 1004	
Soc 1001	
Econ 1001	

Following completion of the above, the student must apply for admission to the program before May 1 of the year entry to LA 3081 is sought.

UPPER DIVISION (IT and IAg)

	Credits
Core Course Requirements	103
LA 1022	
LA 1024	
LA 1025	
LA 3071-3072-3075	
LA 3081-3082-3083	
LA 3091, 3092	
LA 3101	
Studio Arts courses (6 credits)	
AgEn 1400 or CE 3100	
Soil 1122	
Biology courses (10 credits)	
Hort 1021-1022	
Hort 3074	
Ecology courses (4 credits)	
Geography courses (5 credits)	
Rhet 3551 or 3552 (IA's only)	
Elective Requirements	18
Option Requirements	58

OPTIONS

Site Planning and Design

	Credits
Design Area	41
Design:	
LA 3093 (6 cr)	
LA 5101 (6 cr)	
Design course (5 cr)	
LA 5110 (6 cr)	
Theory:	
LA 5115-5116 (2-2 cr)	
LA 5124 (1 cr)	
History:	
ArtH 3001 (4 cr)	
Arch 1021 (4 cr)	
Arch 5056 (4 cr)	

Technology Area 8
LA 3073 (4 cr)
LA 5226 (4 cr)
Special Option Requirements 9
Design course electives as approved by adviser
Total Option Requirements 58

Urban Landscape Design

Design Area 42
Design:
LA 3093 (6 cr)
LA 5103 (6 cr)
Design course (6 cr)
LA 5110 (6 cr)
Theory:
LA 5115 (2 cr)
Arch 5137 (4 cr)
Arch 5138 (4 cr)
History:
LA 1021 (4 cr)
LA 1023 (4 cr)
Technology Area 8
LA 3073 (4 cr)
LA 5226 (4 cr)
Special Option Requirements 8
Design course electives selected in consultation with adviser
Total Option Requirements 58

Regional Landscape Design

Design Area 42
Design:
RCD 5100 (3 cr)
RCD 5101 (4 cr)
LA 5107 (6 cr)
Design course (6 cr)
LA 5110 (6 cr)
Theory:
AgEc 3610 (4 cr)
Soil 5540 (4 cr)
Arch 5136 (4 cr)
Arch 5137 (4 cr)
Hort 3099 (1 cr)
Technology Area 4
Aerial Photographic Interpretation or Land Analysis (4 cr)
Special Option Requirements 12
Soc 5401 or 5651 (4 cr)
Electives (8 cr)
Total Option Requirements 58

Recreational Planning and Design

Credits

Design Area 38
Design:
RCD 5100 (3 cr)
RCD 5101 (4 cr)
LA 5105 (6 cr)
Design course (6 cr)
LA 5110 (6 cr)
Theory:
AgEc 3610 (4 cr)
Soil 5540 (4 cr)
LA 5010 (4 cr)
Hort 3099 (1 cr)
Technology Area 4
Aerial Photographic Interpretation or Land Analysis (4 cr)
Ecology Area 7
FW 3050 (3 cr)
Forestry Pathology/Entomology/Arboriculture (4 cr)
Special Option Requirements 9
Soc 5401 or 5651 (4 cr)
Electives (5 cr)
Total Option Requirements 58

Mathematics

The School of Mathematics offers a 4-year curriculum leading to the degree of bachelor of mathematics, B.Math.

In addition to the prescribed courses listed below, a student must meet the minimum liberal education requirement for the Institute of Technology and have sufficient approved electives to total 186 credits in order to graduate.

The course of study is very flexible and can easily be adapted to the needs and interests of all students who wish to concentrate in mathematics as an undergraduate. The graduation requirements can be met by programs emphasizing diverse goals and fields of interest such as graduate school preparation, applied mathematics, engineering science, computer science, actuarial science, etc.

The School of Mathematics has a central advising system. Mathematics majors are required to see an adviser once a year to plan their program for the following year. Students are encouraged to develop individualized programs. Advisers are available throughout the academic year, and appointments can be made in 127 Vincent Hall.

A combined 5-year curriculum is offered in cooperation with the College of Education leading to two degrees, bachelor of mathematics and master of education.

LOWER DIVISION

During their first 2 years students majoring in mathematics are expected to acquire a knowledge of the following subjects (in each case the requirement may be met by the course work alternatives listed):

Calculus of Functions of a Single Variable
- Math 1211-1221-1231
- Math 1311-1321-1331
- (or) Math 1611-1621

Elementary Computer Programming
- CICS 1100 or equivalent

Multi-Variable Calculus, Linear Algebra and Differential Equations
- Math 3511-3521-3531
- Math 3211-3221
- Math 3211, 3142 and either 3066 or 5521
- (or) Math 3611-3621 and either 3066 or 5521
  - (Students electing the latter options may also use Math 5521 to satisfy upper division requirements)

General Physics
- Phys 1271, 1281, 1291
  - (Students must have 1 quarter of calculus before starting this sequence; the associated laboratory course, Phys 1275, 1285, 1295, is recommended but not required)

Mathematics majors who take Math 1211-1221-1231 or 1311-1321-1331 are urged to take Math 3511-3521-3531. Those who take Math 1611-1621 should take 3611-3621. Students who do not take Math 3531 are strongly urged to take 3675 before attempting 5000-level mathematics courses.

In addition to the above, students majoring in mathematics will normally take up to 32 credits of electives during their first 2 years. These electives should include Comp 1001, 1002 and at least 18 credits toward the liberal education requirement.

UPPER DIVISION

All mathematics majors are required to take 48 credits of mathematics at the 5000 level, and the following minimum requirements must be satisfied. (Other sequences may satisfy the depth requirement by petition. The student should check with his or her adviser.)

Analysis Requirement—Completion of one of the following sequences:
Math 5601-5602-5603—Advanced Calculus
Math 5612-5613-5614—Introduction to Analysis

Algebra Requirement—Completion of one of the following sequences:
Math 5242-5243—Linear Algebra with Applications
Math 5282-5273-5274—Modern Applied Algebra
Math 5282-5283-5284—Fundamental Structures of Algebra

Depth Requirement—Completion of one of the following sequences:
Math 5157-5158—Mathematics of Symbol Manipulation Systems
Math 5162-5163-5164—Mathematical Logic
Math 5209, 5244—Theory of Numbers, Group Theory
Math 5341-5342-5343—Introduction to Topology
Math 5366-5367-5368—Geometry
Math 5375-5376-5377—Differential Geometry
Math 5457-5458-5459—Methods of Applied Mathematics
Math 5521-5522-5523—Introduction to Ordinary Differential Equations
Math 5541-5542-5543—Special Functions in Mathematical Analysis
Math 5571-5572-5573—Elementary Partial Differential Equations
Math 5681-5682-5683—Introduction to Probability
Math 5701-5702-5703—Combinatorics
Stat 5131-5132, Math 5676—Theory of Statistics, Introduction to Stochastic Processes

Technical Elective—A 12-credit sequence selected from the following:
Any upper division sequence in the Institute of Technology

(or) Any upper division sequence requiring differential and integral calculus as a prerequisite.

COMBINED MATHEMATICS AND EDUCATION CURRICULUM

The combined 5-year curriculum between the Department of Mathematics and the College of Education leads to the two degrees, bachelor of mathematics (B.Math) and master of education (M.Ed.).

A student may apply for this curriculum during the third quarter of the junior year. The student should have at least a C+(2.50) average in all courses and a B- (2.75) average in mathematics. In addition, completion of the speech, health, and psychological examinations and interviews for the College of Education and approval of the major adviser in Mathematics in the Institute of Technology and the Admission Committee of the College of Education are required.

The student carries courses in both colleges concurrently during the fourth and fifth years and is awarded both degrees when he or she meets the following requirements: 1) Completion of the prescribed courses in both colleges and a total of 231 credits. 2) These must include 45 credits at the 5000 or 8000 level in mathematics and education (minimum of 32 in mathematics) with a B (3.00) average.

Students are advised to obtain a statement of current requirements for the master of education degree at the Education Career Development Office, 1425 University Ave. S.E. In the third quarter of the third year (junior year) the student should apply for the joint program at the Transfer Window, Office of Admissions and Records, Morrill Hall. At the same time he or she should apply for student teaching at the Education Career Development Office. During the third quarter of the fourth year the student should apply for transfer to the College of Education at the Transfer Window, Morrill Hall.

Students in this program are required to satisfy a minor as described in the *College of Education Bulletin*. Normally the minor is in physics, in which the student is required to take the laboratory sequence Phys 1275-1285-1295. (Students minoring in physics must take SeEd 3352, which is offered only in the spring quarter.) Consult the *College of Education Bulletin* for further details. The minor should be completed before the end of the third year of studies.

The required courses for this curriculum are the same as those listed for the B.Math degree, with the following exceptions:

1. The requirement of 48 credits of upper division mathematics courses may be satisfied by substituting Math 3161 or 3675 or 3581 or 3582 for any 5000-level course.
2. Math 3161 is a required course for students in this program and should be taken before the end of the third year of studies.
3. Psy 1001 is required and should be taken before the end of the second year.
4. SeEd 3150, 3155, 3365, 3366, 3661 are required and should be taken before the end of the fourth year.
5. In addition SeEd 3352, HEd 3090, and MthE 8500, 8680 (9 credits), 8980 (3 credits) are required. (Since MthE 8680, 8980 require placement in a secondary school and the writing of an internship paper, students must consult the instructor listed for these courses at the time of registration.)

A student should consult with the College of Education early in his program to make sure that he or she satisfies the requirements for admission to the College of Education.

A sample program of study is available in the School of Mathematics office, 127 Vincent Hall.

CLA students interested in simultaneously obtaining the B.A. degree and the B.S. in education should see the *College of Liberal Arts Bulletin* for details.

Mechanical Engineering

Mechanical engineering is involved in most technological activities of society and dominates many. These include, among others, the automotive, transportation and materials handling fields, environmental and pollution control systems, refrigeration and cryogenics, design of nuclear and conventional power systems, automation, system dynamics and control, and the production of machinery and consumer products. The mechanical engineer may be engaged in design, development, research, testing, manufacturing, administration, sales engineering or education.

The department program provides the scope and emphasis necessary for eventual engineering employment in these fields and preparation for graduate work. The undergraduate receives a strong background in the basic sciences of mathematics, physics and chemistry balanced with courses in engineering science and applied engineering. Through a broad pattern of electives, each student has an opportunity to develop a program of study that reflects his particular area of interest.

Degree Requirements—The 4-year curriculum requires 184 quarter credits which leads to the degree bachelor of mechanical engineering, B.M.E.

ELECTIVE PROGRAMS

The Department of Mechanical Engineering together with the Department of Aeronautics and Engineering Mechanics form the School of Mechanical and Aerospace Engineering. Interdisciplinary programs involving these two departments are available. The student is encouraged to work with his adviser in formulating any cross-disciplinary program which may meet his or her particular objectives.

The total elective program for Mechanical Engineering consists of a minimum of 28 liberal education electives and a coherent program of approximately 24 credits. Thus the student has the responsibility of selecting about 52 credits of course work. It is expected that the student will work closely with the adviser in planning an adjunct elective program. Details of suggested programs are available in 125 Mechanical Engineering, and some are enumerated below:

Power and Propulsion
Design and Controls
Thermodynamics and Heat Transfer
Materials Engineering
Environmental Engineering
Industrial Engineering/Operations Research
Bioengineering
Electromechanical Engineering
Transportation Emphasis

GRADUATE STUDY IN MECHANICAL ENGINEERING

Information regarding a professionally oriented Master's degree program in mechanical engineering and industrial engineering within the Institute of Technology is available in the Mechanical Engineering Department office, 125 Mechanical Engineering. In addition, both the Ph.D. and M.S. degrees with a major in mechanical or industrial engineering are available for those students meeting the entrance requirements of the Graduate School.

SPECIAL PROGRAMS IN MECHANICAL ENGINEERING

Coherent Elective Program—The coherent elective program in Mechanical Engineering provides the flexibility necessary to pursue interdisciplinary study involving several departments, as well as programs involving the community and industry. Detailed information on electives and the coherent elective program is available in 125 Mechanical Engineering. A brief description on a number of the interdisciplinary or special programs is presented below:

Bioengineering—Project work in bioengineering is available at the undergraduate level. In addition, combinations of electives in biology, physiology, chemistry, fluid flow, etc., along with related engineering courses, provide an excellent background for the engineer interested in the bioengineering field and for graduate study in this area. Students preparing for work in bioengineering may also program their work to meet entrance requirements for medical school.

Transportation—The program in transportation typically includes work in several departments. Mechanical Engineering provides transportation project work involving personalized rapid transit, transportation study and planning, statistical planning, vehicle and system design, community impact studies, and many other closely related projects. In addition, propulsion courses relating to vehicle transport as well as a course in urban transportation are offered.

Environmental Engineering—The Mechanical Engineering Department offers work in environmental engineering with emphasis on air pollution, energy utilization, and emission studies. The environmental engineering staff offers courses in particle technology, air quality and conditioning, contaminant control, and thermal environmental engineering. In addition,

the department offers work in propulsion system design, combustion, exhaust emission analysis, and conservation and utilization of energy resources. Environmental work relating to water quality and resources, solid waste disposal, noise pollution, society involvement, etc., is also available in other departments. Combined programs of study can be planned with the adviser.

Nuclear Engineering—An interdisciplinary program in nuclear engineering is available involving course work in the Departments of Mechanical Engineering, Chemical Engineering, and Physics.

Engineering Intern Program—A Mechanical Engineering intern program is available during the last 2 years of study. Completion of the major part of the lower division academic curriculum with a satisfactory GPA is required for admission. Special application must be made in January of the sophomore year. The program provides applied engineering training during alternate quarters of industrial assignments with selected established industries. The student is registered at the University during work periods and is considered a regular full-time student.

The B.M.E. degree will be awarded upon satisfactory completion of all the basic required University work as designated in the regular Mechanical Engineering curriculum, including the 4 alternate quarters of supervised industrial experience. The work assignment credits are considered a part of the coherent elective program requirement.

Students should contact the director of the engineering intern program for information. Candidates will be selected on the basis of scholastic ability, financial need, personal qualifications, and fitness for the work.

Program in Industrial Engineering/Operations Research—Engineering training with specialization in industrial engineering is provided by this program. Students in this program are also eligible to apply for the engineering intern program in Mechanical Engineering. For further descriptive information, see the Industrial Engineering/Operations Research program description.

Preparation for Other Programs—By careful selection of liberal education electives and coherent program electives, one can prepare for a number of other fields for subsequent study. These include combined business and engineering degree programs, preparation for law school, medical school, and so on.

COURSE REQUIREMENTS

The lower division program provides course work in basic and engineering science preparatory to the upper division. The upper division program includes additional engineering science and applied engineering subjects including measurements and design. Additional information, alternate courses, coherent elective program information and specialized preparation is provided in supplemental departmental bulletins available in 125 Mechanical Engineering or through the adviser.

LOWER DIVISION

	Credits
Freshman English or Communications	8
Math 1211, 1221, 1231, 3221, ME 3900**—Analysis I, II, III, Linear Algebra and Differential Equations, Engineering Statistics	24
Phys 1271, 1281, 1291—General Physics	12
Phys 1275, 1285, 1295—Physics Laboratory	3
Chem 1014, MatS 3400** (additional chemistry, biology, ecology, geology, mathematics, physics)	12

**For a complete lower division program description, alternate courses, and suggested scheduling, students should obtain the curriculum handout in 125 Mechanical Engineering.

Introduction to Engineering**	9
EG 1025—Graphics; CICS 3101—Introduction: Fortran Programming; ME 1001—Introduction to Mechanical Engineering	
Engineering Science	16
AEM 3036—Dynamics; AEM 3016—Deformable Body Mechanics; EE 3000—Circuits**; CE 3400 or SMAE 3200—Fluid Mechanics	
Liberal Education Electives (approximate)	8
Total Credits	92

UPPER DIVISION

	Credits
Basic Engineering Program	40
ME 3301, 3303, 5342—*Thermal Engineering*	
ME 3201, 3203, 3205—Mechanical Engineering Systems and Design	
IEOR 5000—Industrial Engineering	
EE 3001—Electronics	
ME 5260—Material Engineering and Processing	
ME 5254—Design Morphology with Applications	
Laboratory Program	8
ME 3701/3702—Basic Measurements Laboratory I, II	
ME 3703/3704—Advanced Mechanical Engineering Laboratory (4 cr)	
Liberal Education Requirement (sufficient to meet liberal education requirements)	20
Coherent Elective Program††	24
Total Credits	92

Metallurgy/Materials Science

(Department of Chemical Engineering and Materials Science)

Metallurgists or materials engineers select and develop metals and alloys, ceramics, and plastics to meet diverse engineering needs. These range from extremely small devices such as microelectronic components to large parts such as turbine rotors for electric generating plants.

Materials engineers also produce materials for metal- and polymer-producing industries. As new products are developed, they are performance tested and their component parts are analyzed by materials engineers, too.

Professionals in this field are indispensable to virtually every product-related industry, as the following list attests:

Industry/Organization	*Metallurgical Engineering Tasks*
aircraft	innovate fatigue, fracture, corrosion and heat resistant materials used from landing gear to engine cowling
automotive	develop high strength, heat resistant materials for low emission gas turbine or steam engines
chemical	select and develop materials to hold exotic combinations of temperature and environment in chemical reactors
communication	provide unique semiconductor devices to represent advances in electronic circuitry
consumer advocates	analyze material failures and recommend solutions for increased product reliability

**For a complete lower division program description, alternate courses, and suggested scheduling, students should obtain the curriculum handout in 125 Mechanical Engineering.

††See information on coherent elective programs under Special Programs in Mechanical Engineering, and obtain an information bulletin in 125 Mechanical Engineering.

energy	develop reliable materials for coal-gassification or fission reactors; develop unique compounds for energy storage, conversion and transmission
medical-dental	create and evaluate potential prosthetic materials
nuclear	develop reliable long-term containment materials for fission and fusion processes
oil and gas	provide basic tools with which the products are extracted and transported
other high technology areas	create new types of metal alloys to push back existing time-environment barriers in aerospace and ocean space exploration

Undergraduate preparation for this field is based on a foundation of mathematics, physics, and chemistry courses, plus specialized professional courses in areas such as materials science, physical and mechanical metallurgy, thermodynamics, polymer engineering and corrosion, and related laboratory work.

Degree Requirements—To receive the bachelor of metallurgical engineering (B.Met.E.) degree, required courses plus electives normally total 191 credits (although the minimum in special cases is 180). Students must complete the IT minimum liberal education requirements (a total of 36 credits including at least 7 in biological science; other categories are explained in Section III of this bulletin), the pre-metallurgical engineering program (91-100 credits), and a coherent degree program of science and technical courses (91-100 credits). Suggested predegree and degree curricula are outlined below. Students, together with an adviser, plan their degree program in two stages: a 1-year plan is submitted at the start of the third year, and, ordinarily, a complete 4-year program is submitted for certification by the department by the beginning of the fourth year. Degree programs may be oriented toward metallurgy or materials science, toward graduate work or professional employment after graduation. Sample programs are available from advisers or from the departmental office, 151 Chemical Engineering.

Transfer Students—Most students intending to transfer from another campus or school with a lower division standing in general engineering have satisfied most course requirements or have equivalent course work to offer. For specific information, such students are encouraged to write or visit the Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, Minnesota 55455. Students can obtain certification of completion of the lower division requirements at the time of transfer.

NORMAL ENGINEERING PROGRAM SATISFYING METALLURGICAL ENGINEERING REQUIREMENTS

First Year Core A (See page 19)

	Credits—f,w,s		
Math 1211, 1221, 1231—Analysis I, II, III	5	5	5
Chem 1031 (or equivalent)—General Principles of Chemistry	5	..	..
Natural Science or Approved Technical Electives	..	4-5	5-9
Comp 1001, 1002—Introductory Composition	4	4	..
Liberal Education Electives	0-4	0-4	4-8

Second Year

ME 3900 (or) Math 3211—Introduction to Engineering Statistics; Analysis IV	4-5	..	..
Math 3221—Linear Algebra and Differential Equations	..	5	..
Phys 1271, 1281, 1291—General Physics	4	4	4

Phys 1275, 1285, 1295—General Physics Laboratory	1	1	1
EBB 3101 (or) GCB 3201—Ecology; Biology	..	4	4
AEM 3016 (and/or) AEM 3036 (and/or) CE 3400—Deformable Body Mechanics; Dynamics; Fluid Mechanics	..	0-8	0-8
Technical Electives	4-5	..	0-5
Electives	0-4	0-4	0-4
Total Credits, Predegree Program			91-100

NORMAL PRE-METALLURGICAL ENGINEERING PROGRAM ON TWIN CITIES CAMPUS

First Year

	Credits—f,w,s		
Math 1211, 1221, 1231—Analysis I, II, III (or) Math 1311, 1321, 1331—Computer Calculus I, II, III	5	5	5
Chem 1031-1032—General Principles I, II	5	5	..
Chemistry or Approved Technical Electives	..	0-5	4-9
Comp 1001, 1002—Introductory Composition	4	4	..
Electives (quarters of registration may be rearranged with Engl 1001, 1002)	..	0-4	4-8

Second Year

Phys 1271, 1281, 1291—Mechanics, Heat and Electricity, Magnetism and Optics	4	4	4
Phys 1275, 1285, 1295—General Physics Laboratory	1	1	1
Math 3211, 3221—Analysis IV, Linear Algebra and Differential Equations	5	5	..
EBB 3101—Ecology for Students of Physical Science	..	4	..
AEM 3016—Deformable Body Mechanics	..	..	4
Technical Electives	4-5	..	0-5
Electives	0-4	0-4	4-8
Total Credits, Predegree Program			91-100

The pre-chemical engineering curriculum also satisfies pre-metallurgical engineering requirements.

Some courses fill both technical and liberal education requirements, such as EBB 3101 and GCB 3201 or approved substitutes for them.

BASIC PROGRAM IN METALLURGICAL ENGINEERING

Third Year

	Credits—f,w,s		
MatS 5011, 5012, 5013—Introduction to Materials Science	4	4	4
Chem 505—Statistical Thermodynamics	4	..	..
ChEn 5001—Mathematical Methods	2	..	..
MatS 5101, 5102—Thermodynamics and Kinetics	..	4	4
MatS 3501, 3521—Quantitative and X-Ray Metallography	3	3	..
Technical Elective	..	..	4
Electives	0-4	4	4

Fourth Year

MatS 5401, 5402, 5403—Principles of Physical Metallurgy	4	4	4
MatS 5301—Advanced Mechanical Metallurgy	4	..	..
MatS 5303—Analysis of Metallurgical Problems	..	..	4
MatS 5610—Polymer Chemistry (or) 5611—Polymer Materials	4	4	..
MatS 5450 (or) Chem 5502 (or) Phys 3501—Corrosion of Metals; Quantum Mechanics; Modern Physics	..	0-4	0-4
AEM 5580 (or) ME 5207—Mechanics of Elastic Solids I; Experimental Stress Analysis	4	..	..
Technical Elective	..	0-4	0-4
Electives	0-4	3-4	3-4
Total Credits, Degree Program			91-100

Mineral Engineering

(Department of Civil and Mineral Engineering)

Production processes in mining involve the development and management of mines, the design of production systems and plants, and economic and technical evaluations of these operations.

Mineral and metal extractive processes include beneficiation of ores and other mineral aggregates, extraction of metals from the ores and beneficiated products, and, frequently, purification of the metals produced by these processes. Beneficiation covers such areas as physical processing, chemical processing, site reduction and gravity, magnetic, and flotation concentration; hydrometallurgy deals with the leaching of ores; pyrometallurgy concerns the high-temperature operations of roasting, agglomeration, smelting, and refining.

Mineral resources engineering blends into a unified and balanced program the disciplines of mineral production processes and mineral and metal extraction processes. This field of study is closely allied with geo-engineering.

A broad undergraduate curriculum includes preparation in basic sciences, engineering, geology, and economics. There is some overlap, since the production engineer and the extractive engineer must be knowledgeable of each other's specialties. Common to both areas of study, for example, is the field of mineral economics, which examines the probability of success or failure of a mineral venture. All courses presented treat the environmental aspects of the mineral industry.

The Mineral Resources Research Center, an integral part of the Department of Civil and Mineral Engineering, offers extensive pilot plant and laboratory facilities which provide a unique opportunity for the training of students in the mineral engineering field. Its staff members teach many undergraduate courses in mineral processing and extractive metallurgy.

A 4-year curriculum is offered that leads to the degree of bachelor of mineral engineering (B.Min.E.). A total of 184 credits (or equivalent demonstrated competence), including field trips, is required for graduation.

Following is a recommended program which can be modified, in consultation with a faculty adviser, to better meet individual student interests.

LOWER DIVISION

	Credits
English Composition or Communications	8
Math 1211, 1221, 1231, 3221—Analysis I, II, III, Introduction to Linear Algebra and Differential Equations	20
Phys 1271, 1275, 1281, 1285, 1291, 1295—General Physics (with Laboratory)	15
Chem 1004, 1005—General Principles of Chemistry	8
Chem 1006—Principles of Solution Chemistry (processing option) (or) AEM 3016—Deformable Body Mechanics (production option)	4
AEM 1015—Statics	4
CE 3010—Data Analysis and Optimization	4
CICS 1100—Fortran Introduction to Computer Programming I	2
CE 3400—Fluid Mechanics (or)	4
MinE 5825—Metal Heat Transfer and Fluid Flow (processing option)	4
EG 1025—Engineering Graphics	4
Liberal Education Elective (EBB 3101—Ecology recommended for engineers, physical scientists)	16
Total Credits	89

UPPER DIVISION—MINERAL PROCESSING AND EXTRACTIVE METALLURGY OPTION

Junior Year

	Credits
MinE 5611, 5612, 5613—Mineral Engineering I, II, III	12
MinE 5800, 5810, 5820—Mineral Processing I, II, Metal Extraction	13

MinE 5830—Microscopy for Mineral Engineers	3
Geo 1111, 3401—Physical Geology, Introductory Mineralogy	10
GeoE 5437—Computer Applications in Geo- and Mineral Engineering	4
Liberal Education Electives	4
Total Credits	46

Senior Year

Chem 5520, 5521—Elementary Physical Chemistry	6
EE 3002—Electrical Machinery and Power Distribution	5
MatS 3400—Mechanical Properties of Materials	4
MinE 5619—Engineering Field Study	3
MinE 5652—Mineral Engineering Design II	4
MinE 5700—Systems Analysis for Mineral Engineers	4
MinE 5710—Environmental Aspects of Mineral Engineering	4
MinE 5910—Metallurgical Unit Processes	4
MinE 5818—Hydrometallurgy	4
Liberal Education Electives	4
Total Credits	42

UPPER DIVISION—MINERAL PRODUCTION OPTION

Junior Year

	Credits
MinE 5611, 5612, 5613—Mineral Engineering I, II, III	12
MinE 5800, 5810, 5820—Mineral Processing I, II, Metal Extraction	13
Geo 1111, 3401—Physical Geology, Introductory Mineralogy	10
Geo 3103—Structural Geology	5
GeoE 5216—Geo-Engineering and Rock Mechanics I	4
GeoE 5437—Computer Applications in Geo- and Mineral Engineering	4
CE 3100—*Introduction to Surveying and Mapping*	4
Total Credits	52

Senior Year

EE 3002—Electric Machinery, Power Distribution	5
MinE 5619—Engineering Field Study (2 weeks in September)	3
MinE 5630—Surface Mining	4
MinE 5650, 5652—Mineral Engineering Design I, II	8
MinE 5700—Systems Analysis: Mineral Engineers	4
MinE 5710—Environmental Aspects of Mineral Engineering	4
MinE 5720, 5722—Mineral Plant Engineering I, II	8
Liberal Education Electives	8
Total Credits	44

Physics

Since physics is concerned with the description of the fundamental properties of the physical universe, the Physics curriculum may appeal to students with many diverse educational objectives. Some seek employment after receiving the Bachelor's degree, often in an industrial or government laboratory. Others will pursue further study, either in physics or in other areas such as biology, medicine, law, or business. Students interested in careers as high school teachers may wish to consider the 5-year program leading to a B.Phys. and an M.Ed. in science, or the 4-year program in the College of Education leading to a B.S. with a major in physics. Both programs lead to certification. Information on these programs is available in the undergraduate office, 148 Tate Laboratory of Physics.

It has been the experience of the department that unless most of a student's grades in the freshman mathematics and physics courses are A or B, he or she will have difficulty pursuing a physics major.

Because of the varied interests of students pursuing this degree, the required courses have been designed to provide a broad foundation in experimental and theoretical physics. The required courses represent a minimum program, and students preparing for certain careers may want to take more physics courses than are required. Many elective courses are available, and students should consult their adviser or the undergraduate office to plan their program. Sample programs for several areas of interest are available in the undergraduate office.

A course of study totaling 180 credits is required for the degree. This assumes that the student has satisfied the IT requirement in English composition and has completed 3 years of foreign language in high school. German, Russian, or French is recommended to fulfill the language requirement.

If a student must take English composition courses at the University of Minnesota, the number of credits taken is added to the graduation requirement. This can increase the number of credits required for graduation by as much as 8 credits.

If the student has not had 3 years of foreign language in high school, he or she must complete the third quarter of a foreign language at the college level. College-level language courses are usually 5 credits per quarter, and of those 5 credits, 3 are added to the graduation requirement and 2 may be applied toward the liberal education requirement described below. For a student who must take three language courses (15 credits) at the college level, this means that the graduation requirement is increased by 9 credits, and 6 credits are applied toward the liberal education requirement.

To summarize the effect of English composition and foreign language on the number of credits required for graduation:

	Credits
English composition and language satisfied in high school	180
Must take 8 credits English composition; language satisfied	188
Must take 15 credits of language; English satisfied	189
Must take both English composition and language	197

In the Physics curriculum the English credits may not be counted toward the 36 liberal education credits required below.

GRADUATION REQUIREMENTS

(Based on 180 credits)

	Credits
Liberal Education	36
Of these 36 credits, at least three courses (12-15 credits) must be in Category 3 (Man and Society), and at least two courses (8-10 credits) must be in Category 4 (Artistic Expression). The remaining courses may be in any category except 1 (Communication, Language, Symbol Systems) or 2 (Physical and Biological Sciences). At least two of the courses must be upper division (3000 level) or upper division/graduate (5000 level).	
Mathematics	
Math 1211-1221-1231 (or) Math 1311-1321-1331 (or) Math 1611-1621	10-15
Math 3211-3221-3231	14
Two additional courses	8-10
Required Physics Courses	
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
Phys 3011—Oscillations	4
Phys 3012—Waves and Optics	4
Phys 3511-3512-3513—Modern Physics	12
Phys 3015—Laboratory in Oscillations and Waves	1
Either of the following sequences:	16-20
a. Phys 5021-5022—Introduction to Analytic Mechanics (and) Phys 5023-5024—Introduction to Electric and Magnetic Fields	
b. Phys 5011-5012-5013—Mechanics, Electricity, and Magnetism (and) Phys 5101-5102—Introduction to Quantum Mechanics	

One course in advanced laboratory (5120 or 5804) and one additional course in either advanced laboratory or electronics	8-9
Physics electives to total 70 credits	4-9
Electives to total 180 credits	35-42
Subtotal	180
English and/or Foreign Language as required	0-17
Total Credits	180-197

Electives—The curriculum includes 4-9 credits of required physics electives and 35-42 credits of completely unspecified electives. Because the specified physics courses represent a minimum requirement, most students will want to take some of the unspecified electives in physics or allied areas.

Some of the electives recommended for students interested in graduate school or a career in industry are shown below. More extensive lists are available in the undergraduate office, 148 Tate Laboratory of Physics.

Electives Suggested for Students Interested in Graduate School:

Topics in Mathematical Physics (Phys 5031-5032-5033)
Sequence a above, with Quantum Mechanics (Phys 5101-5102) as an elective
Thermodynamics, Statistical Mechanics (Phys 5201-5202)
Advanced Laboratory (additional)
Electronics (Phys 5851, 5852, 5853)
One quarter specialty courses (e.g., nuclear, solid state, elementary particle physics, plasma physics, contemporary optics, etc.)
Astronomy (Ast 3051, 5161, 5162)
Mathematics
Chemistry
History of Physics
Computer Programming
Classical Physics (Phys 5051-5052-5053)
Quantum Mechanics (Phys 5151-5152-5153)

Electives Suggested for Students Interested in Industrial Employment:

Electronics (Phys 5851, 5852, 5853)
Chemistry
Advanced Laboratory (additional)
Computer Science
Specialty courses
Technical Writing (Engl 3085)
Thermodynamics (either as physics or chemistry)
Materials Science
Electrical Engineering
Aerospace and Engineering Mechanics (fluid, mechanics, elasticity, acoustics)
Geophysics

III. ACADEMIC REQUIREMENTS

Liberal Education Requirement

Institute of Technology students, whatever their area of specialization, hold in common with all University students the search for a liberal education—one which enhances their powers of judgment and choice. A liberal education implies awareness of the intellectual instruments for acquiring and communicating knowledge, primarily the instruments of language and structure, understanding of the ways in which engineers and scientists contribute to man's knowledge of himself and his environment, historical and philosophical perspective on the nature of the individual and society, and appreciation of the role of literature and the arts in the interpretation of life and nature.

The Institute of Technology faculty accepts the divisions of knowledge outlined below, as developed by the All-University Council on Liberal Education. The Institute of Technology minimum liberal education requirement, together with required courses in English, mathematics, and the physical sciences, exceeds the basic all-University requirements of the Council on Liberal Education. Courses to meet the minimum liberal education requirement are to be selected from the course catalog available in department offices and in 105 Main Engineering. Students are urged to select courses from the required categories in coherent sequences.

Minimum Liberal Education Requirement—In addition to required courses in mathematics and the physical sciences (which meet or exceed the all-University requirements for categories), a minimum of 36 credits of liberal education courses are required, subject to the following distribution requirements:

1. Two courses (8-10 credits) of English composition. If a student is exempt from freshman English, the 8-10 credits may be made up in item 3 below.
2. Three courses (12-15 credits) in Category 3, Man and Society.

   Afro 1015, 1036, 1441, 1442, 3001-3002-3003, 3061-3062, 3075, 3076, 3081-3082, 3091, 3092, 3098, 3455, 5001-5002, 5101, 5102, 5103, 5401
   AgEc 1020
   Air 1201, 1202, 1203, 3401
   AmIn 1101, 1102, 3061, 5112, 5121, 5131, 5570, 5990
   AmSt—All courses
   Anth—All courses except 5421 (now 5161)
   Arch 1001-1002-1003
   CJS—All courses
   Clas 1001, 1002, 1003, 1004, 1005, 1006, 1011, 1022, 1033, 1042, 1044, 1055, 1066, 3071, 3072, 3073, 5004, 5071, 5072, 5073
   CPsy—All courses
   Econ—All courses
   Fren 3501-3502-3503
   FSoS—All courses
   Geog—All courses except 1425
   Ger 5331
   Grk 5794
   Hebr 3131-3132
   Hist—All courses
   Hum—All courses
   Indc 1504-1506, 3506, 3507, 3533, 5511-5512, 5520, 5531-5532-5533
   Ital 3501-3502
   Jour 1003, 1701, 3021, 3776, 5501, 5601, 5603, 5611, 5615, 5721, 5801, 5825
   Lat 5794
   LAS 5101
   Lib 5101, 5221
   MidE 3125, 3501, 3502, 3555
   Mil 1011, 1012, 1013, 1021, 1022, 1023, 5145

Nav 1104, 1205, 3304
Phil 1002, 1003, 1004, 3001, 3002, 3003, 3004, 3202, 3302, 5003, 5005, 5008, 5021, 5033, 5034, 5035, 5036, 5041, 5042, 5043, 5044, 5054, 5301, 5302, 5311, 5414, 5611, 5612, 5621, 5781
Pol—All courses except 3085
Psy—All courses
RelS 1031-1032-1033
Russ 3501, 3502, 3503
Scan 1504, 3501
Soc—All courses
Span 3001
Spch 1103, 3401, 5211, 5222, 5231, 5232, 5233, 5402, 5403, 5421, 5431, 5441, 5451, 5602
SSci—All courses
SW—All courses

3. Two courses (8-10 credits) in Category 4, Artistic Expression.

Afro 1301
Amln 5211
AmSt—All courses
Arab 5211-5212
Arch 1021, 1022, 1023, 5051, 5052, 5053, 5054, 5055, 5056
ArtH—All courses
ArtS—All courses
Clas 3081, 3082, 3083, 5081, 5082, 5083, 5107-5108-5109, 5115
Engl—All courses except 3085
Foreign Languages—Any upper division foreign literature course may be used
Fren 3601-3602-3603
Ger 3104, 3105, 3301, 3302, 3303, 3311, 3312, 3313, 3331, 3341, 3342, 3401, 3402, 3403, 3601, 3602, 3603
Grk 1104-1105, 3106-3107, 3461, 3464, 3471, 3474, 5264, 5265, 5266, 5371, 5372, 5373, 5374, 5375, 5376, 5377, 5378, 5379, 5381
HE 1501, 1521, 1541
Hebr 3201-3202, 3121-3122-3123, 3301
Hum—All courses
Jour 5606, 5171
LA 1021
Lat 1104-1105, 3106, 3461, 3462, 3463, 3464, 3465, 3466, 3467, 3471, 3472, 3473, 3474, 3475, 3476, 5371, 5372, 5373, 5374, 5375, 5376, 5377, 5378, 5379, 5715
MdGk 1104-1105
Mus—All courses
Pers 5990
Phil 5501
Russ 3601-3602, 5403, 5409
Scan 5503, 5512, 5601, 5631, 5632, 5633, 5670
Spch 3201, 3202, 3203, 3204, 5201, 5204
Th—All courses

4. Additional credits may be in any category except courses in astronomy, chemistry, CICS, geology, mathematics, and physics. These additional credits may include any lower division foreign language course and courses in the biological sciences and ecology, unless specifically excluded by the student's department. CLEP examinations may be used for partial fulfillment of requirements. Further, students are strongly urged to take courses which study the impact of science and technology on society and the environment.

The above lists of courses are EXAMPLES ONLY and do not include all of the courses which may fulfill the requirements.

Courses required in a specific curriculum, which otherwise meet the distribution requirements above, can apply toward the IT liberal education distribution requirements.

Normally, students are expected to meet the specific category requirements; *however*, in cases where students, in planning what they believe to be a coherent program, find themselves over in one category and short in another, this imbalance will in all probability be approved if the student petitions and asks for permission to take a particular program or to be exempted from the total credit requirement for a certain category.

Students are encouraged to take higher-level courses and deepen their knowledge of some area in which they are interested. The prerequisites for upper division courses are often quite modest. In addition, students who feel that their education is better served by a certain amount of concentration in one area, even when this does not fulfill the letter of the distribution requirements, may petition to the IT office for waiver of the category requirements.

General Regulations

Grading System—The Institute of Technology uses the same grading and symbol system as the other collegiate units on the Twin Cities Campus—A, B, C, D, S, N, I, and W. Students should check the fall quarter *Class Schedule* or inquire in 105 Main Engineering for more information.

Transcripts—Since fall quarter 1972, academic records of all new freshmen are stored on computer. Computer storage made possible a dual transcript system comprised of an operational record and an external transcript. The operational record, used internally, lists all courses attempted and grades received at the University, including transfer credits accepted from advanced standing students. The external transcript is the official transcript sent by student request to other educational institutions, prospective employers, or others. Grades of N and I and the symbol W do not appear on this transcript.

Academic records of students admitted to the University prior to fall quarter 1972 are maintained on a handwritten document. Grades of F and N and the symbols I and W do appear on this transcript.

Students with only handwritten records (except those who graduated before spring quarter 1974) may have their transcripts converted to the computer system. In doing so, they acquire an external transcript which reports no F and N grades or I and W symbols in courses they have taken since fall quarter 1972. If those evaluations were received in courses taken before fall quarter 1972, they will still appear on the external transcript. A $10 fee is charged for the conversion, and the process takes about 4 weeks to complete. Forms for IT students requesting the change are available at Window 22 in 106 Morrill Hall.

Minimum GPA—Satisfactory work, one of several conditions for continuing enrollment in IT, is represented by a C average; that is, a grade point average (GPA) of 2.00 or above. In addition, IT students taking the following lower division IT sequence courses must earn a grade of at least C each quarter to continue in the sequence:

Chem 1004, 1005
Chem 1031, 1032, 1034, 3034
Chem 1034, 3034
Chem 3301, 3302, 3303
CICS 1100, 1101
EE 1510
Geo 1001, 1002
Math 1201, 1211, 1221, 1231**
Math 1311, 1321, 1331**
Math 1611, 1621**
Math 3211**
Math 3511, 3521, 3531

**Students must earn at least a C in the course listed immediately before the ** to take additional courses in the same department.

Math 3611, 3621
Phys 1121, 1122
Phys 1271, 1281, 1291**
Phys 3511, 3512, 3513

Degree Progress—The Institute of Technology computes what is termed a coefficient of completion for each of its undergraduate students. It is calculated on both a quarterly and a cumulative basis. The coefficient is computed as a ratio of credits satisfactorily completed, divided by the total credits the student had registered for as of 6 weeks into the quarter. Note that a D grade is not considered to be satisfactory completion of a course. Students whose cumulative coefficient of completion is less than .7 following the completion of 3 quarters of work in IT will be placed on academic probation; students whose quarterly coefficient of completion is .5 or less for 2 consecutive quarters will be placed on academic probation. Students on academic probation because of a deficient coefficient of completion must appeal their status to their department's Scholastic Standards Committee prior to a specified deadline date. Lacking a satisfactory appeal, such students will be automatically dropped from the Institute of Technology.

Probation—Students whose cumulative GPA is less than 2.00 at the end of any quarter are placed on academic probation. They are usually given 1 quarter to raise their GPA above 2.00 or will be subject to dismissal. Most departments review their students on academic probation at least once a year; some departments review them more frequently.

Departments initiate the review of students on academic probation by scheduling interviews with the students involved and with the departmental Scholastic Standards Committee. Students appearing before this committee should bring their latest grade slip or an up-to-date transcript to the conference. Before the meeting, two copies of the Academic Probation Appeal form (form E-100) are prepared in the IT office, 105 Main Engineering. After the departmental review, the student returns one copy of the form to the IT office. The department retains the other copy. Following a review of the exclusion appeal by the assistant dean of IT, the department's action is considered final.

Repeating Courses—Students are allowed to repeat courses in which they received a D, and only the last grade earned is then used in computing their GPA for graduation.

Students who want to repeat courses in which they received a grade of C or better must petition for approval to do so. Forms are available in 105 Main Engineering.

Canceling Courses—Students may cancel a course up to the end of the sixth week without receiving a W. A course canceled after the sixth week will receive a W which will be used in computing the coefficient of completion.

Changing Majors—To change majors within IT, students must petition requesting such a change. Forms are available in 105 Main Engineering. Petitions must be approved by the chairman (or his representative) of the department to which the student wishes to transfer.

To change majors from IT to another collegiate unit or campus within the University, students must apply for transfer through the Office of Admissions and Records, as far as possible in advance of the projected transfer. Some units have transfer application deadlines. Students must meet admission requirements of the unit they wish to enter.

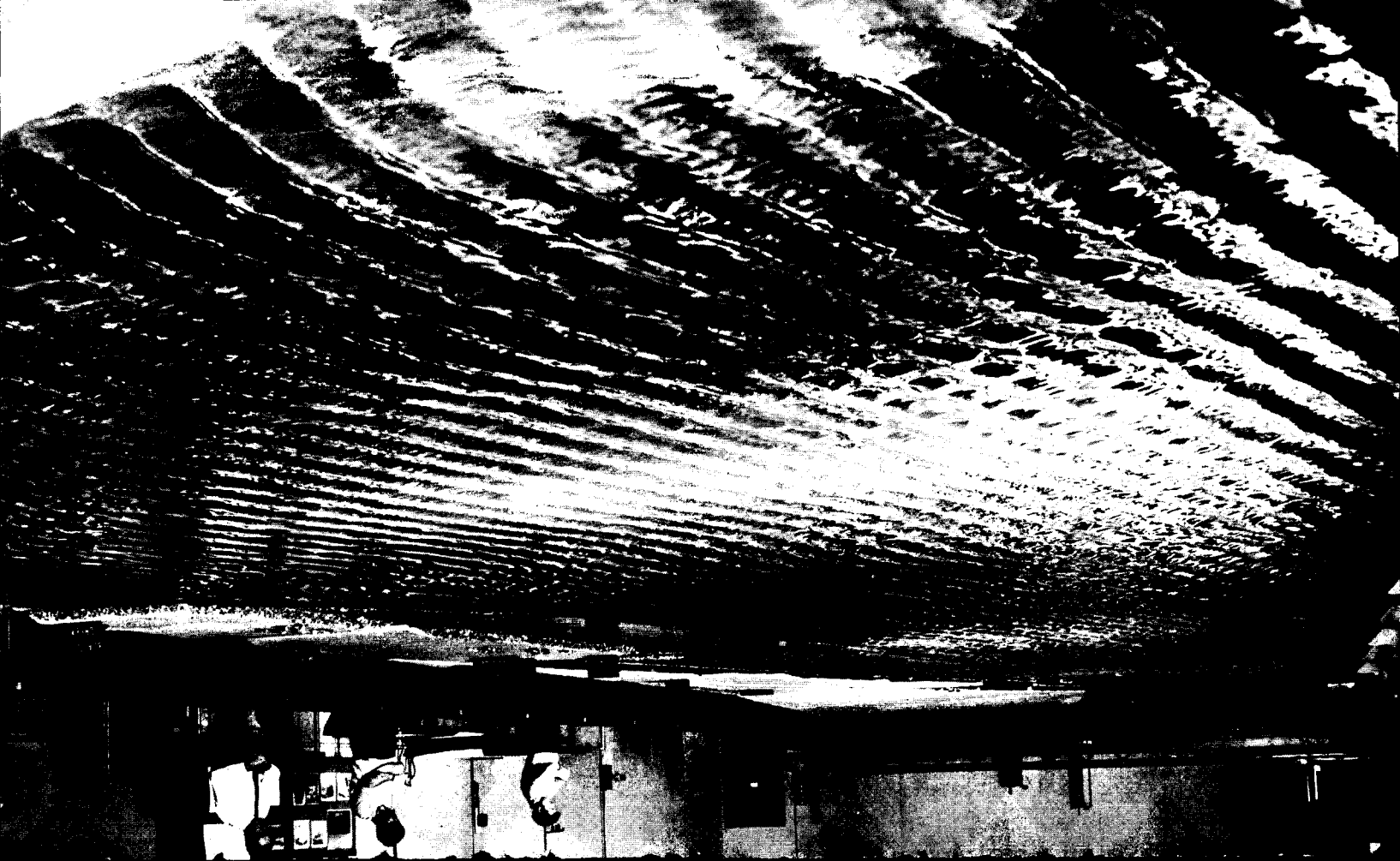
**Students must earn at least a C in the course listed immediately before the ** to take additional courses in the same department.

Transfer Students—Transfer credit is allowed for a grade of D in a technical course sequence only if it is followed by a higher grade in the next course in the sequence.

To receive an undergraduate degree, students entering with advanced standing must present 45 credits earned at the University of Minnesota. Of the last 45 credits earned prior to graduation, 30 credits must be awarded by this University. Credits earned through evening class and independent study work may be applied to the 45-credit residence requirement.

Graduation—The Bachelor's degree with professional designation will be recommended for those students with a grade point average of 2.00 or better who have completed all of the required work and the total number of credits specified in their curriculum.

Prospective graduates should go to Window 22 in 106 Morrill Hall to complete an Application for Degree approximately 1 year prior to the scheduled graduation date.



IV. COURSE DESCRIPTIONS

Symbols—The following symbols are used throughout the course descriptions in lieu of page footnotes:

* Courses in which it is possible for graduate students to prepare Plan B projects.

† All the courses preceding the dagger must be completed before credit will be granted for any quarter of the sequence.

§ Credit will not be given if the equivalent course listed after the section mark has been taken for credit.

¶ Means "concurrent registration."

‡ Means "consent of instructor is required."

△ Means "consent of division, department, or school offering course is required."

f,w,s,su Following a course number indicate fall, winter, spring, or summer quarters.

A hyphen between course numbers (3142-3143-3144) indicates a sequence course which must be taken in the order listed.

A comma between course numbers (1234, 1235, 1236) indicates a series of courses which may be entered any quarter.

Courses numbered 8000 or above are for graduate students only, except by specific permission of the dean of the Graduate School.

A class rank prerequisite (3rd year) means that no one below that rank may register for the course without specific permission from the Scholastic Standards Committee.

A prerequisite course listed by number only (prereq 5246) is always in the same department as the course being described.

Special Interest Courses for IT Students

EBB 3101. ECOLOGY FOR ENGINEERS AND PHYSICAL SCIENTISTS. (4 cr, §1003, §3001, §Biol 1104; not open to biology majors; prereq Math 1231)
Course for engineers and physical science students to present a scientifically sound understanding of the basis for the existence and continued existence of life on the earth.

Engl 3085. TECHNICAL WRITING FOR ENGINEERS. (4 cr; prereq completion of freshman English)
Theory and practice in technical and professional writing.

I of T 1811. HISTORY OF ANCIENT AND MEDIEVAL SCIENCE. (4 cr)
Physics and biological sciences in antiquity and their transmission to and development in the Middle Ages; Egyptian and Babylonian mathematics and astronomy; the systems of Aristotle, Galen, and Ptolemy; medieval mechanics and cosmology; alchemy and astrology.

I of T 1812. HISTORY OF 16TH- AND 18TH-CENTURY SCIENCE. (4 cr)
The "scientific revolution." Copernican revolution; mechanics (Galileo and Newton); anatomy and physiology (Vesalius and Harvey); and chemistry (Lavoisier). The relations of the "new" science to the "new" philosophy and to the emerging Western industrial society.

I of T 1813. HISTORY OF 19TH- AND 20TH-CENTURY SCIENCE. (4 cr)
Development of physics, biology, chemistry, and geology. Darwin and evolution; genetics; electricity; and atomic physics. Philosophical and social issues including social Darwinism and the development of atomic weapons.

SSci 3402. ECOLOGY, TECHNOLOGY, AND SOCIETY. (4 cr)
The impact of technology on society as seen by engineers, scientists, and social scientists. Social problems associated with economic growth such as environmental consequences, the arms race, food and fertilizers, and population growth. Alternative strategies for meeting the problems.

Courses in the history of science and technology (HSci) are available through the College of Liberal Arts. These courses study the origins and development of science and technology and consider their relations to the social, cultural, and philosophical currents of their times. See the current *Class Schedule* for quarterly course offerings.

Aerospace Engineering and Mechanics (AEM)

1001. AEROSPACE ENGINEERING ORIENTATION. (1 cr; prereq 1st-qtr freshman interested in aerospace engineering)
Fundamentals of aerospace engineering practice presented by professional engineers and members of the faculty.

1005-1006. AEROSPACE SURVEY AND LABORATORY. (1 cr per qtr)
Science, engineering, and aerospace technology. Course areas and technical electives in aero curriculum. Trajectories, orbits, flight mechanics, structures, and materials. Experimental and theoretical aerodynamics. Winged atmospheric, ballistic, and space vehicles.

1015. STATICS. (4 cr; prereq Math 1231)
Vector algebra. Principles of statics. Application of the equations of equilibrium to the analysis of simple structures and machines. Statically determinate beams. Cables. Nature and influence of friction.

3016. DEFORMABLE BODY MECHANICS. (4 cr; prereq mathematics through differential equations and linear algebra)
Principles of statics; equilibrium conditions. Uniaxial loading and deformation. Stress and strain at a point. Material behavior; linear elasticity. Torsion. Bending of beams of symmetrical section.

3017. INTERMEDIATE SOLID MECHANICS. (4 cr, §3016; prereq CE 3605 or ‡)
Analysis of stress and strain at a point. Stress equilibrium equations. Strain-displacement equations. Stress-strain-temperature relations. Application to torsion and simple stress concentration problems.

3036. DYNAMICS. (4 cr; prereq mathematics through differential equations and linear algebra)
Review of particle dynamics. Mechanical systems and the rigid-body model. Equilibrium. Kinematics and dynamics of plane systems. Technical applications.

3092. STATICS AND MECHANICS OF MATERIALS. (4 cr; prereq Math 1231, Phys 1121; 3 lect and 2 rec periods per wk)
Forces, equilibrium, and free-body diagrams. Analysis of statically determinate, plane pin-connected trusses and frames. Graphical methods. Moment and shear distribution in beams. Bending of beams. Buckling of columns.

3093. MECHANICAL PROPERTIES OF CONSTRUCTION MATERIALS. (4 cr; prereq 3092; 3 lect and 1 lab period per wk)
Strength and deformation of metals, polymers, timber, ceramics, glass, and composites. Response to tensile, compressive, torsion, and bending loads. Environmental effects. Acoustical properties. Tests for determining mechanical properties.

3401. INTRODUCTION TO DYNAMICAL SYSTEMS. (4 cr, §ME 3201; prereq 3306)
Mathematical modeling of mechanical, hydraulic, and electromechanical systems. Laplace transforms, transfer functions and block diagrams, response of free and forced systems, elementary concepts in feedback control, frequency response.

5200. KINEMATICS AND DYNAMICS OF FLUID FLOW. (4 cr, §CE 3400; prereq mathematics through differential equations and linear algebra; 3 lect and 2 rec hrs per wk)
Kinematics of fluid flow including continuity equation, vorticity, circulation, velocity potential, source, and doublet. Application of Gauss' and Stokes' theorem to fluid flow. Flow about cylinder. Potential flow in two and three dimensions. Dynamics, Euler's equation, Bernoulli's equation. Aerostatics.

5201. SHOCK WAVES AND COMPRESSIBLE FLUID FLOW. (4 cr; prereq 5200; 3 lect and 2 rec hrs per wk)
Basic concepts of thermodynamics. One-dimensional steady isentropic flow. Laval nozzle. Normal and oblique shock waves and reflections. Prandtl-Meyer flow. Supersonic thin airfoil theory.

5202. INCOMPRESSIBLE BOUNDARY LAYER THEORY. (4 cr; prereq 5200; 3 lect and 2 rec hrs per wk)
Curvilinear coordinate systems, cylindrical and spherical. Viscous incompressible flow. Thin airfoil theory. Stress and strain rate. Navier-Stokes' equation. Boundary layer equation and Blasius solution. Von Karman momentum integral. Pohlhausen method. Turbulent boundary layer.

5204. INCOMPRESSIBLE POTENTIAL FLOW. (4 cr; prereq 5200 or ‡)
Irrotational, incompressible flows in two dimensions are solved by complex variable methods. These methods are applied to analysis of airfoils and to other motions of interest in aerodynamics.

5206. AERODYNAMICS OF LIFTING SURFACES. (4 cr; prereq 5200)
Thin airfoil theory, finite wing, aspect ratio, planform, lift distribution, effect of viscosity, the boundary layer, skin friction drag, polar diagrams, dimensional analysis, and dynamic similarity. Review of linearized supersonic theory.

5220. INTERMEDIATE INVISCID FLOW. (4 cr; prereq 5200 or ‡)
Motion and interaction of two-dimensional vortices. Vortex streets and wakes. Application to ground effects, biplane, wake drag. Vector potentials applied to airfoil theory. Three-dimensional flows induced by the motion of solids. Induced mass and impulsive motion.

5240. RAREFIED GAS DYNAMICS. (4 cr; prereq 5201 or ‡)
Elementary kinetic theory. Relationship between continuum and molecular models for gas flow. Free molecule flows. Lift, drag, and energy transfer in free molecule flows. Slip flow and temperature jump.

5241. HIGH SPEED GAS DYNAMICS. (4 cr; prereq 5201)
One-dimensional unsteady flow. Shock tube flows. Characteristics. Weak wave theory. Two-dimensional supersonic airfoil theory. Blast wave theory. Hypersonic similarity. Hypersonic flow past slender bodies with sharp leading edges. Effects of slight leading edge blunting. Resistance and drag. Viscous effects.

5242. ONE-DIMENSIONAL GAS DYNAMICS. (3 cr; prereq 5201)
Properties of normal shocks. Flows through nozzles. One-dimensional channel flow with friction and energy addition. Continuous unsteady one-dimensional flows of perfect fluids. Flows in wind tunnels and diffusers. Shock tube flows.

5270. TURBULENCE AND ATMOSPHERIC FLUID DYNAMICS. (4 cr; prereq some background in viscous flow such as 5202, or ‡)
General survey of the large-scale circulation of the earth's atmosphere. Review of laboratory turbulence and application to the atmospheric boundary layer. Eckman layer. Thermal stratification. Diffusion of pollutants in the atmosphere.

5290. INTRODUCTION TO MAGNETOHYDRODYNAMICS. (4 cr; prereq 5200 or ‡)
Fundamental equations and concepts of magnetohydrodynamics and electrohydrodynamics. Transport of magnetic field, MHD channel flow, Alfven waves, transverse waves, and magnetogasdynamic flow over thin bodies. Steady electrohydrodynamic convection in drops and around bubbles, cellular convection.

5300. FLIGHT MECHANICS. (4 cr; prereq 5206)
Standard atmosphere, analysis of power required, the classical performance data, maximum and minimum speed, maximum rate of climb, angle of climb and glide, absolute ceiling, service ceiling of propeller and jet propelled aircraft. Static longitudinal stability, wing contribution, tail contribution, fuselage contribution, and the neutral point. Power effect and longitudinal control. Introduction to longitudinal dynamics.

5309. ROCKET AND SPACECRAFT PERFORMANCE. (4 cr; prereq 3036)
Single and multistage rocket configurations; stabilization and control by gimbal motors, vernier engines, gyros and other means. Rocket thrust, velocity, and altitude as functions of specific impulse and design parameters. Circular, elliptical, and escape trajectories about a central body; orbit determination, period of orbits and transfer orbits. Terrestrial vacuum trajectories, range, velocity, and period. Reentry trajectories, flight mechanics of shuttle aircraft.

5319. DYNAMIC STABILITY OF AEROSPACE CRAFT. (4 cr; prereq 5206 and 3401)
Static stability coefficients and derivatives about the three main axes. Equations of motion for six degrees of freedom. Decoupled equations of motion about the longitudinal axis, specific and generalized. Effect of elevator and rudder powers, stick-fixed and stick-free conditions. Ruth's discriminant. Aerospace vehicle working equations and solutions. Vehicle response to control actions.

5321. AUTOMATIC FLIGHT CONTROL SYSTEMS. (4 cr; prereq 3401, ¶5300, or equiv or ‡)
Analysis and synthesis of automatic flight control systems for aerospace vehicles, longitudinal and lateral autopilots, gain scheduling, control of inertial cross-coupling.

5330, 5331. DESIGN OF AEROSPACE ELEMENTS AND SYSTEMS. (4 cr per qtr; prereq 4th-yr engineer and ‡)
Interdisciplinary projects with students from other departments.

5359. AERODYNAMIC DECELERATOR PERFORMANCE. (4 cr; prereq 5200 and 3036)
Structurally integrated decelerators, reverser propellers, jet thrust reversers, retrorockets. Types of subsonic, supersonic, and gliding parachutes. Aerodynamic coefficients as function of geometric and cloth porosity. Nominal and effective porosity. Aircraft antispin, brake and landing parachutes. Terrestrial and reentry trajectories, serial delivery, and recovery systems.

5360. DYNAMICS OF AEROSPACE RECOVERY SYSTEMS. (4 cr; prereq 3036 and 5200)
Exact and approximate reentry trajectories. Dynamics and aerodynamics of decelerator deployment and activation. Layout and sequencing of multistage recovery systems for airplanes, airborne and space objects, and shuttle aircraft. Dynamic stability of load-parachute systems.

5370, 5371. AERODYNAMICS OF V/STOL FLIGHT. (4 cr per qtr; prereq 5206)
Aerodynamic characteristics of the classical rotor. Combinations of rotor-wing and direct thrust-wing configurations are analyzed for high-speed V/STOL aircraft. Jet flap, boundary layer control, and ground effect machines.

5410. INTRODUCTION TO CELESTIAL MECHANICS. (4 cr; prereq 3036 or ‡)
Review of central force motion, the two-body problem, classical and modern methods of orbit determination, celestial coordinates, orbital elements and Eulerian angles, transfer orbits based on a two-body model, introduction to the three-body problem.

5435. INTRODUCTION TO RANDOM VIBRATION THEORY. (4 cr; prereq 3036 or ‡)
Statistical descriptions of response of single-degree-of-freedom damped vibrators to non-deterministic forces. Effects of damping and frequency spectra. Measurable quantities. Response of two-degree-of-freedom systems. Impedance methods. Response of linear continuous systems. Comparison, higher approximations, descriptions of damping, modal coupling and spectrum shaping. Acoustic excitation. Fatigue failure criteria. Lecture and laboratory.

5438. INTERMEDIATE DYNAMICS. (4 cr; prereq 3036)
Three-dimensional Newtonian mechanics, kinematics of rigid bodies, dynamics of rigid bodies, analytical mechanics, generalized coordinates, holonomic constraints, Lagrange's equations, application of Lagrange's equations to systems of technological interest.

5440. INTERMEDIATE DYNAMICAL SYSTEMS. (4 cr; prereq 3401)
Modeling of multi-degree-of-freedom systems in vector-matrix form, concept of stability and free vibrations, forced and unforced response of mechanical systems with conservative, dissipative, and gyroscopic forces, response to arbitrary forcing functions, intermediate concepts in feedback control.

5515. AEROSPACE STRUCTURES I. (4 cr; prereq 3016)
Bending of slender, reinforced, thin-wall beams. Shear flow, shear center, thermal stresses. Torsion of slender members; membrane analogy; open and closed thin-wall sections. Energy methods. Bending of thin plates. Buckling of columns and plates. Matrix methods of deflection analysis.

5516. AEROSPACE STRUCTURES II. (4 cr; prereq 5515)
Application of matrix methods to analysis of flight structures. Computer programming and solution of structural problems. Stability analysis of thin-wall columns, plates, and stiffened shells; buckling. Introduction to finite-element methods.

5570. MECHANICS OF BIOMATERIALS. (4 cr; prereq ‡)
Mechanical behavior of metallic systems for implants. Criterion of strength and application of ceramic implants. Other relevant properties of implants. Mechanics of polymers, especially viscoelastic behavior. Principles of fiber reinforcements and rational design of composites. Stress analysis of natural and man-made material systems.

5580. MECHANICS OF ELASTIC SOLIDS I. (4 cr; prereq 3016)
Plane stress and strain; Airy's stress function. Stress concentration. Stress and deformation in three dimensions. Basic problems of isotropic elasticity. St. Venant torsion problem; thin-walled sections; other technical problems for cylindrical bodies.

5581. MECHANICS OF ELASTIC SOLIDS II. (4 cr; prereq 5580)
Thermoelasticity. Strain energy, virtual work, energy theorems for elastic solids. Bending of rings and plates. Vibrations of bars and beams. Plane waves in elastic solids; reflection.

5582. ENERGY METHODS IN SOLIDS. (4 cr; prereq 5580)
Work, energy, and equilibrium. Energy methods for lumped-parameter systems. Virtual work, minimum energy, reciprocal theorems for bars, beams, and plates. Variational techniques; Raleigh-Ritz; Galerkin; error estimates. Vibration and buckling.

5584. MECHANICS OF VISCOELASTIC SOLIDS. (4 cr; prereq 5580)
Viscoelasticity, creep, and relaxation. Linear viscoelasticity. Quasi-static stress analysis. Correspondence principles. Thermal influence. Dynamical problems. Energy storage and loss.

5585. MECHANICS OF PLASTIC SOLIDS. (4 cr; prereq 5580)
One-dimensional plasticity. Bending of beams and frames. Beams and arches under bending and axial force. Circular plates in bending. Torsion of cylindrical bars; combined tension and torsion.

5645, 5646. AEROMECHANICS LABORATORY I, II. (3 cr per qtr; prereq 3016, 5200; 4 lab hrs per wk)
Subsonic and supersonic wind tunnel experiments including lift and drag measurements, flow-visualization methods, pressure-measuring techniques and boundary-layer measurements. Viscous-flow experiments. Vibrations. Analog methods. Rheological and strength properties of materials and structures.

5647. AEROMECHANICS LABORATORY PROJECTS. (3 cr; prereq 5200 and ♯; 4 lab hrs per wk)
Individual experimental projects of a research nature.

5650. AEROELASTICITY I. (4 cr; prereq 5206)
Static aeroelastic phenomena, torsional divergence of a lifting surface, control surfaces reversal and elastic efficiency. Effects of elastic deformations on stability, aeroelastic twisting of propeller blades and rotary wings, theory of lifting surface flutter, problems of gust response and buffeting, scaling of aeroelastic force models.

5680. RANDOM PROCESSES. (3 cr; prereq Math 5211 or equiv or ♯)
Probability densities, averages, correlations, power spectra; interrelations. White noise. Gaussian processes. Random walk problems. Wiener-Hermite functionals for nonlinear processes. Examples for discrete systems and fluid systems.

5687. INTRODUCTION TO ACOUSTICS AND ENVIRONMENTAL NOISE. (4 cr; prereq Phys 1291, Math 3221 or equiv; 3 lect and 1 lab period per wk)
Derivation of the wave equation, plane wave solution, transmission and reflection at boundaries, resonators and mufflers, three-dimensional wave propagation, properties of environmental noise sources, hearing and perception of sound, acoustical properties of rooms, laboratory experience in sound and noise measurements and noise control techniques.

5688. INTERMEDIATE ACOUSTICS. (4 cr; prereq 5687)
Wave propagation in inhomogeneous media with application to atmospheric and underwater acoustics, propagation in ducts, Kirchoff solution to the inhomogeneous wave equation, radiation from moving sources including rotating machinery.

5689. SPECIAL TOPICS IN ACOUSTICS. (4 cr; prereq 5688)
Selected topics of current interest to students and staff.

5800, 5801, 5802. PROBLEMS IN MECHANICS AND MATERIALS. (0-3 cr per qtr; prereq consent of faculty sponsor prior to regis)
Short-duration, individual research problems, literature studies, and reports.

5810, 5811, 5812. PROBLEMS IN FLUID MECHANICS. (0-3 cr per qtr; prereq consent of faculty sponsor prior to regis)
Investigation of analytical and experimental problems approved by faculty member. Undergraduate thesis.

5838, 5839. SUMMER ENGINEERING EMPLOYMENT. (1-3 cr per qtr; prereq completion of 3rd yr and ♯ prior to regis)
Written report based on summer work in an engineering field (not less than 360 hours per summer).

5840-5841-5842-5843. INDUSTRIAL ASSIGNMENT. (2 cr per qtr; prereq regis in engineering intern program)
Engineering intern industrial laboratory. A formal technical report, covering the work during the industrial assignment, is required.

FOR GRADUATE STUDENTS ONLY

8001, 8002, 8003. SEMINAR: AEROSPACE ENGINEERING AND MECHANICS

8201. FOUNDATIONS OF FLUID MECHANICS

8202, 8203. INVISCID FLUID MECHANICS

8207. INSTABILITY OF FLOW OF VISCOUS FLUIDS

8208. NONLINEAR THEORIES OF HYDRODYNAMIC STABILITY

8209. ROTATING FLUIDS

8210-8211. VISCOUS FLUID MECHANICS

8216. THEORY OF TURBULENCE

8217. APPLICATIONS OF TURBULENCE THEORY

8230-8231-8232. TRANSONIC AND HYPERSONIC FLOW

8240. PERTURBATION METHODS IN FLUID MECHANICS

8250-8251-8252. MAGNETO-FLUID DYNAMICS

8280. INTERNAL RAREFIED GAS FLOW

8285-8286. SELECTED TOPICS IN RAREFIED GAS DYNAMICS

8410. DYNAMICAL SYSTEMS I: CLASSICAL MECHANICS

8411. DYNAMICAL SYSTEMS II: LINEAR SYSTEMS

8412. DYNAMICAL SYSTEMS III: NONLINEAR SYSTEMS

8413-8414-8415. DYNAMICAL SYSTEMS IV, V, VI: ADVANCED TOPICS

8510. CONTINUUM MECHANICS I

8511, 8512. CONTINUUM MECHANICS II, III

8522. THEORY OF PLASTICITY

8523. SPECIAL TOPICS IN PLASTICITY

8527. THEORY OF ELASTIC STABILITY

8540. VISCOELASTICITY

8541-8542. THEORY OF VISCOELASTICITY

8570. FRACTURE MECHANICS

8585, 8586, 8587. ADVANCED TOPICS IN CONTINUUM MECHANICS

8590. THEORY OF PLATES AND SHELLS

8594. ELASTOSTATICS I

8595. ELASTOSTATICS II

8596. ELASTODYNAMICS

8606. NUMERICAL METHODS IN MECHANICS

8607. ADVANCED NUMERICAL METHODS IN MECHANICS

8800, 8801, 8802. SELECTED TOPICS IN MECHANICS AND MATERIALS

8810, 8811, 8812. SELECTED TOPICS IN FLUID MECHANICS

Agricultural Engineering (AgEn)

1031. COMPUTATIONS IN AGRICULTURAL ENGINEERING. (2 cr; prereq 1030 or CICS 1100, Math 1211 or 1142; 1 lect and 2 rec hrs per wk)
Introduction to problems in agricultural engineering. Elementary numerical and computational techniques. Applications involving FORTRAN programming.

1060. AGRICULTURAL ENGINEERING ORIENTATION. (1 cr; S-N only; 2 hrs per wk)
Introduction to agricultural engineering practice by lecture, reading, demonstration, and classroom discussion. Professional opportunities and responsibilities.

1071. INTRODUCTION TO AGRICULTURAL ENGINEERING. (2 cr; prereq Math 1211 or 1142; 1 lect and 3 lab hrs per wk)
Analysis of elementary agricultural engineering problems. Introduction to design including problem formulation, analysis, synthesis, evaluation, and specification.

3050. SOIL-PLANT RELATIONS IN AGRICULTURAL ENGINEERING. (4 cr; prereq AEM 3016 or ¶AEM 3016; 3 lect and 3 lab hrs per wk)
Interrelation of the soil-plant system and engineering and management requirements. Plant structure. Growth processes. Soil-plant environment. Energy and water balance. Limiting factors. Mechanical and hydraulic properties of soil profile, moisture relations; strength parameters for structural and mechanical design.

3060. ANALYSIS IN AGRICULTURAL ENGINEERING. (4 cr; prereq 1031, Math 3211; 4 lect hrs per wk)
Introduction to probability. Normal and other frequency distributions. Elementary statistics with applications to problems in agricultural engineering. Engineering economics and benefit cost analysis.

3970. DIRECTED STUDIES IN AGRICULTURAL ENGINEERING. (Cr ar)
Independent study of topic(s) involving physical principles as applied to agricultural production and land resources.

5050. INTERN REPORTS. (1 cr per qtr)
Required of students in the engineering intern program during the employment periods.

5060. PROCESSING. (4 cr; prereq 3050, ME 5342; 3 lect and 3 lab hrs per wk)
Size reduction, cleaning, and conveying of agricultural products. Properties of air, water vapors, and biological materials. Engineering principles of moisture and heat transfer applied to drying of grain crops. Theory and application of refrigerated and controlled atmosphere storage.

5070. AUTOMATIC CONTROL AND INSTRUMENTATION. (4 cr; prereq 3060, EE 3000; 2 lect and 4 lab hrs per wk)
Control of machines and processes. Linear feedback control. Linking of physical and biological control systems. Instrumentation for control systems and industrial development studies.

5081, 5082, 5083, 5084. DESIGN. (4 cr per qtr; prereq 3050, 3060; 1 lect and 6 lab hrs per wk)
An engineering design project in the student's interest area(s), integrating previous work and covering the whole range of the design process from conceptualization through preparation of the project report. 5081: Power and machinery. 5082: Soil and water. 5083: Structures and environment. 5084: Food engineering.

5130. FOOD ENGINEERING I. (4 cr; prereq knowledge of growth and survival of microorganisms, food spoilage and poisoning, food chemistry, thermodynamics of mixtures, 5060 or ¶5060 or ‡; 4 lect hrs per wk)
Fundamental requirements for handling food products. Separation processes in the food industry. Dehydration and storage of foods.

5140. FOOD ENGINEERING II. (4 cr; prereq FScN 5120, chemistry of basic food components and their reactions, introduction to electromagnetics or ‡; 3 lect and 3 lab hrs per wk)
Engineering principles of thermal processing of food, pasteurization, heat exchange, sterilization, baking and microwave heating. Sanitation and microbiological aspects of food engineering.

5191-5192. SPECIAL PROBLEMS IN AGRICULTURAL ENGINEERING. (2-5 cr per qtr; prereq ‡)
Individual study project in agricultural engineering at advanced level. Application of engineering principles to a specific problem.

5330. AGRICULTURAL MACHINERY. (4 cr; prereq ME 3203 or equiv; 3 lect and 3 lab hrs per wk)
Principles of operation and performance characteristics of agricultural machines. Operating forces on selected machine components. Control systems, design for operator convenience and safety. Machinery selection and management. Design of machine elements and assemblies. Motion analysis.

5340. AGRICULTURAL TRACTORS. (4 cr; prereq ME 3303; 3 lect and 3 lab hrs per wk)
Tractor engines. Cycle analysis, combustion fuels, and accessory systems. Chassis mechanics. Hitches and implement control systems. Power transmission systems. Tractor performance.

5540. EROSION CONTROL, WATERSHED ENGINEERING. (4 cr; prereq 3050 or CE 3300, CE 5401 or ‡; 3 lect and 3 lab hrs per wk)
Measurement and mechanics of watershed runoff and soil erosion. Estimating peak runoff, soil losses, and sediment yields. Environmental effects. Principles of small watershed planning for flood control, water storage, and sediment control. Hydraulic design of graded and storage type terraces, grass waterways, diversions, and erosion control structures.

5550. DRAINAGE AND IRRIGATION ENGINEERING. (4 cr; prereq 3050 or CE 3300, CE 5401 or ‡; 3 lect and 3 lab hrs per wk)
Flow of water through agricultural soils. Irrigation and drainage requirements, salinity control, evapotranspiration, water supply development and control. Conveyance of drainage and irrigation waters. Considerations for design, layout, and construction of irrigation and drainage systems. Institutional, environmental, and economic aspects of soil moisture control.

5730. AGRICULTURAL STRUCTURES DESIGN. (4 cr; prereq 3050, AEM 3016; 3 lect and 3 lab hrs per wk)
Building types and materials for agricultural production. Snow and wind loads. Loads associated with agricultural materials in storage. Codes and standards. Foundations and footings. Sanitation. Determinant analysis and indeterminate concepts. Computer-aided design.

5740. ENVIRONMENTAL CONTROL FOR AGRICULTURAL PRODUCTION. (4 cr; prereq ME 5603; 3 lect and 3 lab hrs per wk)
Ventilation, insulation, and condensation control in enclosed plant and animal production structures. Biological constraints upon the system. Temperature, humidity, light, and contaminants; e.g., dust, noxious gases, and pathogens. Simulation of weather phenomena for prediction of environmental conditions.

5910. AGRICULTURAL WASTE MANAGEMENT ENGINEERING I. (4 cr; prereq 3050, Chem 1005 or 1014, or ♯; 3 lect and 3 lab hrs per wk)
Sources and characteristics of agricultural wastes including animal manures, crop residues, sediments, processing wastes, and domestic wastes. Effects on the environment. Sanitary collection, storage, treatment, and disposal. Utilization of liquid and solid wastes. Nonurban water supply and quality.

5920. AGRICULTURAL WASTE MANAGEMENT ENGINEERING II. (4 cr; prereq 5910; 3 lect and 3 lab hrs per wk)
Design of systems for the collection, storage, treatment, utilization, and disposal of agricultural wastes.

FOR GRADUATE STUDENTS ONLY

8100. SEMINAR

8140. AGRICULTURAL ENGINEERING SIMILITUDE

8190-8191-8192. ADVANCED PROBLEMS AND RESEARCH

8500. HYDROLOGIC MODELING—SMALL WATERSHEDS

8700. MOISTURE AND HEAT TRANSFER

Architecture (Arch)

1001f. ENVIRONMENTAL DESIGN: MAN AND ENVIRONMENT. (4 cr, §LA 1001)
Exploration of interaction of man and his environment using the disciplines of the natural and social sciences and the arts as resource background for readings, lectures, discussions, and workshop sessions.

1002w. ENVIRONMENTAL DESIGN: TOOLS AND PROCESSES. (4 cr, §LA 1002; prereq 1001)
The nature and effects of various tools and processes of environmental change ranging from buildings and landscapes to economic policies, climate, and myths. Readings, lectures, discussions, and workshop sessions.

1003s. ENVIRONMENTAL DESIGN: IMPLEMENTATION AND EVALUATION. (4 cr, §LA 1003; prereq 1002)
Design projects, discussions, and readings exploring personal abilities to implement and evaluate environmental change.

1021f. HISTORY OF ENVIRONMENTAL DEVELOPMENT: ARCHITECTURE. (4 cr, §LA 1021; 4 lect hrs per wk)
Introduction to architecture, philosophy, and principles of architecture as an art; survey of architectural history with emphasis upon development of contemporary architecture from its roots in the 19th century until the present time.

1022w. HISTORY OF ENVIRONMENTAL DEVELOPMENT: LANDSCAPE ARCHITECTURE. (4 cr, §LA 1022; prereq 1021; 4 lect hrs per wk)
Introduction to landscape architecture. Forces and individuals that shaped the form of landscape in 19th- and early 20th-century America.

1023s. HISTORY OF ENVIRONMENTAL DEVELOPMENT: PLANNING. (4 cr, §LA 1023; prereq 1022; 4 lect hrs per wk)
Introduction to urban planning. Survey of the rise and history of cities as centers of civilization. Collaboration among various disciplines for creating better urban environment and improving the quality of human life in cities.

1041-1042-1043. ART FOR ARCHITECTURE STUDENTS. (2 cr per qtr)
Freehand drawing from live models. Emphasis on development of accurate delineation. Various techniques and media are employed.

3061-3062. BUILDING SYSTEMS. (5 cr per qtr; prereq Arch 3083; 4 lect hrs per wk)
Building systems, subsystems, and components; principles of structural theory; materials and methods used in building; new and developing technologies.

3064-3065. ENVIRONMENTAL MANAGEMENT AND CONTROL. (5 cr per qtr; prereq 3062; 4 lect hrs per wk)
Environmental-mechanical considerations including comfort technology, space habitability, climate, psychometrics, control and management systems; waste management including plumbing systems and waste disposal techniques. Electrical systems, energy, power distribution and machinery; lighting systems, physiology of seeing, light sources and control; spatial acoustics, noise barriers, absorption.

3067. INTEGRATED DESIGN SYSTEMS. (4 cr; 2 lect and 2 seminar hrs per wk)
Introduction to integrated design systems; systems approach to defining environmental problems and managing multidisciplinary inputs; analysis of alternative solutions; computer graphics including elements of equipment and interactive modes of use.

3081-3082-3083. ARCHITECTURAL DESIGN. (6 cr per qtr; prereq 2nd yr for IT students, jr for CLA students and △; 18 lab hrs per wk)
Perceptual and conceptual aspects of the physical environment. Fundamentals of architectural design and design methodology. Architectural drawing. Model making.

3091-3092-3093. ARCHITECTURAL DESIGN. (6 cr per qtr; prereq 3083; 18 lab hrs per wk)
Architectural problems with emphasis on development of structures as an integral part of design; site planning; design process.

3970. DIRECTED STUDY. (Cr ar; prereq ♯)
Areas of study useful to individual program objectives not available in regular course offerings.

5051. ANCIENT ARCHITECTURE. (4 cr; prereq 1021; 3 lect and 1 seminar hrs per wk)
History of development of architecture and urban design in Egypt, Mesopotamia, Crete, Mycenae, and classical Greece and Rome until the advent of Christianity.

5052. EARLY MEDIEVAL ARCHITECTURE. (4 cr; prereq 1021; 3 lect and 1 seminar hrs per wk)
History of the development of architecture and urban design during early Christian, Byzantine, Islamic, Carolingian, and Romanesque periods in the Near East and Western Europe until A.D. 1150.

5053. GOTHIC ARCHITECTURE. (4 cr; prereq 1021; 3 lect and 1 seminar hrs per wk)
History of development of architecture and urban design in Western Europe from A.D. 1150 until 1400.

5054. RENAISSANCE AND BAROQUE ARCHITECTURE. (4 cr; prereq 1021; 3 lect and 1 seminar hrs per wk)
History of development of architecture and urban design in Italy, Spain, France, Germany, and the low countries from 1400 until the French Revolution.

5055. ENGLISH AND EARLY AMERICAN ARCHITECTURE. (4 cr; prereq 1021; 3 lect and 1 seminar hrs per wk)
Pre-Columbian civilizations and development of architecture and urban design in America and England from 1500 until 1800.

5056. MODERN ARCHITECTURE. (4 cr; prereq 1021; 3 lect and 1 seminar hrs per wk)
History of development of architecture and urban design in Europe and America from early 19th-century until the present time.

5101, 5102, 5103. TUTORIAL WORK IN HISTORY OF ARCHITECTURE. (Cr ar; prereq 5056 or ♯; 1 conf and 5 research hrs per wk)
Reading and written reports on special historical problems.

5104. SEMINAR: EUROPEAN ARCHITECTURE. (4 cr; prereq 5056 or ♯; 4 seminar hrs per wk)
Contemporary architecture from the beginning of modern movement until the present time with specific emphasis upon the contributions of August Perret, Peter Behrens, Walter Gropius and the Bauhaus, Le Corbusier, and the early work of Mies van der Rohe.

5105. SEMINAR: SCANDINAVIAN ARCHITECTURE. (4 cr; prereq 5056 or ♯; 4 seminar hrs per wk)
Survey of Scandinavian architectural history with emphasis upon the origin and development of modern architecture in Denmark, Finland, Norway, and Sweden.

5106. SEMINAR: AMERICAN ARCHITECTURE. (4 cr; prereq 5056 or ♯; 4 seminar hrs per wk)
Contemporary architecture in the United States from the period of Henry Hobson Richardson until the present time and including the specific contributions of Louis H. Sullivan, Frank Lloyd Wright and his "Prairie School" contemporaries, Eliel and Eero Saarinen, and the later works of Walter Gropius and Mies van der Rohe. Field trip.

5111-5112-5113. ARCHITECTURAL DESIGN. (6 cr per qtr; prereq 3093; 18 lab hrs per wk)
Advanced architectural problems of complex requirements, involving thorough study and detailed solution; electrical and mechanical equipment as well as structure as an integral part of design; research techniques and design process. Individual effort and group collaboration.

5115-5116. STRUCTURE AND FORM IN ARCHITECTURE. (4 cr per qtr; prereq AEM 3092; 2 lect and 3 seminar hrs per wk)
Form as an interface between programmatic requirements for environmental change and the physical means available to the architect; physical parameters of statics, mechanics of solids, and three-dimensional manipulation of material to arrive at logical solutions for given problems of enclosing space; architectural morphology covered through contemporary and ancient examples and experimental work on models; modular and proportional relationships.

5121-5122. ARCHITECTURAL DESIGN. (9 cr per qtr; prereq 5113 and CE 5061; 27 lab hrs per wk)
Building design and development in the urban context. Individual and collaborative effort; survey and analysis of urban problems, reporting and preparation of large-scale proposals; design process.

5123. ARCHITECTURAL THESIS. (12 cr; prereq 5122, submission of a definitive thesis program during qtr prior to thesis and 800 hrs of practical experience; 36 lab hrs per wk)
Individual choice, study, and solution of an architectural problem to demonstrate proficiency in all phases of design.

5126. PROFESSIONAL PRACTICE. (4 cr; prereq 2nd-yr design; two 2-hr seminars per wk, field trips)
Relations of architect to clients, contractors, and fellow practitioners; procedures of architectural practice; preparation of contract documents.

5130. PLANNING: THE DEVELOPMENT OF URBAN FORM. (3 cr; prereq ‡; hrs ar)
Physical development of urban place from early Middle East urban revolution to the Industrial Revolution, as a manifestation of the changes in underlying social, political, and economic forces as well as planning theories, if any, to which they gave rise.

5134-5135-5136. PLANNING. (3 cr per qtr; prereq ‡)
Tutorial work in planning and research.

5137. PLANNING: URBAN FUNCTION AND STRUCTURE. (4 cr; prereq ‡)
Exploration of economic, technological, and social factors which underlie the location, distribution, and internal structure of urban settlements. Quantitative and qualitative analysis of social, economic, and physical problems or consequences of contemporary urbanization.

5138. PLANNING: THEORY AND METHODOLOGY. (4 cr; prereq 5137 or ‡)
Logic of a planning process as a method of decision making. Formulation of goals and evaluation of alternative courses of action, standards, and requirements for specific planning objectives (housing, transportation, and community facilities). Legal, administrative, and fiscal devices for plan implementation. The place of the planning function in government and the role of citizens and private groups.

5139. PLANNING. (4 cr; prereq 5138 or ‡)
Definition of problems of housing, transportation, and other subsystems of urban services. Evaluation of society's goals, private efforts and public programs designed to meet the needs in these areas. The role of technology as it affects problems and solutions.

5150. INSTITUTIONAL PLANNING. (2 cr; prereq 5113 and ‡)

5151, 5152, 5153. THEORY OF ARCHITECTURE. (2 cr per qtr; prereq ‡)
Architecture as seen in a philosophical and theoretical context.

5170. CITYSCAPE. (3 cr; prereq 3093 or ‡; hrs ar)
The city and its components as aesthetic elements. Factors which have helped to generate urban form.

5171, 5172. URBAN FORM. (3 cr per qtr; prereq 5113 and 5138)
Principles and techniques involved in city design.

5970. DIRECTED STUDY. (Cr ar; prereq ‡)
Areas of study useful to individual program objectives not available in regular course offerings.

FOR GRADUATE STUDENTS ONLY

8201, 8202, 8203. SPECIAL RESEARCH IN ARCHITECTURAL HISTORY

8231, 8232, 8233. PLANNING

8251, 8252, 8253, 8254, 8255, 8256. ARCHITECTURAL DESIGN

8261, 8262, 8263. SELECTED PROBLEMS IN ARCHITECTURE

8271, 8272, 8273, 8274, 8275, 8276. PROBLEMS IN CITY AND COMMUNITY DESIGN

Astronomy (Ast)

1011. DESCRIPTIVE ASTRONOMY. (4 cr, §1021; 4 lect hrs per wk)
The sun, the moon, the planets and their motions; stars and stellar systems, galaxies and cosmology. Nonmathematical.

1015. DESCRIPTIVE ASTRONOMY LABORATORY. (1 cr, §1025; S-N only; 1 lab hr per wk)
Laboratory offered in conjunction with 1011. Only opportunity to observe with telescope.

1021. INTRODUCTION TO ASTRONOMY. (4 cr, §1011; prereq high school trigonometry and physics or chemistry; 4 lect hrs per wk)
Solar system, stars, galaxies, and cosmology. A more mathematical and physical discussion than 1011.

1025. INTRODUCTION TO ASTRONOMY LABORATORY. (1 cr, §1015; S-N only; 1 lab hr per wk)
Laboratory offered in conjunction with 1021. Only opportunity to observe with telescope.

1201. TOPICS IN MODERN ASTROPHYSICS. (4 cr; prereq 1011 or 1021 or equiv, ♯)
Current research problems in astronomy and astrophysics. Discussion and participation by class members. Nonmathematical.

3051. INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS. (4 cr; prereq 1 yr calculus and Phys 1106 or 1291 or ♯)
The solar system, stellar systems, galaxies and the extragalactic universe. How information is obtained; conclusions that can be inferred from observations.

5161. ASTROPHYSICS OF DIFFUSE MATTER. (4 cr; prereq 3051 and Phys 3511 or ♯)
Diffuse matter in the solar system, interstellar and extragalactic space; the radiation field in these environments. Gaseous nebulae, radio astronomy and nonthermal radio sources, cosmic rays, some aspects of cosmology.

5162. ASTROPHYSICS OF CONDENSED MATTER. (4 cr; prereq 3051 and Phys 3511 or ♯)
Luminosities, temperatures, masses, and densities of stars; their mechanisms for energy generation. Chemical composition of stars and the probable course of stellar evolution.

FOR GRADUATE STUDENTS ONLY

8200.* SEMINAR: ASTROPHYSICS AND SPACE PHYSICS

Phys 8081-8082.* GENERAL RELATIVITY

Phys 8163-8164.* PLASMA PHYSICS

Phys 8411-8412.* COSMIC-RAY AND SPACE PHYSICS

Phys 8421-8422.* MAGNETOSPHERIC PHYSICS

Phys 8481-8482-8483.* ASTROPHYSICS

Phys 8484.* ORIGIN AND EVOLUTION OF THE SOLAR SYSTEM

Phys 8990. RESEARCH IN PHYSICS

Chemical Engineering (ChEn)

5001. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING AND MATERIALS SCIENCE. (2 cr; 2 lect and 1 rec hrs per wk)
Computer programming with applications to chemical, physical, and engineering problems.

5101. PRINCIPLES OF CHEMICAL ENGINEERING. (4 cr; 3 lect and 2 rec hrs per wk) Staff
Material and energy balances applied to chemical engineering systems.

5102. PRINCIPLES OF CHEMICAL ENGINEERING. (4 cr; prereq 5101; 3 lect and 2 rec hrs per wk) Staff
Fluid dynamics and its applications to chemical engineering unit operations.

5103. PRINCIPLES OF CHEMICAL ENGINEERING. (4 cr; prereq 5102; 3 lect and 2 rec hrs per wk) Staff
Heat and mass transfer and its applications to chemical engineering unit operations.

5104. UNIT OPERATIONS AND SEPARATION PROCESSES. (4 cr; prereq 5101; 3 lect and 2 rec hrs per wk) Staff
Absorption, extraction, distillation, stagewise, and continuous separations.

5201. THERMODYNAMICS AND MATERIAL STATES. (4 cr; 3 lect and 2 rec hrs per wk) Staff
Principles of thermodynamics applied to closed and open systems and to equilibrium states of homogeneous and heterogeneous substances, gases, liquids, and solids.

5202. CHEMICAL ENGINEERING THERMODYNAMICS AND KINETICS. (4 cr; prereq 5201; 3 lect and 2 rec hrs per wk) Staff
Chemical equilibrium and chemical kinetics applied to chemical engineering systems.

5301. CHEMICAL REACTOR ANALYSIS. (4 cr; prereq 5202; 3 lect and 2 rec hrs per wk) Staff
Principles of reactor design for homogeneous and heterogeneous reactions. Analysis of reactors from a kinetic and thermodynamic point of view.

5401-5402-5403. CHEMICAL ENGINEERING LABORATORY. (2 cr per qtr; 4 lab and 1 lab conf hrs per wk)
Applications of unit operations; principles of fluid flow, heat and mass transfer; experiments and reports.

5501. PROCESS EVALUATION AND DESIGN. (4 cr; prereq 4th yr or ♯; 3 lect and 3 design lab hrs per wk) Staff
Dynamics of chemical engineering industries, economics of process evaluation, bases for cost estimations. Plant designs prepared and compared with actual installations. Special applications of unit operations, reaction kinetics, and thermodynamics.

5502. PROCESS EVALUATION AND DESIGN. (2 cr; prereq 5501; 4 design lab and 1 lab conf hrs per wk) Staff
(See 5501) Process design projects.

5601. PROCESS CONTROL. (4 cr; prereq 4th yr or ♯; 3 lect and 2 rec hrs per wk)
Elementary theory of control and its application to chemical processes. Synthesis of feedback control loops for linear systems.

5603. PROCESS CONTROL. (3 cr; prereq 5601 or ♯; 3 lect hrs per wk)
(Continuation of 5601) Advanced topics in control of processes (e.g., observability and compatibility, sampled data systems, optimal control, etc.)

5604. PROCESS CONTROL LABORATORY. (2 cr; prereq 5601)
Experiments designed to illustrate and apply control theory. Measurement techniques, calibration, tuning of controls, characterization of sensors and control circuits.

5701-5702-5703. NUCLEAR REACTOR DESIGN. (3 cr per qtr; prereq ♯; 3 lect hrs per wk) Isbin
An engineering approach to the development and application of nuclear reactor theory, including basic nuclear chemistry and physics, mathematical developments and special techniques, design, operation, and control of homogeneous and heterogeneous reactors, and nuclear reactor economics. Laboratory credit available.

5751-5752-5753. BIOLOGICAL ENGINEERING ANALYSIS. (3 cr per qtr; prereq ♯; 3 lect hrs per wk) Fredrickson, Keller, Swanson
Modeling and analysis of biosystems. Thermodynamics, transport and transfer, biochemical reactions, growth and death processes are discussed from both deterministic and probabilistic viewpoints.

5754-5755. BIOCHEMICAL ENGINEERING. (4 cr per qtr; prereq 5103 or ♯; 3 lect hrs per wk) Tsuchiya, Valentas
Biochemical engineering of industrially important biological materials. Microbiological, biochemical, chemical, and engineering considerations of these systems and their industrial processing.

5801. AIR POLLUTION CONTROL ENGINEERING. (4 cr; 4 lect hrs per wk)
Analysis and design of equipment used to reduce emission of gases and particulates. Methods for controlling air pollution.

5901. CHEMICAL PROCESS LABORATORY. (2 cr; prereq 5301)
Applications of kinetics and heat and mass transfer to batch and continuous flow reactors.

5902, 5903, 5904, 5905. SPECIAL PROBLEMS. (Cr ar; 1 conf hr per wk, lab hrs ar)
Investigations in chemical engineering. Library or laboratory research.

FOR GRADUATE STUDENTS ONLY

8000, 8002, 8003. PHYSICAL RATE PROCESSES AND TRANSFER OPERATIONS

8004. PHYSICAL RATE PROCESSES

8005. PHYSICAL RATE PROCESSES

8101. INTERMEDIATE FLUID MECHANICS

8102. PROBLEMS IN FLUID MECHANICS

8103. TENSORS AND FIELD THEORY WITH APPLICATIONS TO CONTINUUM MECHANICS

8104. BOUNDARY AND INTERFACE MECHANICS

8105. PRINCIPLES AND APPLICATIONS OF RHEOLOGY

8106. ADVANCED TOPICS IN FLUID MECHANICS AND TRANSPORT PROCESSES

8201-8202-8203. ADVANCED MATHEMATICS FOR CHEMICAL ENGINEERS

8301-8302. ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS

8401. CHEMICAL REACTION KINETICS—KINETICS OF HOMOGENEOUS REACTIONS

8402. CHEMICAL REACTION KINETICS—SURFACE CHEMISTRY

8403. CHEMICAL REACTION KINETICS—ADVANCED TOPICS

8500. INTERMEDIATE CHEMICAL REACTOR ANALYSIS

8501-8502-8503. CHEMICAL RATE PROCESSES AND REACTOR DESIGN PRINCIPLES

8601-8602-8603. MOLECULAR THEORY OF TRANSPORT PROCESSES

8701. ANALYSIS OF CHEMICAL ENGINEERING PROBLEMS

8702. ADVANCED TOPICS IN CHEMICAL ENGINEERING

8801-8802-8803. SEMINAR

8850. GENERAL SURVEY OF CHEMICAL ENGINEERING

8901, 8902, 8903. RESEARCH IN CHEMICAL ENGINEERING

Chemistry (Chem)

For Students Taking a Beginning Course in Chemistry—There are no courses intended for students who have not had high school chemistry. Although students without high school chemistry are permitted to enroll in Chem 1001, 1004, and 1014, the large majority of the students in these courses have had high school chemistry. It has been shown that students without this high school background are at a great disadvantage.

Note—Each student must present a deposit card for admission to laboratory sections. See Deposit Cards section of *Class Schedule* for details.

1001-1002†. CHEMICAL PRINCIPLES AND COVALENT SYSTEMS. (See *CLA Bulletin*)

1004-1005†. GENERAL PRINCIPLES OF CHEMISTRY. (5 cr per qtr, §1014, §1031-1032; primarily for nonchemistry majors; prereq predicted mathematics GPA 1.90 on ACT, Math 0009 or college course in algebra...4 yrs high school mathematics and high school chemistry recommended; 4 lect, 1 rec, and 3 lab hrs per wk)
Introduction to chemistry from the standpoint of atomic structure; periodic properties of elements and compounds derivable from structural considerations; laws governing behavior of matter, theories of solutions, acids, bases and equilibria.

1006. PRINCIPLES OF SOLUTION CHEMISTRY. (4 cr; prereq 1005 or 1032; 3 lect and 4 lab hrs per wk; $4 lab fee required)
The chemistry of selected cations and anions. Spectrophotometric, potentiometric, and chromatographic detection methods. Metal ion studies include systematics; acid-base principles; influence on the environment; importance in biological systems; formation and stereochemistry of complexes. Lecture and laboratory.

1014. GENERAL PRINCIPLES OF CHEMISTRY. (4 cr, §1004, §1031; primarily for engineering majors, sophs and above; prereq Phys 1105 or 1281 or ‡; 4 lect hrs per wk)
Fundamental principles of chemistry. A terminal course.

1031. GENERAL PRINCIPLES OF CHEMISTRY. (5 cr, §1004, §1014; primarily for chemistry and chemical engineering majors; prereq 4 yrs high school mathematics, 1 yr high school chemistry...1 yr high school physics recommended; 3 lect, 1 lect discussion, 1 lab discussion, plus one 4-hr lab per wk)
A consolidation of the basic principles of chemistry with those of qualitative and quantitative analysis; stoichiometry, development and use of structural concepts, energetics and geometry of molecules, bonding, and the behavior of the gaseous and liquid states.

1032. GENERAL PRINCIPLES OF CHEMISTRY. (5 cr, §1005; prereq 1031; 3 lect, 1 lect discussion, 1 lab discussion, plus one 4-hr lab per wk)
(Continuation of 1031) Quantitative techniques; the solid state, theory of solutions, equilibrium, gas and condensed phases, behavior and nature of the solution process, acids, and bases.

1034. SYNTHESIS I. (5 cr; prereq 1032; 4 lect, 1 lab discussion, plus one 4-hr lab per wk)
Structure, synthesis, and reactions of organic compounds. The relationship of organic chemistry to problems of health and environment. Laboratory work to illustrate principles. *Final offering 1974-75.*

1133. ELEMENTARY QUANTITATIVE ANALYSIS.** (5 cr; prereq 1032; 3 lect and two 4-hr labs per wk)
An introduction to the theory and practice of chemical methods of analysis.

1301. CARBON COMPOUNDS. (4 cr; for students in engineering, except chemical and mining; prereq 1005 or 1032; 1301 cannot be substituted for 3301 or 3302; 4 lect hrs per wk)
Carbon compounds; compounds useful as engineering materials and processes by which such compounds are made.

3034. SYNTHESIS II. (5 cr; prereq 1034; 4 lect, 1 lab discussion, plus one 4-hr lab per wk)
(Continuation of 1034) The relationship of organic chemistry to living systems. Laboratory work to illustrate. *Final offering 1975-76.*

3100. QUANTITATIVE ANALYSIS. (3 cr, 3101†; for nonchemistry majors; prereq 1005)
Modern quantitative methods of analysis. Lecture.

3101. QUANTITATIVE ANALYSIS. (2 cr; for nonchemistry majors; prereq 3100 or ¶3100; 8 lab hrs per wk)
Modern quantitative methods of analysis including elementary physicochemical procedures. Laboratory.

3201. RATES AND MECHANISMS. (5 cr; prereq 3034 or equiv; 3 lect, one 3-hr lab, plus lab discussion ar per wk)
Fundamentals of rates and mechanisms of chemical processes. Potential energy surfaces. Absolute rate theory. *Final offering 1975-76.*

3301. ELEMENTARY ORGANIC CHEMISTRY. (5 cr; prereq 1005 or 1032 or equiv; 3 lect, 1 lab conf, 1 quiz, and 4 lab hrs per wk)
Important classes of organic compounds, both aliphatic and aromatic, together with some heterocyclic compounds. Preparation of typical substances in laboratory.

3302. ELEMENTARY ORGANIC CHEMISTRY. (5 cr; prereq 3301; 3 lect, 1 lab conf, 1 quiz, and 4 lab hrs per wk)
See 3301.

3303. ELEMENTARY ORGANIC CHEMISTRY. (4 cr; prereq 3302 or 3034; 4 lect hrs per wk)
Basic principles with emphasis on organic reaction mechanisms. Intended to coordinate the knowledge acquired in 3301 and 3302.

3304. ELEMENTARY ORGANIC CHEMISTRY LABORATORY. (4 cr; prereq 3303 or ¶3303 or 3201; 8 lab hrs, 1 lect, and 1 conf per wk)
Reactions of typical functional groups and introduction to methods of organic qualitative analysis.

3331. INTRODUCTORY ORGANIC CHEMISTRY I.** (5 cr, §3301; prereq 1133 or 1 yr college chemistry; 5 lect per wk)
A survey of the important classes of organic compounds; their constitutions, configurations, and conformations; the relationship between molecular structure and chemical reactivity.

3332. INTRODUCTORY ORGANIC CHEMISTRY II.** (3 cr, 3335†; prereq 3331; 3 lect per wk)
A survey of the reactions of organic compounds; nucleophilic substitution; nucleophilic addition; electrophilic substitution; electrophilic addition; elimination reactions; molecular rearrangements; oxidation and reduction.

3333. INTRODUCTORY ORGANIC CHEMISTRY III.** (3 cr; prereq 3332; 3 lect per wk)
Free radical reactions, electrocyclic reactions, photochemistry, organic synthesis, heterocyclic compounds, synthetic polymers, the chemistry of natural products and life.

3335. INTRODUCTORY ORGANIC CHEMISTRY II.** (2 cr; prereq 3332 or ¶3332 [¶3332 is recommended]; two 4-hr labs per wk)
A laboratory course to accompany 3332.

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3336. INTRODUCTORY ORGANIC CHEMISTRY III.** (2 cr; prereq 3333 or ¶3333 [¶3333 is recommended]; to 4-hr labs per wk)
A laboratory course to accompany 3333.

3499. SENIOR THESIS. (Cr ar; prereq 4th yr, ‡)
Written final senior thesis report.

3590. INTRODUCTION TO PRINCIPLES OF CHEMISTRY. (3 cr; prereq Math 1111 or equiv and 1 yr general chemistry and 1 yr college physics)
Primarily for students in biology and biochemistry.

3591, 3592, 3593. SPECIAL TOPICS IN PHYSICAL CHEMISTRY. (2 cr per qtr; primarily for 3rd- and 4th-yr chemistry majors; prereq 2 qtrs physical chemistry)
Areas of current research.

3752, 3753. ADVANCED INORGANIC CHEMISTRY LABORATORY. (2 cr per qtr; prereq 5703, ‡)
Advanced laboratory work in physical and synthetic methods. Specific experiments will be determined by student-instructor consultation. Detailed instructions for a wide variety of experiments.

3970. DIRECTED STUDY. (Cr ar; prereq ‡)
On- or off-campus learning experiences individually arranged between a University undergraduate student and a member of the University faculty for earning academic credit in areas not covered by regular courses.

5122. ADVANCED ANALYTICAL CHEMISTRY. (4 cr; prereq 3100 and 3101 or 1032)
Equilibria in aqueous and nonaqueous systems.

5123. SURVEY OF MODERN ELECTROANALYTICAL TECHNIQUES, PRINCIPLES, AND PRACTICE. (5 cr; prereq 5126 or 8101 or equiv)
Lecture: potentiometry, polarography, coulometry, linear scan, scan, cyclic voltametry, pulse methods. Laboratory: experiments which complement the lectures.

5125. INTRODUCTION TO INSTRUMENTAL MEASUREMENTS. (5 cr; prereq 5505 or ‡; 3 lect and two 4-hr labs per wk)
Instrumental techniques for detection and measurements; analysis of signal flow in control systems; principles of frequency-domain and time-domain filtering, introduction to information flow in nonlinear systems.

5126. MODERN ANALYTICAL CHEMISTRY. (4 or 5 cr [chemistry majors must take for 5 cr]; prereq 3034; 2 lect, two or three 3-hr labs per wk)
Strategies and techniques for solving modern analytical problems. The use of modern instruments in analysis.

5127. ANALOG INSTRUMENTATION. (5 cr; prereq Phys 1291, Math 3211; 3 lect and two 4-hr labs per wk)
Basic principles of electronic design and circuitry, servo systems, operational amplifiers, feedback control, oscillators.

5128. DIGITAL INSTRUMENTATION. (5 cr; prereq Phys 1291, Math 3211; 3 lect and two 4-hr labs per wk)
Simple switching devices such as semiconductor diodes and transistors; high-speed integrated circuits; binary, decimal, and modulo-M counters.

5133. CHEMICAL INSTRUMENTATION AND ANALYSIS.** (5 cr, §5126; prereq 1133, 5534; 3 lect and two 4-hr labs per wk)
An introduction to the methodology and practices of solving analytical problems. The application of modern instrumental techniques to analysis.

5211. ADVANCED CHEMICAL KINETICS. (4 cr; prereq 3201 and 5505)
Factors which govern the rates of chemical reactions in both gaseous and condensed phases. Deduction of reaction mechanisms from rate data and theoretical interpretation in terms of dynamical and statistical models. Coupled reactions.

5301. SPECTRAL METHODS FOR ORGANIC QUALITATIVE ANALYSIS. (4 cr, §8302; prereq 3303; 3 lect and 1 conf hrs per wk)
Practical application of nuclear magnetic resonance and infrared spectral analysis to solution of organic problems.

5302. ORGANIC SYNTHESIS. (4 cr; prereq 3201 or 3303; 8 lab hrs and 2 conf hrs per wk)
Reactions of typical functional groups and introduction to modern laboratory methods of organic synthesis.

**Indicates that the course has been approved by the faculty of the Department of Chemistry and has been submitted to the Institute of Technology for consideration for inclusion in the curriculum.

5305. INTERMEDIATE ORGANIC CHEMISTRY. (4 cr; prereq 3201 or 3303; 3 lect and 1 rec hrs per wk)
Introduction to various aspects of physical organic chemistry with application to typical chemical problems. Reactions of typical functional groups and introduction to modern laboratory methods of organic synthesis.

5309. THEORETICAL ORGANIC CHEMISTRY. (4 cr; prereq 5502 or Phys 3501 or ♯; 3 lect and 1 rec hrs per wk)
Application of quantum mechanics to organic reactions and photochemistry.

5310. CONSUMER CHEMISTRY. (4 cr; prereq 3034 or equiv or ♯; offered spring 1975)
The role of chemistry in relevant consumer concerns.

5342. CHEMISTRY OF NATURAL PRODUCTS. (3 cr; prereq 3303; offered 1976-1977 and alt yrs)
Biosynthesis of secondary natural products with emphasis on alkaloids, terpenes, and acetogenins.

5343. CHEMISTRY OF NATURAL PRODUCTS (STEROIDS). (3 cr; prereq 3303 or 3201; offered 1975-1976 and alt yrs)
Steroidal hormones, their isolation, proof of structure, synthesis, and action.

5344. HETEROCYCLIC COMPOUNDS. (3 cr; prereq 3303; offered 1975-1976 and alt yrs)
Typical classes of heterocyclic compounds, their chemical and physical properties and uses, synthesis.

5365. ORGANIC QUALITATIVE ANALYSIS. (4 cr, §3304; prereq 3201 or 3303; 8 lab hrs and 2 conf hrs per wk)
Reactions of typical functional groups and introduction to methods of organic structure determination.

5502. QUANTUM MECHANICS. (5 cr; prereq 1 yr college chemistry, Phys 1291 or ¶Phys 1291, or 1106 with ♯, Math 3211)
Introductory course for chemists. Laboratory illustrates the quantum properties of nature. *Final offering 1975-76.*

5503. PHYSICAL CHEMISTRY. (4 cr; prereq 5505)
Statistical mechanics and reaction kinetics. *Final offering 1975-76.*

5505. STATISTICAL THERMODYNAMICS. (4 cr; prereq 1 yr college chemistry, Phys 1291 or ¶Phys 1291, or 1106 with ♯, Math 3211)
Classical statistical mechanics as applied to lattice model treatments of liquids and solutions. *Final offering 1975-76.*

5520, 5521. ELEMENTARY PHYSICAL CHEMISTRY. (3 cr per qtr; prereq 1 yr college chemistry, Phys 1291 or ¶Phys 1291, or 1106 with ♯, Math 3211)
Brief general survey. 5520: Chemical thermodynamics. 5521: Kinetics, statistical mechanics, molecular structure.

5522. PHYSICAL BIOCHEMISTRY OF SOLUTIONS. (4 cr, §BioC 5522; prereq 2 qtrs physical chemistry)
Physical chemistry of equilibrium and transport phenomena in solution with application to biochemical systems. Electrolyte and polyelectrolyte solutions, solutions of macromolecules, binding of substrates, diffusion and sedimentation, viscosity diffusion-controlled kinetics, interfacial phenomena colloids and miscelles.

5523. PHYSICAL BIOCHEMISTRY: STRUCTURE AND INTRAMOLECULAR FORCES. (4 cr, §BioC 5523; prereq 5522 or 2 qtrs physical chemistry plus ♯...some biochemistry desirable)
Determination of structure of biological macromolecules by diffraction and spectroscopic methods; energetics and statistical mechanics of biochemical reactions and structural transitions.

5524. BIOPHYSICAL CHEMISTRY: DYNAMICS. (4 cr, §BioC 5524; prereq 2 qtrs physical chemistry, BioC 5741. . .BioC 5002 or equiv desirable)
Application of thermodynamics, statistical mechanics, and chemical kinetics to biological systems. Theoretical and experimental enzyme kinetics, solvent effect, structure-function relation.

5530. THERMODYNAMICS. (4 cr; prereq minimum of 2 qtrs physical chemistry)
Application to gases, chemical reactions, solutions, phase equilibria.

5531. FOUNDATIONS OF QUANTUM CHEMISTRY. (4 cr, §5502; prereq Phys 1291 or equiv plus Math 3211 or 3411 or equiv plus ♯)
Postulates of quantum mechanics. Introduction to wave functions, solutions of the Schroedinger equation, variation and pertubation theory, modern techniques for calculating bound state wave functions and electronic energies of molecules, other material which is necessary background for 8305 and/or 8705.

5533. QUANTUM CHEMISTRY.** (4 cr; prereq 1 yr college chemistry, Phys 1291 or ¶Phys 1291, or Phys 1106 with ‡, Math 3211)
Principles of quantum mechanics, with applications to atomic and molecular structure and to spectroscopy.

5534. CHEMICAL THERMODYNAMICS.** (5 cr; prereq 1 yr college chemistry, Phys 1291 or ¶Phys 1291, or Phys 1106 with ‡, Math 3211)
Principles of thermodynamics with applications to chemical systems.

5535. STATISTICAL MECHANICS AND REACTION KINETICS.** (4 cr; prereq 5534)
(Continuation of 5534) Statistical thermodynamics and the kinetic theory of gases, with applications to reaction rate theory. Phenomenological kinetics and experimental methods.

5536. QUANTUM CHEMISTRY LABORATORY.** (1 cr; prereq 5533 or ¶5533)
Laboratory experiments illustrating principles and methods of quantum mechanics.

5538. PHYSICAL CHEMISTRY LABORATORY.** (1 cr; prereq 5535 or ¶5535)
Experiments in thermodynamics and reaction kinetics.

5571, 5572. MOLECULAR SPECTROSCOPY. (4 cr per qtr; prereq 5502 or 5531 or equiv for 5571)
An examination of various types of molecular spectroscopy from the standpoint of how structure information is obtained from spectra.

5574. MOLECULAR STRUCTURE AND SCATTERING. (3 cr; prereq 5572)
Determination of geometrical structure of molecules by X-ray, electron and neutron scattering. The effect of internal molecular motions on the structural determination. Inelastic scattering and molecular energies.

5580. PHYSICAL CHEMISTRY OF POLYMERS. (3 cr; prereq 5503 or 5505 or ‡; offered spring 1975-1976 and alt yrs)
Molecular weight distribution, statistical mechanics of polymer solutions, network polymers, viscosity, light scattering, viscoelastic behavior.

5610. PRINCIPLES OF POLYMER SCIENCE. (4 cr; prereq physical chemistry or ‡, MatS 5610; 3 lect and 3 lab-rec hrs per wk)
Polymer synthesis and physical chemistry: polymerization kinetics, molecular weight distribution, network formation, macromolecules in solution and their characterization, the glassy state, rubber elasticity, flow and viscoelasticity, environmental degradation.

5703. ADVANCED INORGANIC CHEMISTRY. (5 cr; prereq 3201 and 5502; 3 lect, 1 discussion, and one 3-hr lab per wk)
Modern treatment of transition and nontransition metal chemistry. Structure, bonding, and stereochemistry of inorganic and organometallic compounds. Selected current topics. *Final offering 1976-77.*

5704. ECOLOGY OF WATER. (4 cr; prereq 5505 or equiv or ‡)
Interaction of water with the gases, elements, and compounds of the biosphere.

5705. SYMMETRY IN CHEMISTRY. (4 cr; prereq 5703)
Introduction to group theory: symmetry classification of inorganic and organic molecules; representations of symmetry point groups; and the symmetry of wave functions. Symmetry aspects of molecular orbital theory and symmetry control of organic and inorganic reactions.

5710. ADVANCED INORGANIC CHEMISTRY I: SURVEY OF THE TRANSITION METALS. (4 cr; prereq 1 yr each of organic and physical chemistry)
Reactions and properties of the transition metals, including the rare earths, and their compounds. A survey of coordination chemistry using elementary ideas of ligand field theory.

5711. ADVANCED INORGANIC CHEMISTRY II: SURVEY OF THE CHEMISTRY OF THE NONTRANSITION ELEMENTS. (4 cr; prereq 1 yr each of organic and physical chemistry)
Reactions and properties of the nontransitional elements, including the rare gases, and their compounds.

5731. INORGANIC CHEMISTRY I.** (5 cr; prereq 5533; 4 lect and 3 lab hrs per wk)
Structure, bonding, thermochemistry, acid-base chemistry, physical and chemical properties of inorganic substances. Emphasis on systems where **s** and **p** electrons are important.

5732. INORGANIC CHEMISTRY II.** (5 cr; prereq 5731; 4 lect and 3 lab hrs per wk)
See 5731. Emphasis on transition metal compounds where **d** electrons are important. Current topics such as boron hydrides, inert gas compounds, organometallic compounds, and biologically important metal compounds.

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5791, 5792, 5793. SELECTED TOPICS IN INORGANIC CHEMISTRY. (2 cr per qtr; prereq 5702, △)
Topics of current interest in inorganic chemistry. Consult department for details of topics for any particular quarter.

5801, 5802, 5803. THE CHEMISTRY OF INDUSTRY. (4 cr; prereq 5505 or ‡)
The relation between basic chemical theory and chemical technology including programs of economics, ecology, and resources.

FOR GRADUATE STUDENTS ONLY

8100. GENERAL SURVEY OF ANALYTICAL CHEMISTRY

8101. PHYSICAL-CHEMICAL METHODS OF ANALYSIS (Lecture)

8102. PHYSICAL-CHEMICAL METHODS OF ANALYSIS (Laboratory)

8104. OPTICAL METHODS OF ANALYSIS

8190. SEMINAR: MODERN PROBLEMS IN CHEMISTRY INSTRUMENTATION AND ANALYSIS

8198. RESEARCH SEMINAR: CHEMICAL INSTRUMENTATION AND ANALYSIS

8211. FUNDAMENTALS OF CHEMICAL DYNAMICS

8212. CHEMICAL DYNAMICS IN SOLUTION

8213. CHEMICAL DYNAMICS IN THE GAS PHASE

8300. GENERAL SURVEY OF ORGANIC CHEMISTRY

8301. ADVANCED ORGANIC CHEMISTRY

8302. INTRODUCTION TO RESEARCH

8303. PHYSICAL ORGANIC CHEMISTRY

8304. ADVANCED ORGANIC CHEMISTRY

8305. THEORETICAL ORGANIC CHEMISTRY

8341. STEREOCHEMISTRY

8342. INTRODUCTION TO RESEARCH

8343. THEORETICAL ORGANIC CHEMISTRY

8344. THEORETICAL ORGANIC CHEMISTRY

8390. ORGANIC CHEMISTRY SEMINAR

8500. GENERAL SURVEY OF PHYSICAL CHEMISTRY

8510-8511. QUANTUM MECHANICS

8512. SCATTERING THEORY

8513. GROUP THEORETICAL METHODS IN CHEMISTRY

8514. MOLECULAR QUANTUM MECHANICS

8515. INTERACTION OF RADIATION WITH MATTER

8520-8521. STATISTICAL MECHANICS

8560. SEMINAR: PHYSICAL CHEMISTRY OF BIOLOGICAL SYSTEMS

8565. SEMINAR: PHYSICAL CHEMISTRY OF POLYMERS

8570. SEMINAR: MOLECULAR SPECTROSCOPY

8575. SEMINAR: MAGNETOCHEMISTRY

8580. SEMINAR: PHOTOCHEMISTRY

8585. SEMINAR: THEORETICAL CHEMISTRY

8589. SEPARATION THEORY

8590. SEMINAR: PHYSICAL CHEMISTRY

8601-8602-8603. MOLECULAR THEORY OF TRANSPORT PROCESSES

8700. GENERAL SURVEY OF INORGANIC CHEMISTRY

8703. ADVANCED INORGANIC CHEMISTRY I

8704. ADVANCED INORGANIC CHEMISTRY II

8705. ADVANCED INORGANIC CHEMISTRY III

8751-8752-8753. ADVANCED INORGANIC CHEMISTRY LABORATORY METHODS

8790. SEMINAR: MODERN PROBLEMS IN INORGANIC CHEMISTRY

8990. RESEARCH IN CHEMISTRY

8991, 8992, 8993. SPECIAL TOPICS IN CHEMISTRY.

Civil Engineering (CE)

General Courses

1001. CIVIL ENGINEERING ORIENTATION. (1 cr; S-N only)
Fundamentals of civil engineering practice presented by professional engineers and members of the faculty.

3010. DATA ANALYSIS AND OPTIMIZATION IN CIVIL ENGINEERING. (4 cr; prereq Math 3221, 3 lect and 2 lab hrs per wk)
Introduction to probability, random variables, sampling, statistical inference, regression and correlation, comparison of means, linear programming, and computer programming.

3050. ENGINEERING INTERN WORK ASSIGNMENT. (4 cr [may be taken for cr twice]; S-N only; prereq regis in intern program)
Grades based on formal written report by the student covering his or her work during the professional assignment.

5001. BUILDING AND CONSTRUCTION CONTRACTS AND SPECIFICATIONS. (4 cr)
Synopsis of the law of contracts, sales, agency, negotiable instruments, real property, personal property, partnerships, corporations, insurance contracts, and torts with applications to the performance of engineering and construction contracts.

5097, 5098, 5099. ADVANCED DESIGN, ANALYSIS, RESEARCH, OR TUTORIAL IN CIVIL ENGINEERING. (Cr ar [may be repeated for cr]; prereq approval of faculty adviser)
Planning, design, or analysis of complex civil engineering systems. Individual laboratory research problems, literature, studies, and reports supervised by staff. Studies may be conducted in any discipline within civil engineering including, but not limited to, hydraulics and hydrology, land development, materials, environmental engineering, soil mechanics, structures, and transportation.

Surveying and Mapping

3100. INTRODUCTION TO SURVEYING AND MAPPING. (4 cr; prereq Math 1211; 3 lect, 3 lab hrs per wk)
Theory of precision measurements of distance, elevation, angle, and direction. Elements of coordinate systems, datum planes, and maps. Use of aerial photographs for mapping. Fundamentals of geometrics for design, grades, and vertical and horizontal curvature.

3103. FIELD SURVEYING. (3 cr; prereq 3100; 1 lect and 6 lab hrs per wk)
Theory and practice of precision measurements of distance, elevation, angle, and direction. Laboratory problems related to the use and application of modern surveying instrumentation.

5100. LAND SURVEYING. (4 cr; prereq 3100, 3102 or ♯)
Minnesota Public Land Survey. Federal and state laws governing resurveys, registered land surveys, and subdivision plats. Court decisions and legal principles involving boundary line determinations. Interpreting and writing deed descriptions.

5101. GEODESY. (4 cr; prereq 3100, 3103; 3 lect and 3 lab hrs per wk)
Size and shape of the earth; properties of ellipsoids; reference ellipsoids; Legendre's theorem; geodesic and normal sections; direct and inverse geodetic lines; geodetic datums; deflection of the vertical; LaPlace stations. Survey adjustments.

5102. SITE AND ROUTE ENGINEERING. (4 cr; prereq 3100; 3 lect and 3 lab hrs per wk)
Site and route design fundamentals and problems based on spatial data obtained through photogrammetric mapping. Problems in geometric design; grades, horizontal and vertical curves; fitting of design to topography; earthwork, area and volumes; and drainage. Construction control and layout.

5103. LAND PLANNING AND SUBDIVISION DESIGN. (4 cr; prereq 3100 and 5102; 3 lect and 3 lab hrs per wk)
Minnesota statutes, county and municipal ordinances governing land use and subdivision. Elements of design. Design of a subdivision.

5104. PHOTOGRAMMETRY. (4 cr; prereq Math 1211; 3 lect and 3 lab hrs per wk)
Stereoscopy and parallax; geometry of single and overlapping photographs; stereoscopic plotting instruments; flight planning; aerial cameras and calibration; mosaics; terrestrial photogrammetry; principles of photo interpretation; elements of remote sensing; and applications to resource evaluation.

Transportation

3200. INTRODUCTION TO TRANSPORTATION ENGINEERING. (4 cr; prereq Phys 1271 or equiv)
Application of the physical laws of motion and energy as they relate to calculations of resistances to motion, power, and energy requirements, acceleration-deceleration limits and capacity of various modes of transportation. Engineering economics with particular emphasis on costs of transportation systems.

5200. GEOMETRIC DESIGN OF HIGHWAYS. (4 cr; prereq 3200, 3102, or ‡)
Forecast of traffic volume demand; impact of vehicle type on geometric design; vertical and horizontal alignment; intersection design; highway capacity.

5201. HIGHWAY TRAFFIC CHARACTERISTICS AND OPERATIONS. (4 cr; prereq 3200 or equiv)
Characteristics and measurements of volume, speed, density, and travel time; characteristics of vehicles and road users; parking characteristics and design of facilities; implications of signs, signals, and markings in traffic control.

5202. AIRPORT DESIGN. (4 cr; prereq 3200, 3300)
Nature of air transport. Airfield site selection and runway patterns. Geometric design of runways; capacity. Drainage and pavement design.

5210. INTRODUCTION TO TRANSPORTATION PLANNING. (4 cr; prereq ‡)
Outline of the transportation planning process as applied to urban areas; data requirements and travel characteristics; trip generation analysis; models of travel distribution; transit characteristics and usage; selection and evaluation of alternate transportation proposals; transportation and land use linkages.

Geomechanics (Soil Mechanics and Rock Mechanics)

3300. ELEMENTS OF SOIL MECHANICS. (4 cr; 3 lect and 3 lab hrs per wk)
Physical properties of soils; relationships with water; stress distribution. Classification, compaction, and strength tests. Geological features and engineering properties of rocks.

5304. DESIGN OF HIGHWAY AND AIRPORT PAVEMENTS. (4 cr; prereq 3300, 3700)
Theories of pavement design, flexible and rigid; equivalent wheel loads. Strength tests and frost action. Design procedures for flexible and rigid pavements.

5311. SHEAR STRENGTH OF SOILS. (4 cr; prereq 3300; 3 lect and 3 lab hrs per wk)
Methods for evaluating the strength of various soils to be used for engineering projects.

5320.†† FUNDAMENTALS OF GEOMECHANICS. (4 cr; prereq 3300; 3 lect and 2 rec hrs per wk)
Groundwater flow; stress and strain analysis in soil and rock; effective stresses; testing techniques; solutions of simple elasticity problems; stress-strain relations in soil and rock.

5321.†† SLOPES AND FOUNDATIONS I. (4 cr; prereq 5320; 3 lect and 2 rec hrs per wk)
One-dimensional consolidation; tests; bearing capacity and settlements; retaining walls and excavations; slope stability in soil and rock; influence of groundwater; pile foundations.

5322.†† SLOPES AND FOUNDATIONS II. (4 cr; prereq 5321; 3 lect and 2 rec hrs per wk)
Settlements due to two and three dimensional consolidation, pumping and subsidence, negative skin friction of pile foundations. Stress analysis in the failure zone of granular materials; field tests; ground strengthening.

Water Resources, Hydraulic Engineering, and Hydrology

3400. FLUID MECHANICS. (4 cr, §AEM 5200; prereq Math 3221, AEM 1015; (or) 3016; 3 lect and 3 lab hrs per wk)
Fluid properties, fluid statics for liquids and gases. Kinematics of fluid flow. Viscous effects. Introduction to incompressible and compressible duct flow, boundary layers, lift and drag, potential flow. Fluid measurements.

††Final approval of course pending at time of bulletin publication.

5401. WATER RESOURCES ENGINEERING. (5 cr; prereq 3400 or AEM 5200 or ‡; 4 lect and 3 lab hrs per wk)
Introduction to hydrology including precipitation and flood analysis; hydraulic engineering, including conduit flow, pumps, open channel flow, culvert flow, flow measurement; hydraulic structures; introduction to the systems approach.

5402. HYDRAULIC ANALYSIS. (4 cr; prereq 5401 or ‡; 3 lect and 3 lab hrs per wk)
Computer application in hydraulic engineering, open channel controls, spillways and stilling basins, bridge waterways, culvert analyses, selected problems in conduit flow, wave action on breakwaters, elementary water hammer and surge analysis.

5405. HYDROLOGY. (4 cr; prereq 5401 or ‡; 3 lect and 3 lab hrs per wk)
Hydrologic cycle, precipitation, evaporation infiltration, runoff analysis, flood routing, statistical procedures in hydrology, urban hydrology, introduction to mathematical models of medium and large watersheds.

5410. OPEN CHANNEL HYDRAULICS. (4 cr; prereq 5401 or ‡; 3 lect and 2 lab hrs per wk)
Mechanics of flow in open channels including gradually varied, spatially varied, and rapidly varied flow; unsteady flow (waves and surges) and flow in alluvial channels.

5420. INTRODUCTION TO WATER RESOURCES MANAGEMENT. (4 cr)
The present state of our water resources; water resources planning; implementation.

5435. INTERMEDIATE FLUID MECHANICS WITH APPLICATIONS. (4 cr; prereq 3400)
Basic laws and equations of fluid flows; exact and approximate solutions; very viscous flow; flow through porous media, potential flows, interfacial flows; boundary layer flow; turbulence and transport phenomena.

Environmental Engineering

3500. INTRODUCTION TO ENVIRONMENTAL ENGINEERING. (4 cr; prereq 3400 or ¶3400 or ‡)
Needs of urbanized society and their impact on the environment; physical, chemical, and biological characterization of the environment; environmental quality standards; technology for pollution abatement.

5500. ANALYSIS AND DESIGN OF WATER SUPPLY SYSTEMS. (4 cr; prereq 3500 or ‡; 3 lect and 3 lab hrs per wk)
Planning and engineering design considerations in developing water supply systems for urban centers. Supply quality, storage, treatment, distribution, and cost analysis.

5501. ANALYSIS AND DESIGN OF WASTE WATER SYSTEMS. (4 cr; prereq 3500 or ‡; 3 lect and 3 lab hrs per wk)
Planning and engineering design considerations in developing waste disposal systems for urban centers. Volumes and quality of waste streams, treatment and ultimate disposal of domestic and industrial waste waters, and storm water runoff. Environmental effects, cost, and political aspects of ultimate disposal.

5505. MANAGEMENT OF THE AQUATIC ENVIRONMENT. (4 cr; prereq 3500 or ‡)
Man's impact on the aquatic environment. Water quality objectives; mathematical models are used to assess the quantitative effects of pollution sources. Biological aspects of water quality management.

5510. SOLID WASTE MANAGEMENT. (4 cr; prereq 3500 or ‡; 3 lect and 3 lab hrs per wk)
Solid waste disposal for urban areas in terms of volume, composition, and chemical characteristics. Methods and equipment of collection and treatment. Various disposal methods in terms of their effects on the environment and the unit costs.

Structural Engineering

3600-3601. ELEMENTARY STRUCTURAL DESIGN FOR ARCHITECTS. (4 cr per qtr; prereq AEM 3093)
Elementary behavior, analysis, and design of structural systems in steel, reinforced concrete, and timber.

3605. INTRODUCTION TO STRUCTURAL ANALYSIS. (4 cr; prereq AEM 1015)
Principles of structural mechanics; forces and deformations in one-dimensional structural elements; elementary design considerations.

5600. LINEAR STRUCTURAL SYSTEMS. (4 cr; prereq 3605)
Analysis of indeterminate structural systems.

5601. ANALYSIS OF STRUCTURES. (4 cr; prereq 5600)
Analysis of linear structural systems by matrix methods.

5610. DESIGN OF METAL STRUCTURES. (4 cr; prereq 5600)
Elastic and plastic philosophies of design and related properties of structural metals. Design of tension members, columns, beams, trusses, and plate girders. Connections, plastic design.

5611. DESIGN OF REINFORCED CONCRETE STRUCTURES. (4 cr; prereq 5600)
Principles of strength and serviceability in reinforced concrete structural design. Strength analysis, design of beams, joists, one-way slabs for flexure and shear. Anchorage, development, splicing of reinforcement. Stresses at service, loads deflections, cracking, long-term effects. Introduction to design of columns; continuity; simple footings.

5612. DESIGN OF METAL STRUCTURES: INTERMEDIATE. (4 cr; prereq 5610)
Design of complete metal structures; industrial buildings, multistory structural frames.

5613. INTERMEDIATE REINFORCED CONCRETE DESIGN. (4 cr; prereq 5611; 4 lect hrs per wk)
Eccentrically loaded columns. Shear friction, design of brackets. Deep beam design. Continuous beams and frames. Combined and continuous footings. Retaining walls. Combination of shear and torsion. Two-way slabs.

5615. PRESTRESSED CONCRETE. (4 cr; prereq 5611. . .5613 recommended; 4 lect hrs per wk)
Types and properties of high-strength concretes and steels for prestressed concrete. Design of pretensioned and posttensioned members. Posttensioning systems. Precast prestressed building systems, floors, roofs, bridges. Continuity in precast prestressed systems. Design of connections.

Construction Materials

3700. INTRODUCTION TO CONSTRUCTION MATERIALS. (4 cr; prereq AEM 1015; 3 lect and 3 lab hrs per wk)
Basic concepts of the behavior mechanisms of materials and characterization of specific materials such as concretes, metals, woods, and others.

5701. CEMENTED MATERIALS: PROPERTIES, EVALUATION, AND MIXTURE DESIGN. (4 cr; prereq 3700; 3 lect and 3 lab hrs per wk)
Characteristics and performance evaluation concepts of construction materials; properties and design of cemented mixtures such as concrete, bituminous mixtures, stabilized soils and rocks.

5702. MANUFACTURE AND QUALITY CONTROL OF CONSTRUCTION MATERIALS. (4 cr; prereq 3700; 3 lect and 3 lab hrs per wk)
Methods of manufacture, especially of cemented materials such as concrete, stabilized soils and rock; expected variations and quality control concepts; optimization techniques developed to establish procedures and best material to use for a given situation.

FOR GRADUATE STUDENTS ONLY

8097-8098-8099. CIVIL ENGINEERING RESEARCH

8200. SEMINAR: THEORY OF TRAFFIC FLOW

8201. SEMINAR: URBAN TRAFFIC OPERATIONS

8202. SEMINAR: FREEWAY TRAFFIC OPERATIONS

8210. SEMINAR: ADVANCED TRANSPORTATION PLANNING

8300-8301. ADVANCED SOIL MECHANICS LABORATORY

8302. ADVANCED HIGHWAY LABORATORY

8303. SPECIAL PROBLEMS IN CONCRETE MATERIALS

8310. FOUNDATION AND HARBOR ENGINEERING

8400. HYDRAULIC TRANSIENTS

8410. FLUID TURBULENCE

8412. MECHANICS OF SIMILITUDE AND DIMENSIONAL ANALYSIS

8413. MECHANICS OF SEDIMENT TRANSPORT

8415. WATER POWER

8416. HYDRAULIC MEASUREMENTS

8417. HYDRAULIC PUMPS AND TURBINES

8419. WATER RESOURCES SYSTEMS SIMULATION

8420. WATER RESOURCES SYSTEMS

8421. INCOMPRESSIBLE POTENTIAL FLOW

8422. INCOMPRESSIBLE BOUNDARY LAYER FLOW

8425. GROUNDWATER HYDRAULICS

8430. LAKE, RESERVOIR, AND OCEAN HYDRODYNAMICS

8431-8432-8433. HYDRODYNAMICS OF THE BOUNDARY LAYER

8435-8436-8437. SPECIAL TOPICS IN HYDRODYNAMIC THEORY

8497-8498-8499. ADVANCED HYDRAULIC LABORATORY

8500. PHYSICAL AND CHEMICAL PROCESSES FOR WATER AND WASTE WATER TREATMENT

8501. BIOLOGICAL AND CHEMICAL PROCESSES FOR WASTE WATER TREATMENT

8502. WATER AND WASTE WATER TREATMENT PROCESSES: LABORATORY

8505. AQUATIC CHEMISTRY FOR ENVIRONMENTAL ENGINEERS

8510. INDUSTRIAL WASTE WATER TREATMENT AND DISPOSAL

8520. WATER TREATMENT PLANT DESIGN

8521. WASTE WATER TREATMENT PLANT DESIGN

8550. ANALYSIS AND MODELING OF THE AQUATIC ENVIRONMENT

8551. SEMINAR: MODELS OF AQUATIC ENVIRONMENT

8560. SEMINAR: SPECIAL TOPICS IN ENVIRONMENTAL ENGINEERING

8605-8606. APPROXIMATE METHODS OF STRUCTURAL ANALYSIS I, II

8608. ADVANCED THEORY OF STRUCTURES

8609. PRINCIPLES OF STRUCTURAL STABILITY

8610. SHELL STRUCTURES

8612. STRUCTURAL DESIGN BY ULTIMATE LOAD THEORY

8620-8621. STRUCTURAL DYNAMICS I, II

8697-8698-8699. SEMINAR: STRUCTURES

Computer, Information, and Control Sciences (CICS)

1100. INTRODUCTION TO FORTRAN PROGRAMMING I. (2 cr; prereq Math 1211 or 1311 or 1611 or ¶Math 1211 or ¶1311 or ¶1611 or ‡; informal lab)
Introduction to computer programming using FORTRAN; elementary-intermediate level applications. A choice of problems is provided to allow for students from different academic disciplines. (See 3101 for comparison)

1101. INTRODUCTION TO FORTRAN PROGRAMMING II. (2 cr [not open for cr to CICS majors]; prereq 1100 and Math 1211 or 1311 or 1611 or ‡; informal lab)
(Continuation of 1100) Extended applications including some numerical methods.

3001. PERSPECTIVES ON COMPUTERS AND SOCIETY. (4 cr; prereq soph or ‡; informal lab)
The impact of computers on society. Partnership or confrontation. History of development. Potential for use. Computer utility. Privacy in a computer society. The future of computers. The ultimate machine. Computers in business, industry, art, music, the home.

3101. A FORTRAN INTRODUCTION TO COMPUTER PROGRAMMING. (4 cr; prereq Math 1211 or 1311 or 1611 or ‡)
FORTRAN computer language with extensions; applications; programming techniques. Brings students to advanced-level competence in FORTRAN programming. Integral non-scheduled laboratory.

3105 (formerly 1105). FUNDAMENTALS OF ALGORITHMS AND LANGUAGES I. (4 cr; prereq 1101 or 3101 or ‡; informal lab)
Informal and formal approaches to algorithms, their properties, analysis, and synthesis (formulation), as well as the correspondence between programming languages and the types of problems to be solved. Numerical algorithms and their implementation in a programming language (FORTRAN).

3106 (formerly 1106). FUNDAMENTALS OF ALGORITHMS AND LANGUAGES II. (4 cr; prereq competence in a high-level language, algorithmic structures at the level of 3105 or ‡; informal lab)
Algorithms for nonnumeric data types. Examples from area of language processors, data structures, string processing. Suitable languages; SNOBOL. Textual analysis, recursive processes, their implications for languages and their implementation; excursion into artificial intelligence.

3107. INTRODUCTION TO THE STRUCTURE AND PROGRAMMING OF COMPUTER SYSTEMS. (4 cr, §5101; intended for CICS majors...nonmajors should take 5101; prereq 1101 or 3101 or equiv or ‡; informal lab)
Organization and logical structure of computer systems. Representation of programs and data. Topics: number systems, primitive computer systems, programming in machine language. Extensions to more sophisticated systems, assembly language, sequencing, decision making, arithmetic, logical operations, character manipulation, iteration, subroutines, data description, introduction to assembler software.

5001. THEORY AND APPLICATION OF LINEAR PROGRAMMING ALGORITHMS. (4 cr; prereq 1101 or 3101, Math 3211 or Math 3142, or ‡; informal lab)
Convex polyhedral sets; extreme points; linear systems; primal and revised simplex algorithms; duality theory and Kuhn-Tucker conditions; postoptimality analysis; obtaining initial feasible solutions; storage and retrieval problems; use of commercial linear programming codes.

5002. COMPUTATIONAL METHODS FOR NONLINEAR PROGRAMMING. (4 cr; prereq 5001 or ‡; informal lab)
Convex functions and domains; nonlinear optimality conditions and duality; unconstrained minimization methods; convergence rates; minimization methods for linear and nonlinear constraints; penalty functions; acceleration of convergence; nonconvex problems.

5101. STRUCTURE AND PROGRAMMING OF SOFTWARE SYSTEMS I. (4 cr, §3107; intended for non-CICS majors...majors should take 3107; prereq 1101 or 3101 or equiv or ‡; informal lab)
The organization and logical structure of computer systems and the representation of programs and data. Topics covered are essentially the same as those listed for 3107; however, the emphasis and projects will be geared to nonmajors.

5102. STRUCTURE AND PROGRAMMING OF SOFTWARE SYSTEMS II. (4 cr; prereq 3107 or 5101 or ‡; informal lab)
Subroutine coding conventions; argument transfer; interrupts and traps; macros; I/O equipment and operations; buffers; conditional assembly and program segmentation. Students will write assembly language programs for an existing modern computer.

5103. INTRODUCTION TO ASSEMBLERS. (4 cr; prereq 5102 or ‡; informal lab)
Relocatability and base addressing. Creating an assembler; source code scanning, symbol table management, stacking, template macroprocessing, etc. Micro programming. Students will design and run an assembler.

5104. SYSTEM SIMULATION: LANGUAGES AND TECHNIQUES. (4 cr; prereq 3107 or 5101, Stat 3091 or ‡; informal lab)
Simulation methodology including random number generation, queuing, service times, discrete random variables, design of experiments. Simulation languages, flow and event oriented: GPSS, SIMULA, SIMSCRIPT. Model building. Application to job shops, business, operations research and operating systems.

5105. THEORY OF MACHINE ARITHMETIC. (4 cr; prereq 3107 or 5101 or ‡; informal lab)
Residue class arithmetic. Congruences and complement arithmetic. Integral additive and subtractive accumulators. Applications to absolute value and sign arithmetic, scaling and floating point operation.

5106. STRUCTURE OF HIGHER LEVEL LANGUAGES. (4 cr; prereq 5102 or ‡)
Formal definition of programming languages. Syntax. Semantics. The Algol Report. Introduction to Algol. Applications. Extensions of concepts to other languages. List structures. List languages. List processing. Basics of compilers and compiler implementation.

5107. COMPUTER GRAPHICS. (4 cr; prereq 3107 or 5101 or ‡)
Arrangement of data base and display files. Representation of data types of display equipment available, calligraphic and raster. Character generators. Display processors. Clipping, windowing, and the hidden surface problem. Applications.

5108. MATRIX DESCRIPTION AND SYNTHESIS OF LOGICAL ALGORITHMS FOR MICROPROGRAMMING. (4 cr; prereq 3107 or 5101, 5201, Math 3211 or ‡; informal lab)
A special matrix calculus is developed and applied to the description and synthesis of combinational, iterative, and sequential networks. Applications to state reduction, minimization of logical algorithms, and structural implementation of microprograms.

5121. INTRODUCTION TO DATA STRUCTURES. (4 cr; prereq 3106 or ‡; informal lab)
Basic concepts of data and its representation. Linear lists and strings. Array structures and allocation. Symbol tables and searching techniques; hash coding techniques. Tree structures. Storage systems and structures. Storage allocation. Multilinked structures. Sorting.

5122. ADVANCED DATA STRUCTURES. (4 cr; prereq 5121 or ‡; informal lab)
Data structure formalisms. Storage structures and organization. Data structures in programming languages. List processing languages. Data definition languages. Data base management systems and design. Problems in information system design. Applications to large data base problems.

5199. PROBLEMS IN LANGUAGES AND SYSTEMS. (1-4 cr [may be repeated for cr]; prereq ‡)
Special courses or individual study arranged with faculty member.

5200. INTRODUCTION TO ANALOG AND HYBRID COMPUTATION. (4 cr; prereq 1101 with ‡, and Math 3221 or Math 3061, or ‡; 3 lect and 1 lab hrs per wk)
Organization of and programming for analog and hybrid computers. Interface equipment including analog-to-digital and digital-to-analog conversion. Simulation languages. Case studies and problem solutions.

5201. FUNDAMENTALS OF LOGIC SYSTEM DESIGN. (4 cr; prereq 3105 or ‡)
Mathematical fundamentals: Sets, set operations, relations, algebraic structures and Boolean algebra, switching functions. Matrix notation and operations for the synthesis of combinational networks and iterative or sequential systems. State reduction and minimization. Design of synchronous flip-flop networks and microprograms for computer algorithms.

5299. PROBLEMS IN MACHINE DESIGN. (1-4 cr [may be repeated for cr]; prereq ‡)
Special courses or individual study arranged with faculty member.

5301. NUMERICAL ANALYSIS. (4 cr, §Math 5472; prereq Math 3221, or Math 3142 and Math 3211, or ‡. . .a knowledge of FORTRAN is assumed; informal lab)
General concept of iteration formulas. Solution of equations. Newton's method. Linear systems. Finite differences. Interpolation. Numerical differentiation and integration. Introduction to initial value problems.

5302. NUMERICAL ANALYSIS. (4 cr, §Math 5473; prereq 5301 or ‡; informal lab)
General theory of linear approximations. Norms. Error estimates. Convergence rates. Least squares. Orthogonal polynomials. Chebychev interpolation theory. Gaussian quadrature. Further solution of equations. Multipoint iteration formulas. Starting values. Iterative schemes for linear algebra. Conditioning. Jacobi's method. Differential equations. Initial value problems. Systems of equations. Runge-Kutta. Stability.

5304. COMPUTATIONAL ASPECTS OF MATRIX THEORY. (4 cr; prereq 5302 or ‡; informal lab)
Computational pitfalls. Conditioning. Iterative methods. Relaxation methods. Various reduction and elimination schemes. Hessenberg matrices. Methods of Lanczos, Givens, Householder. Eigenvalue problems. Bounds for eigenvalues.

5305. NUMERICAL SOLUTIONS OF INITIAL AND BOUNDARY VALUE PROBLEMS. (4 cr; prereq 5302 or ‡; informal lab)
Linear two-point boundary value problems. The eigenvalue problem. Tau and Galerkin methods. Nonlinear two-point problems. Shooting method. Newton-Kantorovich method. Elements of numerical solutions of problems in partial differential equations. Laplace, heat, and wave equations.

5399. PROBLEMS IN NUMERICAL ANALYSIS. (1-4 cr [may be repeated for cr]; prereq ‡)
Special courses or individual study arranged with faculty member.

5400. INTRODUCTION TO AUTOMATA THEORY. (4 cr; prereq 3106 or ‡)
Turing machines, computable functions, unsolvability of the halting problem. Finite state models: equivalence, minimization, synthesis of finite state systems, state assignment, decomposition. Survey of other automata.

5401. INTRODUCTION TO FORMAL LANGUAGES. (4 cr; prereq 5400; informal lab)
Formal grammars and languages and their related automata. Language hierarchy. Context-free languages and grammars. Push-down automata. Normal form theorems. Operations on languages. Decidability and undecidability results. Parsing algorithms. Applications to programming.

5499. PROBLEMS IN COMPUTATIONAL THEORY OR LOGIC. (1-4 cr [may be repeated for cr]; prereq ‡; informal lab)
Special courses or individual study arranged with faculty member.

5501. ARTIFICIAL INTELLIGENCE AND HEURISTIC PROGRAMMING. (4 cr; prereq 3106 or ‡; informal lab)
Concept of a "mechanized" intelligence. The IQ of current systems. Game playing, particularly heuristic search techniques. Introduction to neural networks and their mechanical

analogs. Methodologies in pattern recognition and applications. The frame problem in AI and implications for robotics. Natural language processing and deductive question answering.

5502. INTRODUCTION TO OPERATING SYSTEMS. (4 cr; prereq 5102 or ♯; informal lab)
Definition and historical development of operating systems. Classification of systems as batch-processing, interactive and real-time systems. Abstractions and implementations of properties common to most systems. Concurrency and related control problems. Resource allocation. Storage allocation. Program modularity. Sharing. Multiplexing. Protection. Performance optimization.

5503. INTRODUCTION TO COMPILER CONSTRUCTION. (4 cr; prereq 5103 or ♯; informal lab)
Definition of a language; phrase structure languages; context free languages and grammars; rigorous definition of typical small language in BNF. An actual compiler for programs written in this language is produced and executed: scan and classification of statements; symbol table construction and management; generation of intermediate text and assembly code.

5504. FORMAL METHODS IN COMPILER CONSTRUCTION. (4 cr; prereq 5401 and 5503 or ♯; informal lab)
Syntax-directed approach to the "front-end" of a compiler; review of finite state automata used by the lexical scanner; generative BNF grammars and their use in top-down parsing; boot-strapping techniques; precedence schemes and languages, production of a table-driven, efficient bottom-up parser.

5505. OPTIMIZATION IN COMPILERS. (4 cr; prereq 5503 or ♯; informal lab)
Automatic collection of global information encompassing the structure of the program; usage information for the variables; representation in terms of a program graph. Specific optimizations: elimination of common subexpressions; backward movement of code; strength reductions. Minimization of loads and stores. Optimal global assignment of registers.

5511. ADVANCED TOPICS IN ARTIFICIAL INTELLIGENCE. (4 cr; prereq 5501 and 5400, or ♯)
"Systems" employing AI techniques; examples including Shakey (the SRI robot), the hand-eye project at Edinburgh, the MIT robot project, etc. Methods of integrating eyes, hands, ears, etc., into a functioning unit. Natural language facilities including representational schemes, parsing algorithms and semantic memories. Students will design and implement phases of a large system.

5599, 5699, 5799. PROBLEMS: NONNUMERIC COMPUTATION, CONTROL SCIENCE, INFORMATION SCIENCE. (1-4 cr [may be repeated for cr]; prereq ♯)
Special courses or individual study arranged with faculty member.

FOR GRADUATE STUDENTS ONLY

8101-8102-8103. COMPUTER OPERATING SYSTEMS: MODELING AND ANALYSIS

8199. SEMINAR: LANGUAGES AND SYSTEMS

8201-8202-8203. MATHEMATICS OF COMPUTERS AND CONTROL DEVICES

8299. SEMINAR: MACHINE DESIGN

8301-8302. COMPUTATION OF SPECIAL FUNCTIONS AND FORMULAS

8303-8304. COMPUTATIONAL METHODS FOR INITIAL AND BOUNDARY VALUE PROBLEMS

8399. SEMINAR: NUMERICAL ANALYSIS

8401-8402. ALGORITHMS—TECHNIQUES AND THEORY

8499. SEMINAR: COMPUTATIONAL THEORY AND LOGIC

8501. PATTERN RECOGNITION

8599. SEMINAR: NONNUMERIC COMPUTATION

8699. SEMINAR: CONTROL SCIENCE

8799. SEMINAR: INFORMATION SCIENCE

Electrical Engineering (EE)

1000. INTRODUCTION TO ELECTRICAL ENGINEERING. (1 cr; S-N only; prereq EE lower division)
An introduction to electrical engineering presented by practicing engineers and members of the faculty.

1510. ELEMENTS OF ELECTRICAL ENGINEERING. (5 cr; prereq Math 3221, Phys 1291 or ¶Phys 1291; 5 lect-rec-dem hrs and 3 lab hrs per wk)
Physical principles underlying the modeling of circuit elements. Two- and three-terminal resistive elements. Kirchhoff's laws. Simple resistive circuits. Linearity in circuits. Storage elements. First-order circuits.

3000. CIRCUITS. (4 cr; not for EE majors; prereq Phys 1291, Math 3221 or ¶Math 3221; 3 lect and 2 rec lab hrs per wk)
Analysis of linear passive circuits; natural and forced response. Steady-state AC analysis; resonance.

3001. ELECTRONICS. (4 cr; not for EE majors; prereq 3000 or 3010; 3 lect and 2 rec or lab hrs per wk)
Network theorems; two-ports, active device models; vacuum diodes, semiconductors, amplifiers, nonlinear devices; logic circuits.

3002. ELECTRIC MACHINERY AND POWER DISTRIBUTION. (5 cr; not for EE majors; prereq Math 3221 or equiv, Phys 1291 or equiv; 4 lect and 2 lab hrs per wk)
Fundamentals of electric circuit theory; methods of analysis. Transformer operation and polyphase connections. Principles of rotating electric machines. Performance characteristics and application considerations of DC machines, induction machines, and synchronous machines. Introduction to electric power distribution systems.

3010-3011-3012. CIRCUITS, SIGNALS, AND SYSTEMS I, II, III. (4 cr per qtr, §1501-5000-5001; prereq 1510; 3 lect and 2 rec-dem hrs per wk)
3010: Modeling of lumped-parameter networks. Second-order circuits. Sinusoidal steady-state analysis. Two-port networks. 3011: Fourier methods of analysis. Laplace transforms and applications. Frequency and time-domain responses. 3012: Continuous, discrete-time systems. Feedback: stability, applications.

3010H-3011H-3012H. HONORS COURSE: CIRCUITS, SIGNALS, AND SYSTEMS I, II, III. (4 cr per qtr; prereq △)

3050-3051. ELECTRONICS. (4 cr per qtr; prereq 3010-3011 or ¶3010-3011; 3 lect and 2 rec-dem hrs per wk)
3050: Diode circuits and applications. Semiconductor properties. P-N junctions. Junction diodes; JFET characteristics; MOSFET characteristics. FET amplifiers; biasing. 3051: BJT characteristics. Biasing of BJT's. Low-frequency amplifiers; BJT's and FET's. Vacuum tubes. High-frequency amplifiers. Miller approximation; BJT's and FET's.

3050H-3051H. HONORS COURSE: ELECTRONICS I-II. (4 cr per qtr; prereq △)

3100-3101. ELECTROMAGNETIC FIELDS I, II. (4 cr per qtr; prereq Phys 1291, Math 3231 or ¶Math 3231 with ‡; 3 lect hrs and 2 rec-dem hrs per wk)
Electrostatic, magnetostatic, and electromagnetic field theory based on fundamental experimental laws, including properties of dielectric and magnetic materials.

3100H-3101H. HONORS COURSE: ELECTROMAGNETIC FIELDS. (4 cr per qtr; prereq △)

3400-3401-3402. JUNIOR ELECTRICAL ENGINEERING LABORATORY. (3/3/2 cr per qtr; prereq 3050-3051-5050 or ¶3050-3051-5050)
Experiments in circuits, electronics, and electromagnetic fields.

3450H-3451H-3452H. ELECTRICAL ENGINEERING HONORS COURSE. (4/4/3 cr, §3400-3401-3402; prereq △)
Special studies for third-year students in Electrical Engineering honors program.

3470-3471. SUMMER ENGINEERING EMPLOYMENT. (1-3 cr per qtr; prereq completion of 2nd- or 3rd-yr work, declaration of intention before end of spring qtr, regis in fall qtr)
Summer work in an engineering field; minimum of 360 hours per summer. Requires a technical report.

3476-3477-3478-3479†. INDUSTRIAL ASSIGNMENT I, II, III, IV. (2 cr per qtr; prereq regis in intern program)
Industrial work assignment in engineering intern program. Grade based on student's formal written report covering the quarter's work assignment.

3950H-3951H-3952H. HONORS PROJECT. (3 cr per qtr; prereq △)
Design project for fourth-year students in Electrical Engineering honors program.

3970. DIRECTED STUDY. (Cr ar [may be repeated for cr]; prereq approval of faculty sponsor)
Undergraduate studies of approved topics, theoretical or experimental in nature.

5002. METHODS OF NETWORK AND SYSTEM ANALYSIS. (4 cr; prereq 3012; 3 lect and 2 rec-dem-comp hrs per wk)
Topological and matrix methods. State-space methods. Discrete-time systems. Computer methods.

5012. ACTIVE FILTER DESIGN. (4 cr; prereq 3012 or ♯; 3 lect and 2 lab-rec hrs per wk)
Description and analysis of linear networks in the frequency domain. Two-port network analysis. Design of active RC filters using operational amplifiers, second-order filters using Sallen-Key circuits, coefficient matching of multiple feedback circuits, state-variable method, etc. Sensitivity and tuning considerations.

5050. NONLINEAR ELECTRONIC CIRCUITS. (4 cr; prereq 3051, 3012 or ¶3012; 3 lect and 2 rec-dem hrs per wk)
Linear wave-shaping circuits. Piece-wise linear circuit analysis. Switching models of diodes and transistors. Transistor logic circuits. Bistable multivibrators. Astable multivibrators. Nearly sinusoidal oscillators.

5050H. HONORS COURSE: NONLINEAR ELECTRONIC CIRCUITS. (4 cr; prereq △)

5051. INTRODUCTION TO LOGIC DESIGN. (4 cr, §5060, §5350; prereq 3051 or ♯; 3 lect and 2 rec hrs per wk)
Integrated logic circuits. Design using logic circuits, memory elements, sequential circuits. Transmission lines and digital signals.

5052. LOGIC DESIGN LABORATORY. (1 cr; prereq ¶5051; 2 lab hrs per wk)

5053. DESIGN OF DIGITAL CIRCUITS. (4 cr, §5060; prereq 5050, 5051, or ♯; 3 lect and 2 lab hrs per wk)
Design of digital and nonlinear circuits; circuit structures, device topologies and performance criteria of IC gates. Flip-flops, counters and A/D converters at subsystem level. Theoretical analysis and use of nonlinear behavior of devices.

5055. LINEAR ELECTRONIC CIRCUITS. (4 cr; prereq 3051, 3012 or ¶3012, or ♯; 3 lect and 2 rec hrs per wk)
Multistage, untuned, small-signal amplifiers. Feedback amplifiers. Untuned power amplifiers. Regulated power supplies.

5056. ELECTRONIC CIRCUITS LABORATORY. (1 cr; prereq 3401, ¶5055; 2 lab hrs per wk)

5062. COMMUNICATION CIRCUITS. (4 cr, §5061; prereq 3012, 5055, or ♯; 3 lect and 2 lab hrs per wk)
Design and analysis of electronic circuits common to communication systems and instrumentation, incorporating the latest IC technology. Typical circuits include tuned amplifiers, mixers, modulators, and phase-locked loops.

5100. ELECTROMAGNETIC FIELDS III. (4 cr; prereq 3101; 3 lect hrs and 2 rec-dem hrs per wk)
Plane-wave propagation, transmission lines, antennas, and other topics.

5101. ELECTROMAGNETIC FIELDS LABORATORY. (1 cr; prereq 3401, 5100 or ¶5100)

5112. ELECTROMAGNETIC BOUNDARY VALUE PROBLEMS. (4 cr, §old 5110-5111; prereq 5100 or ♯; 3 lect and 2 lab hrs per wk)
Review of static field theory with applications. Boundary-value problems. Quasi-statics. Reflection and refraction of plane waves. Properties of guided waves. Rectangular and circular wave guides. Resonant cavities.

5113. PROPAGATION OF ELECTROMAGNETIC FIELDS. (4 cr, §old 5110-5111; prereq 5100 or ♯; 3 lect and 2 lab hrs per wk)
Review of transients on transmission lines. Pulses on lossy transmission lines. Coupled transmission lines. Superconducting transmission lines. Microwave networks and S-parameter design. Radiation and antenna arrays. Wave propagation in anisotropic media. Microwave electronics.

5120. ACOUSTICS FOR ARCHITECTS AND PLANNERS. (3 cr; not for EE majors; prereq Math 1231, Phys 1122 or 1052, or ♯...some background in statistical methods desirable)
Studies of sound both indoors and out-of-doors with special reference to noise and its abatement. Building and community noise sources, their properties and response measures. Design procedures for noise control in building technology and urban planning.

5150. ELECTRICAL ENGINEERING MATERIALS. (4 cr; prereq 3101, Phys 3501, or ♯; 3 lect and 2 rec hrs per wk)
Electric, magnetic, and dielectric properties of materials as related to devices used in electrical engineering.

5160-5161. PHYSICAL ELECTRONICS. (4 cr per qtr; prereq 3101 or ♯; 3 lect and 2 lab hrs per wk)
Physical principles underlying devices used in electrical engineering; elementary quantum and statistical mechanics, photoemission, electron diffraction and emission. Charged-particle dynamics and diffraction. Semiconductor properties. Special topics of current interest.

5202. ANALOG COMMUNICATION. (4 cr, §5200; prereq 3012, Stat 3091, or ♯; 3 lect and 2 lab hrs per wk)

Selected topics in analog communication systems: Amplitude and frequency modulation. Spectral analysis and effect of noise in modulation systems. Detection.

5203. DATA COMMUNICATION. (4 cr, §5201; prereq 3012, Stat 3091, or ‡; 3 lect and 2 lab hrs per wk)
Selected topics in pulse and digital communication systems: pulse-modulation systems, pulse-code modulation. Data-transmission systems including phase-shift keying and frequency-shift keying. Effect of noise. Coding.

5252. DISCRETE CONTROL SYSTEMS. (4 cr, §5251; prereq 5002 or ¶5002, or ‡; 3 lect and 2 lab hrs per wk)
Time-domain representation and analysis of discrete systems; Z-transform. Design of discrete controllers. Computer control systems. Computer simulation.

5253. LINEAR CONTROL SYSTEMS. (4 cr, §5250; prereq 3012 or ‡; 3 lect and 2 lab hrs per wk)
Modeling, characteristics, and performance of feedback control systems. Stability, root-locus and frequency-response methods. Compensator design.

5300. ELECTROMECHANICS. (4 cr; prereq 3101, 3011, or ‡; 3 lect and 2 lab-rec hrs per wk)
Lumped-parameter models of magnetic- and electric-field systems; energy methods, quasi-static electromagnetics and circuit characterization. Induction and synchronous rotating machines; incremental-motion transducers. Associated laboratory using a generalized rotating machine to illustrate the basic characteristics of typical electromagnetic energy-conversion machines.

5310. ELECTRIC POWER SYSTEMS. (4 cr; prereq 5300, 5002 or ¶5002, or ‡; 3 lect and 2 lab hrs per wk)
Introduction to power-system engineering. Modeling of power-system components: transformers, synchronous generators, transmission lines, cables, and circuit breakers. Describing equations for power networks. Solution techniques for load-flow and fault studies. Power-system relaying.

5322. ELECTROMECHANICAL PROCESSES AND DEVICES. (4 cr, §old 5320-5321; prereq 5300, 5002 or ¶5002, or ‡; 3 lect and 2 lab hrs per wk)
Principles of electromechanical energy conversion. Modeling of rotating machines. Computer-aided steady-state analysis of DC and AC machines. Special purpose devices: Single-phase machines, linear machines, stepper motors. Solid-state motor control.

5332. ENERGY CONVERSION SYSTEMS. (4 cr; prereq sr standing in IT or ‡; 3 lect and 2 lab-rec hrs per wk)
Energy-conversion problem. Principles of energy conversion; laws of thermodynamics. Thermoelectric generators, thermionic converters, magnetohydrodynamic systems. Solar energy conversion, geothermal systems, fuel cells. Nuclear plants, fusion power.

5352. DESIGN OF DIGITAL SYSTEMS. (4 cr, §5851, §5852, §old 5351; prereq 5051, 5052 or ‡; 3 lect and 2 lab hrs per wk)
Structure of a digital system. Systematic design procedure. Clock and sequencer design and control. The digital computer.

5450. SPECIAL INVESTIGATIONS. (Cr ar [may be repeated for cr]; prereq △)
Studies of approved topics, theoretical or experimental in nature.

FOR GRADUATE STUDENTS AND QUALIFIED SENIORS

5500-5501-5502. SYNTHESIS OF ACTIVE AND PASSIVE NETWORKS. (3 cr per qtr; prereq 5012 or grad standing or ‡)
5500: Two-port parameters, indefinite admittance matrix, and their applications. Theory and testing of positive real functions. Synthesis of two-element-kind networks and RLC driving-point functions. Properties of two-port network functions. 5501: Relationship between parts of network functions. Butterworth, Thomson, Chebyshev, and elliptic approximations; frequency transformation and distortion. Synthesis of LC, RC, and RLC two-ports. 5502: Properties and frequency compensation of operational amplifiers and gyrators. Synthesis of active RC filters by several methods. Sensitivity analysis and comparison of active filters.

5550-5551-5552. SWITCHING AND DIGITAL CIRCUITS. (3 cr per qtr; prereq 5050 or ‡)
Transient response of junction diodes, bipolar and field-effect transistors; large-signal models of semiconductor devices; bistable, monostable, and astable semiconductor circuits in discrete and microelectronic forms; phase-plane analysis of large-signal oscillators; digital logic circuits, comparison of discrete and integrated circuits; calculation of circuit response by approximate methods and by digital computer; verification of circuit solutions by laboratory examples and problems.

5560. BIOMEDICAL INSTRUMENTATION. (4 cr; prereq ‡)
Biological signal sources. Electrodes, microelectrodes, other transducers. Characteristics of amplifiers for biomedical applications. Noise in biological signals. Filtering, recording,

and display. Protection of patients from electrical hazard. Experiments in neural and muscle stimulation, EKG and EMG recording, neuron simulation, filtering and low-noise amplifiers.

5610. ENGINEERING APPLICATIONS OF COHERENT LIGHT. (3 cr; prereq 5100 or Phys 3011 or ‡; 3 lect hrs per wk)
Sources of coherent light. Coherent light beams with treatment of coherence, diffraction, gaussian beams, and phase locking. Properties and uses of crystalline materials as modulators. Topics include holography, integrated optics, and laser-induced fusion.

5620. ENVIRONMENTAL ACOUSTICS AND NOISE. (4 cr; prereq sr standing in IT or ‡; 3 lect and 1 rec hrs per wk)
Energy and Fourier methods with other quantitative aspects of noise including spectra; spectral level, the decibel and its utility; methods of noise source modeling; acoustic propagation effects, attenuation. Noise impact prediction methods for transportation systems and building technology. Methods of noise abatement, influence of criteria and standards.

5650. DYNAMICAL METHODS IN ELECTRICAL ENGINEERING. (3 cr; prereq ‡)
Lagrangian and Hamiltonian formulations of dynamics, with applications to electromagnetic systems. Lagrange's equations; dissipative forces, normal coordinates and small oscillations; Hamilton's equations; variational principles for discrete and continuous systems.

5651. THERMODYNAMIC METHODS IN ELECTRICAL ENGINEERING. (3 cr; prereq ‡)
Basic thermodynamic concepts and laws, with special applications to electromagnetic systems. Energy, entropy, and thermodynamic potentials; application to electrically and magnetically polarizable materials, rigid or elastic, piezoelectricity, magnetostriction, thermoelectricity, reciprocal relations in reversible and irreversible processes.

5652. STATISTICAL-MECHANICAL METHODS IN ELECTRICAL ENGINEERING. (3 cr; prereq 5650, 5651 or ‡)
Classical and quantum-statistical mechanics with applications to materials and problems of electrical engineering. Statistical ensembles, phase space, Liouville's theorem, the canonical ensemble, the partition function. Classical and quantum statistics. Relation between statistical mechanics and thermodynamics. Classical and quantum calculations of susceptibilities.

5660-5661-5662. SEMICONDUCTOR PROPERTIES AND DEVICES. (3 cr per qtr; prereq 3101 or ‡)
Principles and properties of semiconductor devices. Selected topics in quantum and statistical mechanics, crystal structures, semiconductor properties; transistor action and other device phenomena; influence of surfaces. Treatment of actual devices. Large-scale integrated-circuit principles.

5666-5667-5668. MAGNETIC PROPERTIES OF MATERIALS AND APPLICATIONS. (3 cr per qtr; prereq ‡)
5666: Magnetic measurement techniques, physical principles of magnetism, and properties of magnetic materials with applications. 5667: Physical principles of crystalline and induced magnetic anisotropy, magnetostriction, magnetic domains and the magnetization process, fine particles and thin films and magnetization dynamics. 5668: Properties of soft and hard magnetic materials with applications such as thin film memories, permanent magnets, magnetic recording, and magneto-optics.

5670. BASIC MICROELECTRONICS. (4 cr; prereq ‡; 2 lect and 3 lab hrs per wk)
Experimental and theoretical studies of the basic physical processes used in microelectronic device fabrication. Transistor and integrated-circuit layout, fabrication, and evaluation.

5700. INFORMATION THEORY AND CODING. (3 cr; prereq Stat 3091 or ‡)
Discrete information sources and channels, source encoding, the binary channel and Shannon's theorem. Block codes for the binary channel.

5702. STOCHASTIC PROCESSES AND OPTIMUM FILTERING. (3 cr; prereq 5002, Stat 3091, or ‡)
Stochastic processes, linear system response to stochastic inputs. Gaussian process, Markov process. Linear filtering, maximum-likelihood estimate, stochastic control.

5703. MODULATION SYSTEMS. (3 cr; prereq 5702)
Mathematical models and effects of noise on modulation systems such as AM, FM, PCM. Data-communication systems including frequency- and phase-shift keying; bit-error probabilities.

5750. TOPICS IN SYSTEM ANALYSIS. (3 cr; prereq 5002 or grad standing)
Linear system models, controllability, observability, stability. Structure of linear systems. Minimization on inner-product spaces.

5751. OPTIMIZATION TECHNIQUES. (3 cr; prereq 5002 or grad standing)
Finite dimensional optimization, infinite dimensional optimization. Controller synthesis for the linear, quadratic problem.

5752. NONLINEAR SYSTEM DESIGN. (3 cr; prereq 5002 or grad standing)
Characteristics of nonlinear systems, analysis of singular points, limit cycles, describing functions, Lyapunov and Popov stability, computer simulation.

5760. BIOLOGICAL SYSTEM MODELING AND ANALYSIS. (4 cr; prereq ‡)
Purposes of biological system modeling; advantages, limitations, and special problems. Models of nerve excitation and propagation. Biological control systems: respiratory system, cardiovascular system. Sensory organs and various theories of perception. Limbs and locomotion.

5802. ELECTRIC POWER SYSTEM ANALYSIS. (3 cr; prereq ‡)
Formulation of describing equations and advanced computer methods of analysis of large-scale electric power systems. Applications to the load-flow problem, faulted-system calculations, stability studies, and economic environmental dispatch.

5805. ELECTRIC POWER SYSTEM ENGINEERING. (3 cr; prereq ‡)
Control of large power systems. Power system overvoltages and transients caused by faults, switching surges, and lightning. AC and DC electric power transmission and distribution, overhead and underground. Environmental impact of electrical energy systems. Current research topics.

5820. ELECTROMECHANICAL SYSTEM DYNAMICS. (3 cr; prereq ‡)
Electromechanical transducers and rotating machines and their dynamic performance in systems. State models of machines. Computer-aided analysis of typical transient operations. Small-signal analysis. Transient stability of power systems. Electromechanical components in control systems. Engineering applications.

5851. APPLIED SWITCHING THEORY. (3 cr; prereq 5051 or ‡)
Boolean algebra. Synthesis with practical logic circuits. Combinational logic hazards. Sequential circuit theory and practical design techniques.

5852-5853. DIGITAL COMPUTER SYSTEMS. (3 cr per qtr; prereq 5851, CICS 3101 or CICS 1101 or ‡)
Digital computer organization; register-level simulation; control unit design; microprogramming; memory organization. Computer input/output techniques; arithmetic unit design; high-speed arithmetic; features of larger computers.

FOR GRADUATE STUDENTS ONLY

8000, 8001, 8002. ADVANCED TOPICS IN NETWORK THEORY

8051-8052-8053. LARGE-SCALE INTEGRATED CIRCUITS

8090. ELECTRONICS SEMINAR

8100-8101-8102. PROBLEMS IN ELECTROMAGNETISM

8110-8111-8112. PLASMA PHYSICS

8120-8121-8122. FUNDAMENTALS OF ACOUSTICS

8140. SEMINAR: PLASMA PHYSICS

8143. SEMINAR: MODERN OPTICS

8150-8151. SOLID STATE PHYSICS

8152. MAGNETIC PROPERTIES OF SOLIDS

8153-8154-8155. PROPERTIES OF SEMICONDUCTORS

8156-8157-8158. FERROMAGNETISM AND RELATED PHENOMENA

8160-8161-8162. QUANTUM ELECTRONICS

8170-8171-8172. FLUCTUATION PHENOMENA

8190. SEMINAR: QUANTUM ELECTRONICS

8191. SEMINAR: SURFACE PHYSICS

8192. SEMINAR: MAGNETICS

8204. SIGNAL DETECTION AND ESTIMATION THEORY WITH APPLICATIONS

8211. CODING THEORY

8220. TOPICS IN STATISTICAL THEORY OF COMMUNICATION

8240. SEMINAR: COMMUNICATION

8250-8251-8252. ADVANCED CONTROL TOPICS

8253. LARGE-SCALE SYSTEM MODELS

8254. STRUCTURAL TECHNIQUES IN ANALYSIS AND CONTROL OF LARGE-SCALE SYSTEMS

8255. CONTROL AND OPTIMIZATION IN LARGE-SCALE SYSTEMS

8256. TOPICS IN STOCHASTIC FILTERING AND CONTROL

8260-8261-8262. NONLINEAR SYSTEMS

8290. SEMINAR: CONTROL THEORY

8291. SEMINAR: SYSTEM THEORY

8300-8301-8302. ADVANCED POWER-SYSTEM TOPICS

8340. SEMINAR: ELECTRIC POWER

8341. SEMINAR: ENERGY CONVERSION

8350. MODELS FOR COMPUTING MACHINES

8352. ADVANCED SWITCHING THEORY

8353. SEQUENTIAL CIRCUIT THEORY

8355. COMPUTER ARCHITECTURE I

8356. COMPUTER ARCHITECTURE II

8390. COMPUTER SYSTEMS SEMINAR

8450. SPECIAL INVESTIGATIONS

8451. ADVANCED TOPICS IN ELECTRICAL ENGINEERING

Engineering Graphics (EG)

0001. THE SLIDE RULE. (1 cr [no cr for IT students]; previous courses in higher algebra and trigonometry recommended; 1 lect per wk)
Computation practice and theory. Design of special scales.

1025. ENGINEERING GRAPHICS. (4 cr; ¶Math 1211 or equiv recommended; 3 lect, 1 rec, and open lab hrs per wk)
Engineering representation and analysis of systems of projection; the coordinate system, graphical and parallel numerical and computer solutions of space problems, intersections and developments. Techniques of sketching; pictorial projection systems, size description, standard and simplified practices applied to graphic communication.

1026, 1027. ENGINEERING GRAPHICS. (2 cr per qtr, §1025; prereq high school or other appropriate background in graphics and △ for 1026; 2 lect hrs per wk, open lab)
1027 is intended for those with a background in graphics and may be taken without the prerequisite of 1026 by those having had graphics in high school.

3028. GRAPHICAL COMPUTATION AND EMPIRICAL ANALYSIS. (4 cr; Math 1221 and Phys 1271 or equiv recommended; 3 lect hrs per wk, open lab)
Graphical computation of engineering problems involving algebra, calculus, and basic physical relationships. Functional scales, nomography and the derivation of empirical equations correlating graphic, algebraic, and computer methods.

3029. GRAPHICAL COMMUNICATION AND ILLUSTRATION FOR DESIGN. (4 cr; 1025 or equiv recommended; 3 lect hrs per wk, open lab)
Engineering representation in one-view and multiview systems. Dimensioning systems. Graphical approach relating functional design to space requirements. Pictorial representation and the principles and techniques of shading. Sketching.

5194. GRAPHICS IN ENGINEERING. (2-4 cr; 1025 or equiv recommended; hrs ar)
A synthesis and extension of the procedures of graphical mathematics, nomography, and/or descriptive geometry as applied to solutions of complex problems within the student's area of interest pursued as an individualized project and usually resulting in a comprehensive report.

Geo-Engineering (GeoE)

1001. GEO-ENGINEERING LABORATORY. (1 cr)
The field of geo-engineering and closely associated field of mineral engineering described and discussed in lectures and laboratories.

3012. GEO-ENGINEERING SURVEYING. (2 cr; prereq CE 3100 or ‡)
Mine and geologic field survey control systems. Triangulation, stadia, plane table. Compass surveys. Drill hole and joint systems surveys. Point and stereo diagrams. Underground mine survey control, meridian transfer, gyrotheodolite, stope surveys, special problems.

3015. SURVEY FIELDWORK. (2 cr; prereq 3012; hrs ar)
Open pit and underground surveying, shaft plumbing, stripping estimates; plane table work; solar and stellar observations; special problems.

5180. GEOCHEMICAL EXPLORATION. (3 cr; prereq sr or ‡)
Geochemical principles and techniques involved in the search for ore bodies. Basic premises, primary and secondary distribution halos, Eh-pH, geochemical provinces, interpretation of data, case studies. Laboratory work on colorimetric analysis of rock, soil, water.

5190. SELECTED TOPICS IN MINERAL EXPLORATION. (3 cr; prereq sr, grad)
Exploration programming in relation to theories of ore genesis. Analyses of effects of contract and lease requirements on decisions and planning. Statistical analyses in ore estimates. Case histories. Special problems.

5216. GEO-ENGINEERING AND ROCK MECHANICS I. (4 cr)
Site plans, geologic defects, rock properties, geophysical methods, vibration damage criteria, design of rock mass improvement systems including rock bolting, prestressing, and grouting. Cleft-water pressures, case histories. Elementary analysis of stress and strain in rock.

5218. TUNNELING TECHNOLOGY. (3 cr; prereq 5216 or CE 3300 or ‡; 3 lect hrs per wk)
Site investigation; excavation and material handling systems; groundwater control; ventilation systems; introduction to selection of support and lining systems; portals; introduction to cost estimates; construction in both soil and rock by either cut and cover or mining. Case histories.

5260-5262. GEO-ENGINEERING ANALYSIS. (2 cr for 5260, 3 cr for 5262; prereq sr or ‡; 2 lab hrs per wk for 5260, 6 lab hrs per wk for 5262)
Comprehensive analysis of a geological engineering or rock mechanics problem. Involves the integration of concepts of rock and soil mechanics, geology and geophysics, mineral engineering and economics, in a specific problem chosen by the student and staff. Preparation of a professional report.

5320. FUNDAMENTALS OF GEOMECHANICS. (4 cr; prereq 3300; 3 lect and 2 rec hrs per wk)
Groundwater flow; stress and strain analysis in soil and rock; effective stresses; testing techniques; solutions of simple elasticity problems; stress-strain relations in soil and rock.

5321.†† SLOPES AND FOUNDATIONS I. (4 cr; prereq 5320; 3 lect and 2 rec hrs per wk)
One-dimensional consolidation; tests; bearing capacity and settlements; retaining walls and excavations; slope stability in soil and rock; influence of groundwater; pile foundations.

5322.†† SLOPES AND FOUNDATIONS II. (4 cr; prereq 5321; 3 lect and 2 rec hrs per wk)
Settlements due to two- and three-dimensional consolidation, pumping and subsidence, negative skin friction of pile foundations; stress analysis in the failure zone of granular materials; field tests; ground strengthening.

5330. GEO-ENGINEERING AND ROCK MECHANICS II. (4 cr)
Design of blasting patterns and control of blast damage in rock, stress in room and pillar systems, foundations for structures, in situ stress measurements, disintegration, and comminution.

5437. COMPUTER APPLICATIONS IN GEO- AND MINERAL ENGINEERING. (4 cr)
Finite differences applications in ore-reserve estimates, volume of fill, haulage, heat transfer, and fluid flow. Solution of linear equations, curve fitting, regression analysis and iterative methods in structural and ventilation analysis. Introduction to random numbers, simulation and computer models.

5660. SPECIAL GEO-ENGINEERING PROBLEMS. (Cr and hrs ar; prereq sr or ‡)
Literature survey, research work or design study in geo-engineering problems.

††Final approval of course pending at time of bulletin publication.

FOR GRADUATE STUDENTS ONLY

8336. ANALYTICAL METHODS IN ROCK MECHANICS

8350-8352. ADVANCED ROCK MECHANICS I, II

Geology and Geophysics (Geo)

1001f,w,s. PHYSICAL GEOLOGY. (5 cr; 3 lect hrs, one 2-hr lab, 1 rec hr per wk) Staff
A first course in geology. Introduction to scientific method and nature of the earth; main features of the physical world and processes that have formed them.

1001H. HONORS SECTION: PHYSICAL GEOLOGY. (5 cr) Staff
A special course for nonscience majors, taught on an informal basis by senior faculty. An introduction to the world of geology. Lectures, field trips, and special lab problems.

1002f,w,s. HISTORICAL GEOLOGY. (4 cr; prereq 1001; 3 lect hrs and one 2-hr lab per wk) Sloan
Evolution of earth from its origin to present; special attention to succession of physical and biological events of past 600 million years.

1007s. ENVIRONMENTAL GEOLOGY. (4 cr, §1008; prereq 1001)
Geological application in resource management, land use planning, technology, and conservation. Geological evolution of the biosphere and the impact of man's activities on land, sea, and air resources. Geological hazards. The Twin Cities metropolitan areas as a geological environment. Lectures, labs, and field trips.

1008w. GEOLOGY AND MAN. (4 cr, §1001, §1007) Hall
Man in his physical environment; geological hazards (e.g., earthquakes); the nature and use of natural resources; geological aspects of pollution, recreation, and land use; the effect of the composition of rocks and soils on nutrition and disease. An introduction to the broad nature of earth science.

1011w. DRIFTING CONTINENTS. (4 cr; 3 lect hrs and one 2-hr lab per wk) Sawkins, Chase
Introduces the student to a set of concepts that have completely revolutionized geological thinking. These concepts allow the integration of many diverse geological elements; e.g., volcanoes, earthquakes, mountain chains, wandering continents, and earth resources.

1012f. EARTH AS A PLANET. (4 cr; 3 lect and 1 lab hr per wk) Murthy
A survey of the origin and evolution of the earth, its structure and composition in relation to other planets, and the cosmic abundances and mode of formation of elements in the solar system.

1013f. ORIGIN AND EVOLUTION OF LIFE. (4 cr; 3 lect and 1 lab hrs per wk) Sloan
Geological evidence of the origin and increasing complexity of living systems, including biogenesis, single-celled organisms, planets, animals, and ecosystems. Problems of extraterrestrial life.

1111f. INTRODUCTORY PHYSICAL GEOLOGY. (5 cr; prereq high school or college chemistry or ‡; 3 lect hrs, 1 rec hr, and two 2-hr labs per wk) Chase, Stout
For prospective majors and others desiring a more intensive lecture and laboratory sequence than 1001.

3099f,w,s. PROBLEMS IN GEOLOGY AND GEOPHYSICS. (1-6 cr; prereq ‡ and △)
Individual research or problem selected on the basis of individual interests and background.

3101f. SURFICIAL GEOLOGIC PROCESSES. (5 cr; prereq 3102 and 3401 or ‡)
Geological processes acting at the surface of the earth. Topics include geomorphology, limnology, groundwater geology, and sedimentology. Field trips.

3102s. PETROLOGY. (5 cr; prereq 3401 or ‡) Stout, Weiblen
Introduction to the lithologic character and genesis of igneous and metamorphic rocks.

3103s. STRUCTURAL GEOLOGY. (5 cr; prereq 3102 or ‡) Hudleston
Primary and secondary structures of rocks; mechanics and modes of deformation, and an introduction to field methods in geology. Field trips.

3112s. EARTH HISTORY. (5 cr; prereq 1111 or ‡; 3 lect hrs, 1 rec hr, two 2-hr labs per wk) Swain
For prospective majors and others desiring more intensive course than 1002.

3201. SEMINAR: CONTINENTAL DRIFT. (5 cr; prereq 1001 and 1002, or 1111 and 3112) Chase, Sawkins, Sloan
Use of synthesis of regional geology and geophysics to study past configurations of the continents and timing of their breakup and collision. Lectures, readings, seminar presentations by students, term paper.

3401w. INTRODUCTORY MINERALOGY. (5 cr; prereq 1001 or 1111 or ‡, 1 term college chemistry, Math 1221; 3 lect and 6 lab hrs per wk) Zoltai, Stout
Introduction to crystallography, crystal chemistry, and crystal physics. Physical and chemical properties, crystal structures, and chemical equilibria of the major mineral groups. Laboratory includes crystallographic, polarizing microscope, X-ray powder diffraction exercises, and hand specimen mineral identification.

5002s. STRUCTURAL GEOLOGY. (4 cr, §3103 or equiv; not open to geology, geophysics, geo-engineering, mineral resources engineering, and metallurgy/materials science majors; prereq 3401 or 5004 or ‡; 3 lect and 2 lab hrs per wk) Hudleston
Primary and secondary structures of rocks, mechanics and modes of deformation, and structural techniques. Laboratory exercises in three-dimensional representation and solution of selected structural problems.

5004w.* MINERALOGY. (4 cr, §3401; not open to geology, geophysics, and geological, mineral, and metallurgical engineering majors . . . open to agriculture and forestry students and postgrad students in education; prereq 1001 or ‡, 1 term college chemistry, Math 1221, 3 lect and 6 lab hrs per wk) Zoltai, Stout
See 3401.

5051su. PHYSICAL GEOLOGY FOR TEACHERS. (4 cr, §1001, §1111; open only to students holding degrees in education; prereq 1 term college chemistry or physics)
Introduction to scientific methods and nature of the earth; main features of physical world and processes that have formed them.

5052su. HISTORICAL GEOLOGY FOR TEACHERS. (4 cr, §1002, §3112; open only to students holding degrees in education; prereq 1001 or 1111 or 5051 or ‡)
Introduction to origin of the earth, physical evolution of its crust through geological time, and biological changes that occurred during its history. Laboratory, fieldwork, and seminar.

5100. ADVANCED GENERAL GEOLOGY. (2 cr [may be repeated for cr]; S-N only; prereq 1001 or 1111) Staff
Seminar course on geology of an area, followed by field trip to the location being studied. Region studied will vary from year to year.

5102.* PHYSICAL STRATIGRAPHY. (4 cr; prereq 3103) Swain
Lectures, readings, discussions of modern literature, and laboratory work on Paleozoic, Mesozoic, and Cenozoic stratigraphy; geosynclinal and shelf development, oceanic and lacustrine deposits.

5103. BIOSTRATIGRAPHY. (3 cr; prereq 5102 and 5151) Swain
Fundamentals of biostratigraphic analysis of fossil assemblages with emphasis on Mesozoic and Cenozoic zonation.

5108w. ADVANCED ENVIRONMENTAL GEOLOGY. (4 cr; prereq geology core curriculum 1111 through 3103 or equiv) Parham
Man's impact on the geological environment and the effect of geology/geologic processes on man. Land use planning, geologic hazards, geologic aspects of health and disease, mineral conservation, waste disposal, and geologic controls and limitations in developed versus underdeveloped countries.

5110su. FIELD GEOLOGY. (9 cr; open only to geology, geophysics, and geo-engineering majors; prereq 3103 and ‡)
Measurement of stratigraphic sections. Fossils and igneous, sedimentary, and metamorphic rocks. Geological surveying on aerial photographs and topographic maps. Preparation of geologic maps and cross sections. Structural and geomorphic features and geologic setting of mineral deposits.

5151f. INTRODUCTION TO PALEONTOLOGY. (5 cr; prereq 1002 or 3112 or ‡) Sloan
Introduction to morphology and classification of major fossil groups.

5152. INVERTEBRATE PALEONTOLOGY. (5 cr; prereq 5151; 3 lect and 4 lab hrs per wk; offered when demand warrants) Staff
Detailed study of morphology, classification, and ecology of selected groups of invertebrate fossils.

5154w. VERTEBRATE PALEONTOLOGY I. (5 cr; prereq 5151 or Zool 5124) Sloan
Morphology, evolution, and stratigraphic distribution of fossil fish, amphibians, reptiles, and birds.

5155s. VERTEBRATE PALEONTOLOGY II. (5 cr; prereq 5151 or Zool 5124) Sloan
Morphology, evolution, and stratigraphic distribution of fossil mammals.

5156. MICROPALEONTOLOGY. (3 cr; prereq 5151 or ‡) Swain
Major groups of microfossils: morphology, classification, and geologic distribution.

5251s.* GEOMORPHOLOGY. (4 cr [5 cr with term project]; prereq 1001, Math 1111, or ‡) Hooke
The origin, development, and continuing evolution of landforms in various environments. Environmental implications are emphasized. Weathering, slope and shore processes, fluvial erosion and deposition, wind action, tectonics, and impact phenomena.

5252.* PROBLEMS IN GEOMORPHOLOGY. (3 cr; prereq 5251 or ‡) Hooke
Detailed study of selected geomorphic processes. Topics vary with interests of students involved, but fluvial processes and arid-region geomorphology are generally emphasized.

5255.* GLACIOLOGY. (3 cr [4 cr with term project]; prereq Math 3221 or equiv or ‡) Hooke
Theories of glacier flow. Internal structures and heat flow in glaciers and ice sheets. Reading assignments and problems.

5261.* GLACIAL GEOLOGY. (4 cr [5 cr with term paper]; prereq 1002 or 3112) Wright
Formation and characteristics of modern glaciers; erosional and depositional features of Pleistocene glaciers; history of Quaternary environmental changes in glaciated and non-glaciated areas. Field trips.

5301. CHEMICAL EQUILIBRIA IN THE EARTH. (3 cr; prereq Chem 5501 or 5520 or ¶) Hall
Recitation-problems course dealing with the application of thermodynamics and kinetics to chemical systems in the earth sciences. Reactions to natural gases, solid-state mineral transformations, melting and solid-solution phenomena, rates of nucleation and mineral growth, and reactions in natural waters.

5302s. NUCLEAR GEOLOGY. (4 cr; prereq ‡) Alexander
The theory and practice of radioactive dating. Emphasis is on K/Ar, Rb/Sr and U, Th Pb method as applied to geologic problems. Detailed study of the use of istopic tracer techniques in crust-mantle evolution, igneous processes and the early history of the earth.

5351.* METAL SULFIDE DEPOSITS. (5 cr; prereq 3401, 3103 or ‡) Sawkins
Nature and distribution of sulfide deposits, and analysis of the processes by which metals are concentrated in magnetic, hydrothermal, and sedimentary environments.

5352. GEOLOGY OF FERROUS METALS AND NONMETALLIC DEPOSITS. (4 cr; prereq 3401, 3103, or ‡) Sawkins
Environmental setting, mineralogy and genesis of ferrous metal ore deposits and non-metallic deposits.

5361f. GEOLOGY OF FUEL DEPOSITS. (3 cr; prereq 3101, 3103 or 5002 or ‡) Swain
Origin and distribution of petroleum and coal deposits; source materials, reservoir rocks and structures, stratigraphic distribution of important deposits.

5401s.* CRYSTAL CHEMISTRY OF MINERALS. (4 cr; prereq 3401, 1 yr college chemistry; 3 lect and 2 lab hrs per wk) Zoltai
Basic concepts of symmetry, packing, coordination, and bonding of atoms in crystal structures. Classification and discussion of crystal structures and crystal chemistry of minerals.

5442. ADVANCED MINERALOGY. (4 cr; prereq 3401) Rapp
Systematic mineralogy of the rock-forming minerals; their structural, geochemical, petrological, and physical characteristics and relationships. Individual laboratory investigations.

5452s.* IGNEOUS AND METAMORPHIC PETROLOGY. (4 cr; prereq 3102, Chem 5502 or 5521, Math 3211 or ‡) Stout
A theoretically oriented course that develops the basic thermodynamic tools for interpreting the mineralogy of igneous and metamorphic rocks. Integration of the data of experimental petrology, field geology, and petrography with a theoretical approach to better understand chemical processes in the earth's crust and mantle. Laboratory and term paper.

5505f. PHYSICS AND CHEMISTRY OF THE EARTH I. (4 cr; prereq 1111 and Phys 1295) Mooney
Earthquake seismology; physical structure of the earth's crust and deep interior.

5506w. PHYSICS AND CHEMISTRY OF THE EARTH II. (4 cr; prereq 5505 or ‡) Murthy
Origin and chemical evolution of the earth through geologic time.

5507s. PHYSICS AND CHEMISTRY OF THE EARTH III. (4 cr; prereq 5506 or ‡) Banerjee, Chase
Gravity and magnetic fields of the earth; paleomagnetism, thermal history of the earth.

5511f.* PRINCIPLES OF GRAVITY AND MAGNETIC EXPLORATION. (3 cr; prereq Phys 1291) Chase
Instrumentation, surveying techniques, reduction of data, interpretation, case histories.

5512w.* PRINCIPLES OF SEISMIC EXPLORATION. (3 cr, §5522; prereq Phys 1291) Mooney
Reflection and refraction seismology; theory, interpretation, instruments.

5513s.* PRINCIPLES OF ELECTRICAL EXPLORATION. (3 cr; prereq Phys 1291) Mooney
Resistivity, electromagnetic induced polarization, and other methods.

5522w.* PRINCIPLES OF REFRACTION SEISMIC EXPLORATION. (2 cr, §5512; primarily for civil engineering and geo-engineering students; prereq Phys 1291) Mooney
Seismic wave theory; refraction seismology.

5523s. PRINCIPLES OF DIRECT-CURRENT ELECTRICAL EXPLORATION. (2 cr, §5513; primarily for civil engineering and geo-engineering students; prereq Phys 1291) Mooney
Resistivity and other direct-current methods.

5541f.* GEOMAGNETISM. (3 cr; prereq 3 qtrs geology, physics, mathematics) Banerjee
Present geomagnetic field on the earth's surface, its time variation and westward drift, origin of field in terms of a geomagnetic dynamo, behavior of the ancient field including reversals from the paleomagnetic record, continental drift, and sea floor spreading.

5601f. LIMNOLOGY. (4 cr, §EBB 5601; prereq Chem 1005 or equiv) Shapiro
Description and analysis of events occurring in lakes, reservoirs, and ponds, beginning with their origins and progressing through study of their physics, chemistry, and biology. Emphasis on interrelationships of these parameters and on effects of civilization on lakes.

5602f. CASE STUDIES IN LIMNOLOGY. (3 cr; prereq 5601 or EBB 5601, and ♯; offered 1976 and alt yrs) Shapiro

5611s. GROUNDWATER GEOLOGY. (4 cr; prereq 1001 or 1111, Math 1231, 1 qtr physics and chemistry or ♯) Pfannkuch
Origin, occurrence, and movements of groundwater. Characteristics of major aquifers and aquitards. Exploratory investigations. Hydrogeologic units and boundaries. Principles and theoretical aspects of recharge. Quality of groundwater supplies.

5651. SEDIMENTARY GEOCHEMISTRY. (3 cr; prereq 5301 and Chem 5520 or ♯; 3 lect hrs per wk) Hall
Properties of bulk and absorbed water. The thermodynamics of seawater. Chemical equilibria of the seas, the air-sea interface and sea-ocean bottom interface. The origin and chemical history of the earth's ocean. Stable isotope studies.

5652s.* SEDIMENTOLOGY. (4 cr; prereq 3101, 3103 and 5642 or ♯)
Sedimentary processes and products with particular emphasis on modern marine depositional environments. Clastic sedimentation on continental margins.

FOR GRADUATE STUDENTS ONLY OR FOR SENIORS WITH SPECIAL PERMISSION

General Geology

8008. SEMINARS IN CURRENT TOPICS IN GEOLOGY

8099. PROBLEMS: GEOLOGY, GEOPHYSICS

8103. BIOSTRATIGRAPHY

8128. SEMINAR: STRATIGRAPHY

8152. ADVANCED INVERTEBRATE PALEONTOLOGY

8156. MICROPALEONTOLOGY

8158. SEMINAR: PALEONTOLOGY

8159. RESEARCH IN PALEONTOLOGY

8161. PALEOECOLOGY

8168. SEMINAR: PALEOECOLOGY

8201. GEOTECTONICS

8202. ADVANCED STRUCTURAL GEOLOGY

8208. SEMINAR: STRUCTURAL GEOLOGY

8209. RESEARCH IN STRUCTURAL GEOLOGY

8219. RESEARCH IN STRATIGRAPHY

8258. SEMINAR: GEOMORPHOLOGY

8259. RESEARCH IN GEOMORPHOLOGY

8262. PLEISTOCENE GEOLOGY

8268. SEMINAR: PLEISTOCENE GEOLOGY

8269. RESEARCH IN PLEISTOCENE GEOLOGY

Mineralogy and Petrology

8308. SEMINAR: GEOCHEMISTRY
8309. RESEARCH IN GEOCHEMISTRY
8351. ADVANCED MINERAL DEPOSITS I
8352. ADVANCED MINERAL DEPOSITS II
8355. GEOLOGY OF FERROUS METAL AND NONMETALLIC DEPOSITS
8358. SEMINAR: MINERAL DEPOSITS
8359. RESEARCH IN MINERAL DEPOSITS
8361. GEOLOGY OF FUEL DEPOSITS
8402. X-RAY MINERALOGY
8404. X-RAY CRYSTALLOGRAPHY
8408. SEMINAR: MINERALOGY AND CRYSTALLOGRAPHY
8409. RESEARCH IN MINERALOGY AND CRYSTALLOGRAPHY
8419. SEMINAR: CLAY MINERALOGY
8453. PHASE EQUILIBRIA IN MINERAL SYSTEMS
8454. IGNEOUS PETROLOGY
8455. METAMORPHIC PETROLOGY
8458. SEMINAR: PETROLOGY
8459. RESEARCH IN PETROLOGY

Hydrogeology

8311. ORGANIC GEOCHEMISTRY
8318. SEMINAR: ORGANIC GEOCHEMISTRY
8602. ADVANCED LIMNOLOGY
8603. METHODS FOR ANALYSIS OF NATURAL WATERS
8608. SEMINAR: LIMNOLOGY
8609. RESEARCH IN LIMNOLOGY
8611. TRANSPORT PHENOMENA IN NATURAL POROUS MEDIA
8612. ANALYTICAL GEOHYDROLOGY
8618. SEMINAR: GROUNDWATER GEOLOGY
8619. RESEARCH IN GROUNDWATER GEOLOGY
8651. SEDIMENTARY GEOCHEMISTRY
8658. SEMINAR: SEDIMENTOLOGY
8659. RESEARCH IN SEDIMENTOLOGY

Geophysics

8521. LINEAR DATA PROCESSING WITH GEOPHYSICAL APPLICATIONS
8531-8532. THEORY OF ELASTIC WAVE PROPAGATION I, II
8542. PRINCIPLES OF ROCK MAGNETISM
8562. STUDIES OF THE CRUST AND UPPER MANTLE
8568. SEMINAR: GEOPHYSICS
8569. RESEARCH IN GEOPHYSICS

Industrial Engineering/Operations Research (IEOR)

5000. INTRODUCTION TO INDUSTRIAL ENGINEERING ANALYSIS. (4 cr; prereq Math 1231. . . ME 3900 recommended; 3 lect and 1 rec hrs per wk)
Scientific management, mathematical models, methods engineering, work measurement, worker satisfaction and participation, wage payment plans, break-even analysis, incremental costs, the time value of money and the present value concept; cost quality and inventory control; production scheduling, plant locations, and layout; linear programming, PERT, and the systems approach to management problems.

5010. INTRODUCTION TO WORK ANALYSIS. (4 cr; prereq 5000; 3 lect and 1 rec hrs per wk)
Fundamentals of methods engineering, work measurement, and plant layout; charting techniques, process charts, predetermined time systems, work sampling, time study, master standard data, cross charting, and line balancing.

5020. ENGINEERING COST ACCOUNTING, ANALYSIS AND CONTROL. (4 cr; 5000 and ME 3900 recommended; 3 lect and 1 rec hrs per wk)
Basic accounting concepts, financial statements, analysis and control of current assets such as cash, receivables, and inventory; income tax planning, cost analysis, standard costs for product costing, time value of money, quantification of risk and uncertainty, utility theory, cost of capital and capital structure, capital budgeting under capital rationing, management decisions, and investment decisions.

5030. QUALITY CONTROL AND RELIABILITY. (4 cr; prereq Math 1231, ME 3900 . . . IEOR 5000 recommended; 3 lect and 1 rec hrs per wk)
History of quality control, quality policies and objectives, economics of quality, design for system effectiveness, reliability and maintainability, statistical aids to reliability, quality specifications, inspection, acceptance sampling, vendor relations, process control, movivation for quality, quality assurance, and quality control engineering.

5040. INTRODUCTION TO OPERATIONS RESEARCH. (4 cr; prereq Math 1231 . . . IEOR 5000 recommended; 3 lect and 1 rec hrs per wk)
Linear programming, algebra and geometry of linear models, simplex method, sensitivity testing, and duality; network models, network algorithms, and dynamic models.

5180, 5181. APPLIED INDUSTRIAL ENGINEERING. (3-5 cr [1-2 cr term paper option]; prereq background in all basic industrial engineering areas [5000, 5010, 5020, 5030 and 5040])
Industrial engineering surveys and programs, case problems, studies in local plants.

5221. INDUSTRIAL PLANTS. (4 cr; prereq 5010; 3 lect and 1 rec hrs per wk)
Layout of production and service facilities in manufacturing operations, analysis of materials flow, development of materials handling systems, and industrial packaging techniques.

5311. MANAGEMENT FOR ENGINEERS. (3-5 cr [1-2 cr term paper option]; prereq 5000; 3 lect hrs per wk)
Historical development of management concepts; organizational systems and authority relationships; planning, communication, and management responsibility.

5321. INDUSTRIAL SAFETY. (3-5 cr [1-2 cr term paper option]; 5000 recommended; 3 lect hrs per wk)
Definition and philosophy of safety, safety training, safety requirements for production processes, equipment and plants, industry standards, safety devices, and product safety.

5351. ANALYSIS OF PRODUCTION PROCESSES. (3-5 cr [1-2 cr term paper option]; prereq 5020 . . . background in all basic industrial engineering areas [5000, 5010, 5030 and 5040] recommended; 3 lect hrs per wk)
A case course of problems in production engineering and production management. Analysis of production problems from selected industries. Development of ability to recognize and diagnose industrial problems.

5361. INVENTORY AND PRODUCTION CONTROL. (4 cr; prereq 5000, 5040, ME 3900; 3 lect and 1 rec hrs per wk)
Forecasting techniques and analysis of inventory systems, aggregate planning, capacity decision, scheduling techniques, line balancing, use of linear programming models in the design, operation, and control of production and distribution systems.

5441. OPERATIONS RESEARCH II. (4 cr; prereq 5040, Math 1231, ME 3900; 3 lect and 1 rec hrs per wk)
Dynamic programming, integer programming, nonlinear and probabilistic models.

5442. OPERATIONS RESEARCH III. (4 cr; prereq 5441; 3 lect and 1 rec hrs per wk)
Optimization in probability models, Markow chains, queuing theory, and simulation.

5445. TOPICS IN MANAGEMENT SCIENCE. (3-5 cr [1-2 cr term paper option]; background in all areas of industrial engineering [5010, 5020, 5030 and 5040] recommended; 3 lect hrs per wk)
Specialized topics in management science. Analytical tools for decision making and management of the production function. Emphasis on topics appearing in the current literature. Topics change from quarter to quarter.

5531. INDUSTRIAL SAMPLING TECHNIQUES. (4 cr; prereq 5030, ME 3900; 3 lect and 1 rec hrs per wk)
An in-depth coverage of industrial sampling plans. Single, double, and multiple sampling plans; sequential, continuous, and variable sampling plans; life testing plans; administrative and economic considerations.

5550. DESIGN AND ANALYSIS OF EXPERIMENTS I. (4 cr; prereq ME 3900 or Stat 3092 or Stat 5121 or Stat 5131 or equiv; 3 lect and 1 rec hrs per wk)
One-factor experiments, analysis of variance, estimation and comparison of effects, orthogonal contrasts, fixed, random and mixed models, incomplete block design.

5551. DESIGN AND ANALYSIS OF EXPERIMENTS II. (4 cr; prereq 5550, ME 3900; 3 lect and 1 rec hrs per wk)
Experiments of two or more factors. Designs involving crossed, nested, and mixed classifications; orthogonal polynomials; block confounding; fractional factorial designs; and computer programs for analysis.

FOR GRADUATE STUDENTS ONLY

8110-8111-8112. ADVANCED INDUSTRIAL ENGINEERING

8310-8311-8312. PRODUCTION ENGINEERING PROBLEMS

8410-8411-8412. INDUSTRIAL ENGINEERING RESEARCH

8420. LINEAR PROGRAMMING

8430. NONLINEAR PROGRAMMING

8440. DYNAMIC PROGRAMMING

8450. QUEUING THEORY

8460. STOCHASTIC PROGRAMMING

8470. ADVANCED INVENTORY AND PRODUCTION CONTROL

8773-8774-8775. GRADUATE SEMINAR

Landscape Architecture (LA)

1001f. ENVIRONMENTAL DESIGN: MAN AND ENVIRONMENT. (4 cr, §Arch 1001)
See Arch 1001 for description.

1002w. ENVIRONMENTAL DESIGN: TOOLS AND PROCESSES. (4 cr, §Arch 1002; prereq 1001)
See Arch 1002 for description.

1003s. ENVIRONMENTAL DESIGN: IMPLEMENTATION AND EVALUATION. (4 cr, §Arch 1003; prereq 1002)
See Arch 1003 for description.

1021f. HISTORY OF ENVIRONMENTAL DEVELOPMENT: ARCHITECTURE. (4 cr, §Arch 1021; 4 lect hrs per wk)
See Arch 1021 for description.

1022w. HISTORY OF ENVIRONMENTAL DEVELOPMENT: LANDSCAPE ARCHITECTURE. (4 cr, §Arch 1022; prereq 1021; 4 lect hrs per wk)
See Arch 1022 for description.

1023s. HISTORY OF ENVIRONMENTAL DEVELOPMENT: PLANNING. (4 cr, §Arch 1023; prereq 1022; 4 lect hrs per wk)
See Arch 1023 for description.

1024. LANDSCAPE THEORY. (4 cr; 3 lect and 3 lab hrs per wk)
Analysis of design elements and forms involving direction, shape, proportion, and color, with emphasis on their function in design; a study of perception and man's relationship to his environment, and the social effects and psychological basis for design.

1025. BASIC VISUALIZATION. (4 cr; 2 lect and 4 lab hrs per wk; prereq LA major or ‡)
Perspective drawing, landscape sketching, visual analysis of landscape materials, presentation techniques for plans, sections, elevations, and diagrams.

1031. INTRODUCTION TO LANDSCAPE ARCHITECTURE. (4 cr; 4 lect hrs per wk)
Design potential of materials of the landscape; exercises in assessment of land developments and detail landscapes; the role of the landscape architect in shaping the natural and cultural environment; brief historical review of site developments.

3071. LANDSCAPE TECHNOLOGY: GROUND FORM DESIGN. (4 cr; prereq CE 3100 and AgEn 1400 and LA 3083; 2 lect and 6 lab hrs per wk)
Lectures, exercises, and projects in ground form manipulation, earthwork computation and surface drainage techniques.

3072. LANDSCAPE TECHNOLOGY: CIRCULATION AND UTILITIES DESIGN. (4 cr; prereq 3071 and 3091; 2 lect and 6 lab hrs per wk)
Lectures, exercises, and projects in layout of circulation and landscape utilities systems.

3073. LANDSCAPE TECHNOLOGY: LAND ANALYSIS TECHNIQUES. (4 cr; prereq 3072; 2 lect and 6 lab hrs per wk)
Lectures, exercises, and projects in land analysis techniques for use in assessment of land development potential.

3075. LANDSCAPE TECHNOLOGY: MATERIALS AND CONSTRUCTION DESIGN. (4 cr; prereq 3072 and 3092; 2 lect and 6 lab hrs per wk)
Lectures, exercises, and project in materials and construction techniques and working document preparation.

3081-3082-3083. BASIC DESIGN. (6 cr per qtr; prereq LA student; 1 lect and 15 lab hrs per wk)
Lectures and projects to expand awareness of the design potential of the environment, develop processes and graphic techniques for problem solving, develop methods of presenting ideas verbally and visually. Design of small-scale site systems with simple variables.

3091-3092. INTERMEDIATE DESIGN. (6 cr per qtr; prereq 3083; 2 lect and 12 lab hrs per wk)
Lectures and projects in the design potential of natural land materials, landscape survey and analysis techniques, elements of the environment as they condition design potential, methodologies for solving design problems, methods of expressing landscape form both geographically and through models; design of site systems with simple variations.

3093. DETAIL SITE DESIGN. (6 cr; prereq 3092)
Design of small-scale site systems with complex variables.

3096. SPECIAL PROBLEMS IN LANDSCAPE ARCHITECTURAL HISTORY. (1-6 cr; prereq ‡)

3097. SPECIAL PROBLEMS IN LANDSCAPE ARCHITECTURAL THEORY. (1-6 cr; prereq ‡)

3098. SPECIAL PROBLEMS IN LANDSCAPE ARCHITECTURAL DESIGN. (1-6 cr; prereq ‡)

3099. SPECIAL PROBLEMS IN LANDSCAPE ARCHITECTURAL TECHNOLOGY. (1-6 cr; prereq ‡)

3101. COMMUNICATING LANDSCAPE QUALITY. (4 cr; prereq 1025 and 3082; 2 lect and 6 lab hrs per wk)
Lectures and exercises in drawing techniques focused on developing graphic skills for designers working predominantly with exterior environments.

5010. PRINCIPLES OF OUTDOOR RECREATION DESIGN AND PLANNING. (4 cr; 4 lect hrs per wk)
For advanced students associated with design, management, and planning of recreational facilities. Planning and design principles related to recreational land use and development; parks, campsites, water areas, highways, summer and winter recreational facilities.

5101. SITE PLANNING AND DESIGN. (6 cr; prereq 3093; 2 lect and 12 lab hrs per wk)
Case study analysis and design of site organizational systems.

5103. URBAN LANDSCAPE DESIGN. (6 cr; prereq 3093; 2 lect and 12 lab hrs per wk)
Case study analysis and design of urban environments.

5105. RECREATIONAL PLANNING AND DESIGN. (6 cr; prereq 5010; 2 lect and 12 lab hrs per wk)
Analysis development and presentation of landscape design solutions for diverse recreational land use.

5107. REGIONAL LANDSCAPE DESIGN. (6 cr; prereq 3092; 3 lect and 12 lab hrs per wk)
Emphasis on the study of large-scale land areas. Analyzing development potential and evolving solutions for integration of divergent land use patterns such as agricultural, residential, commercial, industrial, and recreational.

5110. ADVANCED LANDSCAPE PLANNING AND DESIGN. (6 cr; prereq terminal qtr; 2 lect and 12 lab hrs per wk)
Advanced studies in area of student's option.

5115-5116. THEORY OF LANDSCAPE FORM AND STRUCTURE. (2 cr per qtr; prereq 3091 or ♯; 4 discussion hrs per wk)
Studies in landscape perception; lectures, discussions, and exercises in application of abstract design principles to the assessment of land developments; psychological and social implications of land developments; design potential of landscape materials; contemporary problems in land development including all scales and types of land uses.

5124. LANDSCAPE ARCHITECTURAL SEMINAR. (1 cr; prereq terminal yr of study)
Analysis of design principles and design goals in modern society. Current site development projects. In-depth investigation of specific areas of land development.

5131-5132-5133. SELECTED PROBLEMS IN LANDSCAPE ARCHITECTURE. (Cr ar; prereq ♯)

5226. PROFESSIONAL PRACTICE. (4 cr; prereq terminal yr of study)
Professional ethics, responsibility, and relations in business. Office management, preparation of professional communications, estimates, specifications, and contracts. Lectures, written exercises, and office visits.

5262. HISTORY AND LITERATURE OF LANDSCAPE ARCHITECTURE. (4 cr; prereq 1022; 4 lect hrs per wk)
Design principles as expressed in landscape created by man from ancient times to the contemporary period. Analysis of the visual form of environments as outgrowths of geographical, cultural, and technological determinants.

Mathematics (Math)

0006. ELEMENTARY ALGEBRA (See *Evening Classes Bulletin*)

0007. PLANE GEOMETRY. (See *Evening Classes Bulletin*)

0008. SOLID GEOMETRY. (See *Evening Classes Bulletin*)

0009. PREPARATORY MATHEMATICS. (See *College of Liberal Arts Bulletin*)

0090. CALCULUS REFRESHER. (See *Evening Classes Bulletin*)

1001f-1002w. MATHEMATICS. (See *College of Liberal Arts Bulletin*)

1005f,w,s-1006w,s. FOUNDATIONS OF ARITHMETIC. (See *College of Liberal Arts Bulletin*)

1008f,w,s. TRIGONOMETRY. (See *College of Liberal Arts Bulletin*)

1111f,w,s. COLLEGE ALGEBRA AND ANALYTIC GEOMETRY. (See *College of Liberal Arts Bulletin*)

1131f,w,s. FINITE MATHEMATICS. (See *College of Liberal Arts Bulletin*)

1142f,w,s. INTRODUCTION TO CALCULUS. (See *College of Liberal Arts Bulletin*)

1201f,w,s. PRE-CALCULUS. (5 cr, §1111, §1141; for students who intend to take a calculus sequence but lack preparation; prereq high school higher algebra, high school trigonometry or 1008, mathematics placement score)
Inequalities, analytical geometry; complex numbers, binomial theorem; mathematical induction; functions and graphs; trigonometric, exponential, and logarithmic functions.

1211f-1221w-1231s. ANALYSIS I-II-III. (5 cr per qtr; prereq grade of C or better in 1201 or high school higher algebra, trigonometry, geometry, and math placement score for 1211...grade of C or better in 1211 for 1221...grade of C or better in 1221 for 1231)
Analytical geometry and calculus of functions of one variable, applications.

1311f-1321w-1331s. COMPUTER CALCULUS I-II-III. (5 cr per qtr; prereq grade of C or better in 1201 or high school higher algebra, trigonometry, geometry, and math placement score for 1311...grade of C or better in 1311 for 1321...grade of C or better in 1321 for 1331)
Content essentially the same as 1211-1221-1231 and 1611-1621, plus topics in elementary computer programming. Much of the material is presented from a computer point of view.

1511f-1521w-1531s. HONORS CALCULUS. (5 cr per qtr; prereq △)
Calculus of functions of one variable with emphasis on theory. Emphasis on basic concepts and proofs. Computational aspects.

1611f-1621w. ANALYSIS I-II. (5 cr per qtr; prereq 4 yrs high school math incl trigonometry and △ for 1611...grade of C or better in 1611 for 1621)
Accelerated sequence for high ability students (continued in 3611-3621). Covers content of 1211-1221-1231.

3057. ACTUARIAL SCIENCE PRINCIPLES. (See *College of Liberal Arts Bulletin*)

3066f,w,s. ELEMENTARY DIFFERENTIAL EQUATIONS. (4 cr, §3221, §5512, §5521; prereq 1431 or 1231 or equiv)
Elementary techniques of problem solving. First- and second-order equations, linear equations of higher order.

3071f-3072w-3073s. HISTORY OF MATHEMATICS. (2 cr per qtr; for students with general knowledge of mathematics and some curiosity about historical development of mankind; prereq 1331 or 1231 for each qtr)
Development of main branches of contemporary mathematics within framework of history of ideas as well as of techniques. Impact of thought of previous generations on modern developments. Term paper each qtr. 3071: Greek mathematics. 3072: Creation of calculus. 3073: Topics in history of mathematics.

3099. SEMINAR: MATHEMATICAL PROBLEMS. (4 cr; prereq 3211 and 3221 or equiv)
Problems ranging from elementary algebra and geometry through undergraduate mathematics.

3142f,w,s. INTRODUCTION TO LINEAR ALGEBRA. (4 cr, §3221, §3511; prereq 2 qtrs calculus)
Vectors, systems of linear equations, matrices, determinants, eigenvalues, applications. Emphasizes techniques but includes some proofs of theorems.

3161f,w,s. SYNTHETIC METRIC GEOMETRY. (4 cr; prereq 1211 or 1311 or equiv)
Euclidean geometry: ruler and compass constructions and theorems on triangle and circle not studied in high school plane geometry.

3211f,w,s. ANALYSIS IV. (5 cr, §3411, §3521; prereq grade of C or better in 1231 or equiv)
Partial differentiation, chain rule, implicit functions, applications. Multiple integrals in two and three dimensions. Infinite series, power series.

3221f,w,s. INTRODUCTION TO LINEAR ALGEBRA AND LINEAR DIFFERENTIAL EQUATIONS. (5 cr, §3142, §3511; prereq 1231 or equiv)
Vectors, systems of linear equations, matrices, determinants, bases, eigenvalues.. Linear differential equations and systems with constant coefficients, initial value problem and general solution, variation of parameters for inhomogeneous equations.

3231f,w,s. VECTOR ANALYSIS. (4 cr, §5601-5602; prereq grade of C or better in 3211 or equiv)
Scalar and vector products, derivatives, geometry of space curves, del operator, line and surface integrals, divergence and Stokes' theorem, transformation of coordinates, dyadics, applications.

3511f,w,s. ANALYSIS IV. (5 cr, §3142, §3221; primarily for math majors in IT and in the College of Education; prereq 1231, 1331, 1531 or 1621)
Abstract approach to study of finite dimensional vector spaces. Linear independence, linear transformations, matrices and determinants.

3521f,w,s. ANALYSIS V. (4 cr, §3211, §3411; primarily for math majors in IT and in the College of Education; prereq 3511)
The calculus of several variables relying heavily on linear algebra. Differentiation and integration of functions of several variables, coordinate systems, Jacobian of a map, implicit function theorem.

3531f,w,s. ANALYSIS VI. (4 cr, §3675; primarily for math majors in IT and in the College of Education; prereq 3521)
(Continuation of 3521) Differential equations, vector analysis.

3581f. FOUNDATIONS OF ARITHMETIC. (4 cr; prereq 3411 or 3211)
Sets, relations, order. Real number system. Continuous functions.

3582w. FOUNDATIONS OF ALGEBRA. (4 cr; prereq 3411 or 3211)
Groups, rings, fields. Applications to number theory and polynomials.

3583s. FOUNDATIONS OF GEOMETRY. (4 cr; prereq 3161)
Axiomatics. Non-Euclidean geometry. Theorems of Desargues and Pappus.

3611s-3621f. ANALYSIS III-IV. (5 cr per qtr; prereq 1621 for 3611)
A unified treatment of multivariable calculus and linear algebra.

3675f,w,s. INTRODUCTORY MATHEMATICS. (4 cr, §3531; prereq 1231 or 1331 or equiv)
Designed to prepare the sophomore mathematics major for the theoretical courses he will encounter during the junior and senior years.

5151f. ELEMENTARY SET THEORY. (4 cr; prereq 3211 or 3411)
Basic properties of operations on sets, cardinal numbers, simply ordered sets, well-ordered sets, ordinal numbers, axiom of choice, axiomatics.

5152w. ELEMENTARY MATHEMATICAL LOGIC. (4 cr, §5162; prereq 3211 or 3411)
Sets and relations; statement calculus; Boolean algebra; predicate calculus, models, validity and truth; examples of first-order theories as illustrations of the axiomatic method; the completeness theorem, the incompleteness theorem, and metamathematics (discussion only).

5154s. AN INTRODUCTION TO RECURSIVE FUNCTION THEORY. (4 cr; prereq 3211 or 3411 or ♯)
Alternative definitions of computability (viz., etc.); primitive, partial, and general recursive functions; Church's thesis; Kleene's normal form theorem and recursive theorem; recursive and recursively enumerable sets; applications to mathematical logic.

5157f-5158w-5159s. MATHEMATICS OF SYMBOL MANIPULATION SYSTEMS. (4 cr per qtr; prereq 1211 or 1311, 3rd-yr standing or ♯)
5157: Finite automata theory: switching circuits, Boolean algebra, and propositional logic. Kleene's theorem on regular sets. Algebraic aspects of finite automata; minimization, decomposition, synthesis. 5158: Computability of numerical functions: proofs for basic result connecting abstract models of programmed digital computers, Turing machines, and general recursive functions. Normal form theorem. Universal machines. Unsolvability of halting problem. 5159: Symbol manipulation systems: formal systems of Herbrand-Godel and Post. Post's normal form theorem. Formal grammars; introduction of Chomsky theory on context-free and other languages and related automata. Transduction of languages by automata.

5162f-5163w-5164s. MATHEMATICAL LOGIC. (4 cr per qtr; prereq 3211 with 3221 or 3411 with 3142 or Phil 5202 or ♯)
Propositional and predicate calculi, models for systems of logic, recursive functions, decision and completeness problems.

5200. TOPICS IN ALGEBRA. (4 cr [may be repeated for cr with △]; prereq ♯)
Topics vary from quarter to quarter.

5209w,s. THEORY OF NUMBERS. (4 cr; prereq 3211 or 3411)
Elementary properties of integers; prime and composite numbers; Euclid's algorithm; congruences; theorems of Fermat and Wilson; primitive roots; indices; Diophantine equations.

5242f-5243w,s. LINEAR ALGEBRA WITH APPLICATIONS. (4 cr per qtr, §5283-5284; prereq 3221 or 3142 or 3511)
Systems of linear equations, finite dimensional linear spaces, bases, linear transformations, matrices, determinants, eigenvalues, reduction to canonical forms, quadratic and bilinear forms, applications.

5244s. GROUP THEORY. (4 cr; prereq 3221 or 3142 or 3511)
Permutation groups; groups related to geometrical configuration; invariant subgroups, Jordan-Holder composition theorem, Sylow groups, Abelian groups, elementary divisors, applications.

5282f-5283w,s-5284f,s. FUNDAMENTAL STRUCTURES OF ALGEBRA. (4 cr per qtr, §5244 for 5282; principally for students planning grad work with a major in mathematics; prereq 3675, 3221 or 3142 or 3511)
Theory oriented. Group theory: normal subgroups, homomorphisms, automorphisms, and the theorems of Lagrange, Cayley, and Sylow. Ring theory: rings, ideals, integral domains, Euclidian rings, polynomial rings, field. Linear algebra: abstract approach to vector spaces, linear transformations, and the theory of canonical forms including the Jordan and rational canonical forms.

5300. TOPICS IN GEOMETRY. (4 cr [may be repeated for cr with △]; prereq ♯)
Topics vary from quarter to quarter.

5341f,w-5342w,s. INTRODUCTION TO TOPOLOGY. (4 cr per qtr; prereq 3675, 3211 or 3411 or 3521)
Set theory; axiom of choice, Zorn's lemma. Metric spaces: completeness, compactness, continuity. Basic point set topology: countability and separation axioms, Urysohn's lemma, compactness, connectedness, product spaces.

5343. INTRODUCTION TO ALGEBRAIC TOPOLOGY. (4 cr; prereq 5342)
An introduction to algebraic topology. Classification of two-manifolds, fundamental group, homology theory.

5359. NON-EUCLIDEAN GEOMETRY. (4 cr; prereq 3211 or 3411)
Foundations of Euclidean geometry. Euclid's fifth postulate and its implications. Hyperbolic plane geometry and trigonometry. Elliptic plane geometry and trigonometry. Consistency of non-Euclidean geometry.

5366f-5367w-5368s. GEOMETRY. (4 cr per qtr; prereq 3211 or 3411 for each qtr)
Selected areas of geometry such as convex bodies, projective geometry, geometry and imagination, elementary algebraic geometry, geometry of transformation groups, axiomatic geometry, geometrical constructions.

5375f. DIFFERENTIAL GEOMETRY. (4 cr; prereq 3231 or 5602)
Plane and space curves. Frenet formulas, elementary theory of surfaces.

5376w-5377s. DIFFERENTIAL GEOMETRY. (4 cr per qtr; prereq 5375 and 1 qtr linear algebra)
Introduction to differential forms. Advanced theory of surfaces, integral geometry, Riemannian geometry.

5404w. VARIATIONAL PROBLEMS. (4 cr; prereq 5602 or 5512 or ♯)
Euler-Lagrange equations, isoperimetric problems, geodesics, Fermat's and Hamilton's principles, methods of Rayleigh-Ritz, eigenvalues and eigenfunctions.

5427-5428. APPLIED MATHEMATICS FOR SOCIAL AND BIOLOGICAL SCIENCES. (4 cr per qtr; not acceptable for math majors [all degrees] as part of their math program; prereq 3211 with 3221 or 3411 with 3142)
Mathematical tools and concepts other than statistics useful in behavioral sciences. Examples and problems from fields concerned. Matrices, functions of several variables, probability, difference equations, learning models, two-person games.

5441w. MATHEMATICAL THEORY OF FLUID FLOW. (4 cr; prereq 3231 or 5602, and 5568 or 5572)
General equations of fluid mechanics; thermodynamics. Classical constitutive equations. Specialization for various subfields of fluid mechanics, hydrostatics, barotropic perfect fluids, gas dynamics, and viscous flow theory. Examples of exact solutions.

5457f-5458w-5459s. METHODS OF APPLIED MATHEMATICS. (4 cr per qtr; prereq 5603 or 5614)
Integrated study of analytic tools used in applications of mathematics; emphasis on technique. Real and complex variables, matrices, ordinary and partial differential equations, calculus of variations, asymptotic expansions.

5472f-5473w. INTRODUCTION TO NUMERICAL ANALYSIS. (4 cr per qtr, §CICS 5301, 5302; prereq 3211, 3221, CICS 1100)
5472: Finite differences, interpolation, summation of series, numerical integration, Euler-MacLaurin formula and asymptotic expansions. Numerical solutions of systems of algebraic and transcendental equations. Newton's and Graeffe's method. 5473: Approximation of functions and least squares. Approximate solution of ordinary and partial differential equations. Moulton's, Runge's relaxation and iteration methods. Calculation of eigenvalues of matrices and differential problems, Rayleigh-Ritz method. Integral equations.

5476s. THEORY OF APPROXIMATION IN NUMERICAL ANALYSIS. (4 cr; prereq 5473, 5568 or 5573)
Orthogonal functions, Chebyshev approximations, trigonometric approximations, saturation classes, rational approximations, approximations in several variables, spline interpolation and approximations, use of approximation in computing.

5512f,w,s. DIFFERENTIAL EQUATIONS. (4 cr, §5523; prereq 3211 or equiv)
First- and second-order equations. Power series solutions. Bessel functions. Legendre polynomials. Introduction to boundary value problems. Mostly a technique course.

5514s. INTEGRAL EQUATIONS. (4 cr; prereq 3211 and 3221 or equiv)
Introduction to integral equations; Fredholm formula, Neumann series, Laplace transforms, successive approximations and numerical methods. Relation of integral equations to systems of linear algebraic equations and to differential equations.

5521f,w,s-5522w,s-5523s. INTRODUCTION TO ORDINARY DIFFERENTIAL EQUATIONS. (4 cr per qtr; prereq 3142 or 3221 or 3511, 3211 or 3411 or 3521)
5521: Existence and uniqueness theorems; successive approximations; differential inequalities; linear systems; fundamental matrix solutions; linear systems with constant coefficients; variation of parameters. 5522: Phase plane analysis; Poincare-Bendixson theory; linear and nonlinear oscillations; stability theory; asymptotic behavior of solutions; control theory. 5523: Formal and convergent of power series solutions majorant method; regular and irregular singular points; error estimates perturbation methods.

5541-5542-5543. SPECIAL FUNCTIONS IN MATHEMATICAL ANALYSIS. (4 cr per qtr; prereq 5568 or 5573)
Properties of gamma, hypergeometric, Bessel, and Hermite functions. Applications to mathematical physics. Relationship between symmetry groups and special functions.

5567f,w. FOURIER SERIES AND BOUNDARY VALUE PROBLEMS. (4 cr, §5571; prereq 3211, 3221 or equiv)
Partial differential equations of theoretical physics. Fourier series, proof of convergence, orthogonal systems. Sturm-Liouville systems, solution of boundary value problems by separation of variables, applications.

5568w,s. ELEMENTARY THEORY OF COMPLEX VARIABLES. (4 cr; prereq 5602 or equiv)
Derivative and integral of a function of a complex variable. Cauchy's integral theorem and formula, residues. Application to evaluation of integrals, conformal mapping.

5569s. OPERATIONAL MATHEMATICS. (4 cr; prereq 5568)
Laplace transforms, Fourier transforms, inversion theorems; applications to differential equators.

5571f-5572w-5573s. ELEMENTARY PARTIAL DIFFERENTIAL EQUATIONS. (4 cr per qtr, §5567, §5568; prereq 3211, 3221 or equiv)
Partial differential equations of theoretical physics, one-dimensional wave equations, characteristics, classification of second-order equations, heat and Laplace equations, uniqueness, maximum principle, orthogonal systems, Fourier series, separation of variables. Complex numbers, derivatives and integrals of analytic functions, elementary functions and their geometry. Cauchy's integral theorem and formula, Laurent expansions, evaluation of contour integrals by residues. Fourier and Laplace transforms and their inversion, method of residues, applications to ordinary and partial differential equations, applications of heat, wave, and Laplace equations.

5600. TOPICS IN ANALYSIS. (4 cr; prereq ‡)
Topics vary from quarter to quarter. With departmental approval this may be repeated for credit.

5601f,w-5602w,s-5603s. ADVANCED CALCULUS. (4 cr per qtr; prereq 3211 or 3411)
5601: Differentiation of functions of several variables; vector algebra; curves in three dimensions; directional derivative and gradient inverse transformation and implicit function theorems; change of variables in multiple integrals. 5602: Line and surface integrals; Stokes' theorem; convergence of infinite series; orthogonal functions; uniform convergence; integration and differentiation of series. 5603: Real numbers; continuous functions; limits; properties of continuous functions; differentiation; the Riemann integral; improper integrals.

5612f-5613w-5614s. INTRODUCTION TO ANALYSIS. (4 cr per qtr; principally for students planning grad work with a major in mathematics, as preparation for grad courses in analysis; prereq 3675, 3521 or 3211 with 3221 or 3411 with 3142)
Theory of real numbers; elements of point set theory; limits; differentiation; multivariable analysis.

5615s. LEBESGUE INTEGRAL. (4 cr; prereq 5602 or 5612 or 5607 or ‡)
Basic limit theorems. Comparison with Riemann integral. Lebesgue measure. Absolute continuity.

5625s. DEVELOPMENT OF NUMBER SYSTEMS. (4 cr, §5612; prereq 3211 or 3411)
Systematic construction of real number system by extension from natural numbers via rational numbers to irrational numbers; negative numbers, properties of the system; operations with numbers and laws governing operations.

5661-5662. PROBABILITY WITH TECHNOLOGICAL APPLICATIONS. (4 cr per qtr; prereq Stat 5131 and ‡)
Spectral analysis of stationary processes, linear and nonlinear transformations, prediction and smoothing, recurrent events, random walk and diffusion, Markov chains, Poisson processes.

5676. INTRODUCTION TO STOCHASTIC PROCESSES. (4 cr; prereq Stat 5132)
Introduction to stochastic processes, especially to various Markov processes which arise in applications.

5679. PROBABILITY. (4 cr, §5681; prereq 3211 or 3411 or 3521)
Elementary principles of probability, total and compound probability, expectation, repeated trials. As time permits, topics chosen from Stirling's formula, the probability integral, geometrical probability, probability of causes, Bayes' theorem, errors of observation, principle of least squares.

5681f-5682w-5683s. INTRODUCTION TO PROBABILITY. (4 cr per qtr; prereq 5602 or Stat 5133 or ‡)
Logical development and various applications of probability. Probability spaces, random variables, central limit theorem; Markov chains.

5701f. INTRODUCTION TO COMBINATORICS. (4 cr; prereq 3211 or 3411 and 3rd-yr standing... soph-level linear algebra is helpful)
Basic concepts. Enumeration including binomial counting, permutations, generating functions, inclusion-exclusion principle, recurrence relations. Emphasis on application. Introduction to matching theory and designs.

5702w. INTRODUCTION TO GRAPH THEORY. (4 cr; prereq 3211 or 3411 and 3rd-yr standing... soph-level linear algebra is helpful)
Basic concepts. Topics from connectedness, Eulerian graphs, trees, matrices, Hamiltonian graphs, coloring problems, plane graphs, enumeration. Applications may be discussed.

5703s. COMBINATORIAL ALGORITHMS AND OPTIMIZATION. (4 cr; prereq 3211 or equiv and knowledge of some programming language)
An introduction to basic algorithmic methods in combinatorics with emphasis on optimization.

5900. TUTORIAL COURSE IN ADVANCED MATHEMATICS. (Cr ar; prereq #)
Qualified students may make arrangements for study content of other graduate courses regularly offered by the department.

5910. PROBLEMS COURSE. (4 cr [may be repeated for cr with △]; prereq #)
Problem-solving techniques in many areas of mathematics. Topics from elementary to advanced levels, adapted to students of varied backgrounds.

5920f,w,s. MATHEMATICS ORIENTATION SEMINAR. (1 cr [may be repeated for 3 cr]; prereq math major with 3rd-yr standing or #)
A nonstructured seminar to facilitate contact between students and faculty. Primarily a discussion course, providing opportunity to examine topics that do not fit into the standard curriculum.

FOR GRADUATE STUDENTS ONLY

8150-8151-8152. AXIOMATIC SET THEORY

8166-8167-8168. RECURSION THEORY

8172-8173-8174. MODEL THEORY

8181-8182-8183. FORMAL LANGUAGES AND AUTOMATA

8190-8191-8192. TOPICS IN LOGIC

8200-8201-8202. GENERAL ALGEBRA

8230-8231-8232. FOUNDATIONS OF ALGEBRA

8236-8237-8238. STRUCTURE OF RINGS AND ALGEBRAS

8245-8246-8247. GROUP THEORY

8260-8261-8262. TOPICS IN NUMBER THEORY AND ALGEBRAIC GEOMETRY

8270-8271-8272. LIE GROUPS AND LIE ALGEBRAS

8290-8291-8292. TOPICS IN ALGEBRA

8306-8307-8308. ALGEBRAIC TOPOLOGY

8321-8322-8323. HOMOTOPY THEORY

8330-8331-8332. DIFFERENTIAL TOPOLOGY

8342-8343-8344. TOPOLOGICAL DYNAMICS

8365-8366-8367. RIEMANNIAN GEOMETRY

8374-8375-8376. ALGEBRAIC GEOMETRY

8380-8381-8382. TOPICS IN ADVANCED DIFFERENTIAL GEOMETRY

8406-8407-8408. ADVANCED METHODS OF APPLIED MATHEMATICS

8412-8413-8414. PARTIAL DIFFERENTIAL AND INTEGRAL EQUATIONS OF APPLIED MATHEMATICS

8430-8431-8432. MATHEMATICAL THEORY OF FLUID DYNAMICS

8433. MATHEMATICAL ASPECTS OF BOUNDARY LAYER THEORY

8440. VARIATIONAL METHODS IN BOUNDARY VALUE PROBLEMS

8441. VARIATIONAL METHODS IN EIGENVALUE PROBLEMS

8445. ADVANCED NUMERICAL ANALYSIS OF LINEAR SYSTEMS

8446. ADVANCED NUMERICAL ANALYSIS OF PARTIAL DIFFERENTIAL EQUATIONS

8460-8461-8462. MATHEMATICAL PROBLEMS IN THEORETICAL PHYSICS

8466-8467-8468. JOINT SEMINAR WITH AERONAUTICAL ENGINEERING

8480-8481-8482. SELECTED TOPICS OF CELESTIAL MECHANICS

8500-8501-8502. THEORY OF ORDINARY DIFFERENTIAL EQUATIONS

8516-8517-8518. THEORY OF NONLINEAR OSCILLATIONS

8530-8531. TOPICS IN CONTROL THEORY

8540-8541-8542. TOPICS IN DIFFERENTIAL AND DIFFERENCE EQUATIONS

8550-8551-8552. THEORY OF PARTIAL DIFFERENTIAL EQUATIONS

8560-8561-8562. CALCULUS OF VARIATIONS AND MINIMAL SURFACES

8566-8567-8568. CALCULUS OF VARIATIONS IN THE LARGE

8590-8591-8592. TOPICS IN PARTIAL DIFFERENTIAL EQUATIONS

8600-8601-8602. REAL ANALYSIS

8609-8610. THEORY OF DIFFERENTIATION

8624-8625-8626. GENERALIZED FUNCTIONS, DISTRIBUTIONS, AND APPLICATIONS

8630-8631-8632. WIENER AND FEYNMAN INTEGRALS

8640-8641-8642. TOPICS IN REAL ANALYSIS

8650-8651-8652. THEORY OF PROBABILITY

8656-8657-8658. MEASURE THEORY AND PROBABILITY

8660-8661-8662. STOCHASTIC PROCESSES

8666-8667-8668. STOCHASTIC CONTROL THEORY

8672-8673-8674. COMBINATIONAL THEORY

8675. INFORMATION THEORY

8680-8681-8682. ERGODIC THEORY

8690-8691-8692. TOPICS IN THE THEORY OF PROBABILITY

8700-8701-8702. COMPLEX ANALYSIS

8706, 8707, 8708. REAL AND COMPLEX ANALYSIS

8720-8721-8722. CONFORMAL MAPPING

8735-8736-8737. RIEMANN SURFACES

8740-8741-8742. THEORY OF QUASI-CONFORMAL MAPPING

8780-8781-8782. TOPICS IN SEVERAL COMPLEX VARIABLES

8790-8791-8792. TOPICS IN THE THEORY OF ANALYTIC FUNCTIONS

8800-8801-8802. FUNCTIONAL ANALYSIS

8810-8811-8812. TOPOLOGICAL GROUPS

8830-8831-8832. BANACH ALGEBRAS AND HARMONIC ANALYSIS

8845-8846-8847. GROUP REPRESENTATIONS

8874-8875-8876. NONLINEAR FUNCTIONAL ANALYSIS AND ITS APPLICATION

8880-8881-8882. TOPICS IN OPERATOR THEORY

8990-8991-8992. READING AND RESEARCH

Mechanical and Aerospace Engineering, School of (SMAE)

1010. FRESHMAN PROJECTS. (1-6 cr; prereq ‡)
Individual projects. Freshman assists senior in upper division design or laboratory course or in course-related project.

3010. FRESHMAN PROJECTS. (1-6 cr; prereq ‡)
Individual projects. Freshman assists senior in upper division design or lab course or in course-related project.

3200. INTRODUCTION TO ENGINEERING FLUID MECHANICS. (4 cr, §AEM 5200, §CE 3400; prereq Math 3221)
The flow of viscous incompressible fluids; fluid statics, Bernoulli flow, momentum conservation, laminar and turbulent pipe flow, laminar and turbulent boundary layers.

5711. ADVANCED URBAN TRANSPORT SYSTEMS. (4 cr; prereq CE 5210)
The urban transportation problem. Capabilities of rapid rail and bus systems. Characteristics of dial-a-ride, dual mode, personal rapid transit, automated highways. Technical problems associated with personal rapid transit and dual mode systems. Environmental, energy, and economic considerations associated with advanced urban transportation systems.

Mechanical Engineering (ME)

1001. INTRODUCTION TO MECHANICAL ENGINEERING. (1 cr; S-N only; 1 lect hr per wk)
An introduction to the field presented by practicing engineers and members of the faculty. Topics include the Mechanical Engineering curriculum, the elective program, the profession, and related areas of research.

3201. MECHANICAL ENGINEERING SYSTEMS ANALYSIS. (4 cr, §AEM 3401; prereq Math 3221; 3 lect and 2 lab hrs per wk)
Determination of response of engineering systems utilizing transfer function representation. Analogies between engineering systems based upon transfer function equivalence.

3203. ANALYSIS OF MECHANISM SYSTEMS. (4 cr; prereq AEM 3036 or equiv; 3 lect and 1 rec-lab hrs per wk)
Diagnostics of the performance of mechanism systems involving linkage, hydraulic, pneumatic, and electromechanical components. Energy balance techniques used to describe energy flow through machine systems.

3205. ENGINEERING SYSTEMS DESIGN. (4 cr; prereq 3201, 3203; 3 lect and 2 lab hrs per wk)
Application of fundamental concepts to the design of typical mechanical components. Engineering approach to the analysis and synthesis of machines and systems. Specification of materials in engineering design. Optimum design criteria.

3301. THERMODYNAMICS. (4 cr; prereq Chem 1014 or Phys 1281, Math 3221, or equiv; 4 lect hrs per wk)
Properties, equations of state, processes and cycles for various thermodynamic systems. Development of first and second laws of thermodynamics, correlating heat, work and mass transfer. Equilibrium, irreversibility and mixtures.

3303. APPLIED THERMODYNAMICS. (4 cr, §3305; prereq 3301 or equiv; 4 lect hrs per wk)
Application of laws of thermodynamics to chemically reacting systems and engineering systems. Vapor cycles, gas engine cycles, propulsion systems, refrigeration and air-water vapor mixtures.

3305. PROPULSION THERMODYNAMICS. (4 cr, §3303; prereq 3301 and AEM 5200, or equiv; 4 lect hrs per wk)
Principles of thrust production, momentum, energy and mass flow functions; chemical equilibrium, combustion, flame temperature. Thermodynamics of turbojet, turbofan, turboprop, rocket and engine units.

3701-3702. BASIC MEASUREMENTS LABORATORY I AND II. (2 cr per qtr; prereq 3301 or ¶3301 for 3701...3701 for 3702; 1 lect and 3 lab hrs per wk)
Treatment of experimental data, analysis and study of experimental systems via the computer. Static and dynamic characteristics of measurement systems. Fundamental principles of measurement and calibration. Measurement of temperature, pressure, vacuum, humidity, density, viscosity, heating values, speed, power, force, stress-strain, and radioactivity.

3703-3704-3705. ADVANCED MECHANICAL ENGINEERING LABORATORY. (2 cr; prereq 3702 or equiv; 4 hr lec-lab combination per wk)
Systems measurement and evaluation involving various areas of study in mechanical engineering. Each quarter involves two 5-week laboratory modules as selected by the student.

3740. INDUSTRIAL ASSIGNMENT. (2 cr per qtr [may be repeated for cr]; prereq regis in intern program)
Industrial work assignment in engineering intern program. Grade based on formal written report written by the student covering the quarter's work assignment.

3900. INTRODUCTION TO ENGINEERING STATISTICS. (4 cr; prereq Math 1231 or equiv; 3 lect and 1 rec hrs per wk)
Elements of probability, descriptive statistics, binomial and Poisson distributions; normal distribution, estimation, hypothesis testing, regression analysis and analysis of variance.

5190. ADVANCED ENGINEERING PROBLEMS. (2-4 cr; open to upper division students; prereq approved deptl permission form)
Special investigations in various fields of mechanical engineering and related areas including independent study project.

5203. ADVANCED ANALYSIS AND SYNTHESIS OF MECHANISM SYSTEMS. (3-4 cr; 3203 or equiv...computer programming desirable; 3 lect hrs per wk)
Analytical methods of kinematic, dynamic, and kinetoelastodynamic analysis and synthesis of mechanisms. Computerized design for function, path and motion generation based on Burmester theory.

5205. CREATIVITY IN ENGINEERING DESIGN. (3-4 cr [1 cr term paper option]; completion of basic core of ME program or equiv desirable; 3 lect hrs per wk)
The role of creative action at various stages in the morphology of the design process. Creative decision making in developing design criteria, alternative solutions, and their evaluation.

5207. EXPERIMENTAL STRESS ANALYSIS. (4 cr; prereq AEM 3016; 3 lect and 3 lab hrs per wk)
Experimental application and theoretical evaluation of methods of stress analysis. Strain gages, surface coatings, photoelasticity techniques. Design of transducing systems utilizing strain.

5209. FRICTION AND LUBRICATION. (3-4 cr [1 cr term paper option]; prereq CE 3400 or equiv; 3 lect hrs per wk)
Solid friction mechanism and boundary lubrication. Hydrodynamic and hydrostatic lubrication theory applied to bearing design. Introduction to gas bearings.

5244. VIBRATION ENGINEERING. (4 cr; prereq 3201 or equiv; 4 lect hrs per wk)
Applications of the theory of vibration to the design and optimization of isolators, detuning mechanism, viscoelastic suspensions and structures.

5254. DESIGN MORPHOLOGY WITH APPLICATIONS. (4 cr; completion of 3rd-yr basic engineering courses desirable; 2 lect and 2 lab sessions per wk)
Detailed study of design problem formulation and the structure of the open-ended solution process based on design morphology. Case studies and student projects as instructional vehicles.

5255. ENGINEERING DESIGN PROJECT. (4 cr [may be repeated for cr]; 5254 or equiv desirable; 1 lect and 2 lab sessions per wk)
Participation in solution of systems design problems which have developed criteria, order-of-magnitude evaluation of alternatives, and generation of preliminary design.

5260. ENGINEERING MATERIALS AND PROCESSING. (4 cr; prereq Phys 1291, Chem 1004, and 1st-yr calculus; 3 lect and 1 rec per wk)
Introduction to materials and processing including physical and metallurgical properties, consolidation, etc. Material processing including machining, welding, and deformation processes.

5262. MATERIAL WORKING AND FABRICATION PROCESSES. (4 cr; prereq 5260 or equiv; 3 lect and 1 rec per wk)
Theory and application of joining techniques, welding, brazing, and adhesive bonding. Metal forming operations, rolling, swaging, drawing, etc. Inspection and test methods to control and evaluate fabrication processes including X-ray, magnetic, metallographic, and chemical methods.

5264. MATERIAL CONSOLIDATION PROCESSES. (4 cr; prereq 5260 or equiv; 3 lect and 1 rec per wk)
Theory and practice of material consolidation including casting and powder metal processes. Composite materials techniques.

5266. MATERIAL FINISHING PROCESSES. (4 cr; prereq 5260 or equiv; 3 lect and 1 rec per wk)
Theory and practice of metal removal and finishing including mechanical, chemical, and electrolytical methods. Techniques of surface preparation, plating, abrasive and chemical cleansing, coatings, and films.

5268. PROPERTIES AND FABRICATION OF PLASTICS. (4 cr; prereq 5260 or equiv; 3 lect and 1 lab-rec hrs per wk)
Materials, equipment, and processes for fabrication of plastics. Principles of products and tool design. Hydraulic and temperature circuit control for equipment.

5270. MATERIALS—DESIGN REQUIREMENTS. (4 cr; prereq 5260 or equiv; 3 lect and 1 rec hrs per wk)
Fundamental properties of engineering materials including fabrication, treating, physical and corrosive properties. Failure mechanism, cost and value analysis as related to material selection and specification.

5283. INDUSTRIAL INSTRUMENTATION AND AUTOMATIC CONTROL. (4 cr; prereq 3201 or equiv; 3 lect and 3 lab hrs per wk)
Theory and operation of instruments and automatic control. Industrial controls including fluidic controls. On-off, proportional, floating, and rate response in control systems.

5284. CONTROL SYSTEMS. (4 cr; prereq 3201 or equiv; 4 lect hrs per wk)
Basic theory of linear feedback control systems. Transfer function representation of solid body, fluid, pneumatic and electromechanical components. On-off, proportional, floating, and rate response in control systems, including industrial instrumentation.

5342. HEAT TRANSFER. (4 cr; prereq 3301, Math 3221, and CE 3400, or equiv; 4 lect hrs per wk)
Steady and unsteady conduction of heat. Convection heat transfer in boundary layer and duct flows; forced and free convection; condensation and boiling; heat exchangers. Heat transfer by thermal radiation; radiative properties of black bodies and real surfaces.

5344. THERMODYNAMICS OF FLUID FLOW. (4 cr; prereq 3301 and CE 3400, or equiv; 4 lect hrs per wk)
Compressible flow of gases in engineering systems such as nozzles, ducts, combustion chambers, ramjets, pipelines, etc. Isentropic flow in variable area passages. Shock waves. Flow with wall friction, heat transfer, and mass transfer.

5380. REACTOR HEAT TRANSFER. (3 cr; prereq 5342 or equiv; 3 rec hrs per wk)
Heat conduction with internal heat generation, thermal stresses, liquid metal heat transfer, forced convection in noncircular ducts, boiling, and two-phase flow.

5442. VAPOR CYCLE POWER SYSTEMS. (3-5 cr [1-2 cr term paper option]; prereq 3303 or equiv; 3 lect hrs per wk)
Vapor cycle analysis, regeneration, reheat, compound cycle modifications, combined gas turbine-vapor cycle systems and binary systems. Combustion problems; solar, nuclear, and unusual energy sources for space power systems.

5443. TURBOMACHINERY. (3-5 cr [1-2 cr term paper option]; prereq 3301 or equiv; 3 lect hrs per wk)
Theoretical analysis of energy transfer between fluid and rotor, principles of axial, mixed, and radial flow compressors and turbines. Applications to power plants, fluid transmissions, and propulsion systems.

5446. AN INTRODUCTION TO COMBUSTION. (4 cr; prereq 5342 or equiv; 4 lect hrs per wk)
Flame propagation, quenching and ignition in a gaseous mixture; combustion of solid and liquid particles, and gaseous jets. Applications to selected propulsion systems.

5455. ROCKET PROPULSION. (3-5 cr [1-2 cr term paper option]; prereq 3303 or equiv; 3 lect hrs per wk)
Mode of operation and performance limitations of chemical rockets with liquid, solid, and free radical propellants, nuclear and solar rockets with thermal and electromagnetic propellant acceleration.

5460. INTERNAL COMBUSTION ENGINES. (4 cr; prereq 3301 or equiv; 4 lect hrs per wk)
Principles of power production, fuel consumption, and emissions of gasoline and diesel engines; fuel-air cycle analysis, combustion flames, knock phenomena, air flow and volumetric efficiency, mixture requirements, ignition requirements and performance.

5461. ADVANCED INTERNAL COMBUSTION ENGINES. (3-5 cr [1-2 cr term paper option]; prereq 5460 or equiv; 3 lect hrs per wk)
Hydrocarbon fuels, octane and cetane ratings, additives and deposits; lubrication systems, lubricants, additives for control of friction; air and liquid coolings; engine design problems.

5462. GAS TURBINES. (4 cr; prereq 3301 or equiv; 4 lect hrs per wk)
Gas turbine cycles, regeneration, reheat, and intercooling. Axial and radial flow compressors and turbines; burner types and combustion efficiency; emissions and noise. Matching of compressor and turbine. Turbojet, fan-jet and turboprop engine performance.

5480. BIOLOGICAL FLUID FLOW. (3-4 cr [1 cr term paper option]; prereq CE 3400 or equiv; 3 lect hrs per wk)
Introduction to rheology and fluid dynamics of biological fluids. Blood flow, biological pumping, self-propelled particles, unusual viscoelastic behavior of biological fluids, and other fluid motions.

5603. THERMAL ENVIRONMENTAL ENGINEERING. (4 cr; prereq 3303 and 5342, or equiv; 4 lect hrs per wk)
Thermodynamic properties of moist air; h-W diagram for moist air; solar radiation; heat and water vapor transmission in structures; effects of thermal environments upon people, processes, and materials; thermal loads, thermal environmental control systems.

5605. REFRIGERATION. (4 cr; prereq 3303; 4 lect hrs per wk)
Mechanical vapor compression systems; absorption systems; thermoelectric cooling; gaseous air cycle; steam-jet refrigeration. Liquefaction of air, hydrogen, and helium; production of oxygen and nitrogen by separation of air.

5607. INDUSTRIAL VENTILATION AND CONTAMINANT CONTROL. (4 cr; prereq 3303 and CE 3400, or equiv; 4 lect hrs per wk)

Contaminants, dispersion mechanisms, transport, fans, hoods, gas cleaners, behavior of jets and sinks, closed and open systems, applications to industrial processing and emission control.

5612. ENVIRONMENTAL ENGINEERING. (4 cr; prereq upper division; 4 lect hrs per wk)
Basic principles of engineering assessment and control of emissions to air and water, noise measurement and control, and control, handling, and disposal of solid waste.

5613. PRINCIPLES OF PARTICLE TECHNOLOGY. (4 cr; 3303 desirable; 4 lect hrs per wk)
Definition, theory, and measurement of particle properties, particle statistics, fluid dynamics, optical, electrical, and thermal behavior of particles.

5614. PRINCIPLES OF PARTICLE TECHNOLOGY. (4 cr; prereq 5613; 4 lect hrs per wk)
Gas cleaning, particle transport, comminution, classification, surface properties, packed beds, powder behavior, and miscellaneous topics.

5615. AIR CONTAMINANT MEASUREMENT. (4 cr; prereq 5613 or #)
Principles of operation, application and interpretation of data from instruments and instrument systems used for in-plant contaminants, emissions and air quality measurement.

5721. PROPULSIVE SYSTEMS FOR SURFACE TRANSPORTATION. (4 cr; intended for engineering srs; 3301 recommended; 4 lect hrs per wk)
Characteristics of electrical and mechanical propulsion devices and energy storage systems available for use in various types of surface transport vehicles, worldwide energy sources, environmental implications of transport propulsive devices, power requirements, and thermodynamic constraints.

FOR GRADUATE STUDENTS ONLY

8190. MECHANICAL ENGINEERING GRADUATE SEMINAR

8210. ADVANCED VIBRATION ENGINEERING

8211-8212-8213. APPLIED DYNAMICS

8243. PHOTOELASTICITY

8280-8281-8282. FEEDBACK CONTROL SYSTEMS

8310. ADVANCED THERMODYNAMICS

8311. STATISTICAL AND NONEQUILIBRIUM THERMODYNAMICS

8326. BOILING HEAT TRANSFER AND MULTIPHASE FLOW

8330. CONDUCTION

8331. CONVECTION

8332. RADIATION

8333. ADVANCED THEORY OF HEAT TRANSFER

8350. ADVANCED FLUID THERMODYNAMICS

8360-8361-8362. THERMODYNAMICS OF HIGH TEMPERATURE GASES

8370-8371-8372. MAGNETOHYDRODYNAMICS

8442. ADVANCED POWER PLANTS

8443. THERMOCHEMICAL ANALYSIS OF POWER SYSTEMS

8444-8445. THERMODYNAMICS AND CHEMICAL KINETICS OF COMBUSTION

8446. ENERGY TRANSPORT IN CHEMICALLY REACTING GASES

8447. MASS TRANSFER IN CHEMICALLY REACTING GASES

8448. ATOMIZATION, VAPORIZATION, AND MIXING

8450. DYNAMICS OF HIGH SPEED ENGINES

8453. ADVANCED GAS TURBINES AND JET PROPULSION

8455. ADVANCED ROCKET PROPULSION

8485-8486-8487. BIOMEDICAL ENGINEERING SEMINAR

8600-8601. PSYCHROMETRICS AND AIR CONDITIONING

8603. THEORETICAL REFRIGERATION

8770-8771-8772. MECHANICAL ENGINEERING RESEARCH

8773-8774-8775. GRADUATE SEMINAR

Metallurgy/Materials Science (MatS)

3090, 3091, 3092. INDUSTRIAL EMPLOYMENT. (1-2 cr [depending upon duration of employment]) Employment with industrial firms that perform metallurgical or materials engineering activities. Report covering work required.

3400. MECHANICAL PROPERTIES OF MATERIALS. (4 cr; prereq 2nd-yr IT student)
Introduction to structure and properties of metals, alloys, and polymers; heat treatment; alloy selection and metal processing; specifically for mechanical, aero, civil, and other engineering students outside of chemical engineering and materials science.

3501. QUANTITATIVE METALLOGRAPHY AND ELECTRON MICROSCOPY. (3 cr; 1 lect, 1 rec, and 2 lab hrs per wk)
Microstructure of materials, temperature measurement and control, equilibrium diagrams, quantitative metallography, electron microscopy.

3502. PHYSICAL METALLURGY LABORATORY. (3 cr; 1 lect and 4 lab hrs per wk)
Solidification of metals and alloys, transformations in solids, hardenability surface treatment of metals, metallurgical problems.

3521. X-RAY METALLOGRAPHY. (3 cr; 1 lect, 1 rec, and 2 lab hrs per wk)
Physics of X-ray diffraction, powder patterns, crystal orientation, microradiography, application to metallurgy and materials science, solvus determination, phase equilibria, structure of cold worked metals.

5011-5012-5013. INTRODUCTION TO SCIENCE OF MATERIALS. (4 cr; prereq 3rd-yr IT student)
Introduction to relation between atomic and electronic structure of metals, semiconductors, insulators, polymers, and important properties of materials.

5101. THERMODYNAMICS AND MATERIALS STATES. (4 cr; 3 lect and 2 rec hrs per wk) Staff (Same as ChEn 5201) Principles of thermodynamics applied to closed and open systems and to equilibrium states of homogeneous and heterogeneous substances, gases, liquids, and solids.

5102. THERMODYNAMICS AND KINETICS OF THE SOLID STATE. (4 cr; prereq course in chemical thermodynamics)
Theory of solids, heterogeneous equilibria, free energy-composition diagrams, diffusion and reaction kinetics.

5111. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING AND MATERIALS SCIENCE. (2 cr; 2 lect and 1 rec hrs per wk)
(Same as ChEn 5001) Computer programming with applications to chemical, physical, and engineering problems.

5301. CONTROL OF MECHANICAL PROPERTIES IN METALS AND ALLOYS. (4 cr; 3 lect and 2 lab hrs per wk)
Mechanical properties of metals and alloys in terms of dislocation behavior, creep, fatigue, fracture toughness. Control of mechanical properties through manipulation of microstructure by metal processing.

5303. ANALYSIS OF METALLURGICAL PROBLEMS. (4 cr; 2 lect and 4 lab hrs per wk)
Specialized metallurgical subjects such as embrittlement of steels, residual stresses, wear, and fatigue in metals, with primary emphasis on failure analysis.

5401-5402-5403. PRINCIPLES OF PHYSICAL METALLURGY. (4 cr; prereq 5012 or ♯)
Fundamentals of solidification, transformations: strength, deformation and fracture of solids, casting, hardenability, heat treatment of alloys; surface treatment, joining, working of metals.

5450. CORROSION OF METALS. (3 cr; background in materials science and thermodynamics desirable; 3 lect hrs per wk)
Electrochemical theory, mechanisms of corrosion, theories of passivity, influence of environmental factors on corrosion. High temperature oxidation, corrosion control, organic coatings, alloying, inhibitors.

5481, 5482, 5483. SPECIAL PROBLEMS IN PHYSICAL METALLURGY AND MATERIALS SCIENCE. (Cr and hrs ar; prereq sr standing)
Library or laboratory studies of scientific or engineering problems in physical metallurgy and materials science.

5610. POLYMER CHEMISTRY. (4 cr; prereq Chem 5501 or ♯; 3 lect and 3 lab hrs per wk)
Polymer synthesis and physical chemistry: polymerization kinetics and reactors, molecular weight distribution, network formation, macromolecules in solution and their characterization, the glassy state, rubber elasticity, flow and viscoelasticity, environmental degradation.

5620. POLYMER PROCESSING. (4 cr; prereq 5610 or ‡; 3 lect and one open lab-rec per wk)
Polymer processing principles and applications: rheology of long chain molecules, flow in simple geometries, mixing, thermal properties and phase change; thermoplastic operations: extrusion, calendaring, forming and molding; thermoset operations.

5630. POLYMER PHYSICAL PROPERTIES. (4 cr; prereq 3400, 5011, Chem 5501, or ‡; 3 lect and one open lab per wk)
Polymer structure-property relations: structure and morphology and their characterization, mechanical properties, failure, permeability, optical and electrical properties, polymer composites, effect of processing on properties.

FOR GRADUATE STUDENTS ONLY

8110. THERMODYNAMIC PROPERTIES OF SOLIDS: CLASSICAL AND STATISTICAL MECHANICS APPLIED TO STUDY OF THE PROPERTIES OF SOLIDS

8111. TRANSPORT PROCESSES IN SOLIDS

8112. SOLID STATE REACTIONS

8210. CRYSTALLINE PROPERTIES OF METALS

8211. MODERN THEORY OF METALS AND ALLOYS

8212. IMPERFECTIONS IN METALS

8213, 8214. STRUCTURE AND COHESION OF METALS AND SEMICONDUCTORS

8220. TOPICS IN LOW TEMPERATURE METAL PHYSICS

8301. ELECTRON INTERACTION WITH SOLIDS

8310-8311. THEORIES OF MECHANICAL BEHAVIOR OF SOLIDS

8320. HIGH TEMPERATURE PROPERTIES OF MATERIALS

8401, 8402. TRANSFORMATIONS IN MICROSTRUCTURE

8470, 8471, 8472. SEMINAR: MATERIALS SCIENCE AND ENGINEERING

8480, 8481, 8482. SELECTED TOPICS IN MATERIALS SCIENCE AND ENGINEERING

8520. ELECTRON DIFFRACTION AND ELECTRON MICROSCOPY

8522. ADVANCED X-RAY DIFFRACTION OF METALS

Mineral Engineering (MinE)

5530. FLUID FLOW THROUGH POROUS SOLIDS I. (4 cr; prereq 5534 or ‡)
Petrophysics of porous rocks and aquifers; porosity, permeability, mineral surface areas; linear, radial, and spherical flow for various types of fluids; units. Laboratory experiments.

5532. FLUID FLOW THROUGH POROUS SOLIDS II. (4 cr; prereq 5530 or ‡)
Fluid flow possibilities. Darcy's generalized equations; vertical flow; units. Kozeny equations derived; fracture and channel flow; electrical, acoustical, and radioactive properties of rocks pertaining to porosity and connate water of rocks treated. Oil reservoirs, material balance and volumetric petroleum reserves estimations; rock compressibility effects; fractional flow equations.

5534. EARTH FLUIDS AND FLUID FLOW. (4 cr; prereq 3rd yr or ‡)
Sedimentary rocks and earth fluids characteristics. Fluid flow through porous rocks. Basic principles of oil reservoir engineering; energies and mechanisms of petroleum production.

5611. MINERAL RESOURCES I: EXPLORATION AND DEVELOPMENT. (4 cr; prereq 3rd yr or ‡; 3 lect and 3 lab hrs per wk)
Mineral distribution and demand; nongeologic ore determinants; mineral law, taxation, liquidation value; options and leases; ore guides; drilling, sampling, and combining theory; geostatics and concepts of risk elimination.

5612. MINERAL RESOURCES II: DEVELOPMENT AND PRODUCTION SYSTEMS. (4 cr; prereq 3rd yr or ‡; 3 lect and 2 rec hrs per wk)
Development and production systems for mineral properties. Essential criteria for design and selection of mining methods. Unit operations; drilling, blasting, loading, and hauling.

5613. MINERAL RESOURCES III: EXAMINATION AND VALUATION OF MINERAL PROPERTY. (4 cr; prereq 5612 or 5630 and Geo 1111 desirable or ♯)
Geologic factors sampling and reserve estimates. U.S., Canadian, and Mexican mineral rights laws. Analysis of costs and profitability. Taxation, depreciation, and depletion. Present worth and rate-of-return computations; financing methods.

5619. ENGINEERING FIELD STUDY. (3 cr; prereq sr or grad in mineral or geological engineering or ♯; 2 wks during summer)
Mining and petroleum operations; mine and petroleum metallurgical plants; research engineering offices in selected regions.

5630. SURFACE MINING ENGINEERING. (4 cr; prereq 5611 and Geo 1111 and/or ♯)
Unit operations of drilling, blasting, loading, hauling, and transportation of surface rocks and soils. Equipment productivity, selection, and cost estimating. Design of open pits and quarries. Economics, environment, and organization.

5640. MINERAL ECONOMICS. (3 cr; prereq 5613 or ♯)
Distribution, demand, and conservation of strategic supplies. Marketing and prices. State and national policies affecting development. Analysis of mineral data.

5642. MINERAL ECONOMICS: MINERALS IN NATIONAL AND WORLD AFFAIRS. (3 cr; prereq upper division; 3 lect hrs per wk)
The importance and distinctive features of mineral wealth. Distribution, demand, and conservation of strategic supplies. Marketing and prices. State and national policies affecting development. Analysis of mineral data.

5650-5652. MINERAL ENGINEERING DESIGN I, II. (4 cr per qtr; prereq sr or grad student in mineral engineering; 12 design hrs per wk)
Systems approach to selected aspects of a mining project: exploration, mining, mineral processing, metals extraction. Integration of classroom concepts. Cost estimation and economic evaluation. Preparation of report on case example chosen by student.

5660. SPECIAL MINERAL ENGINEERING PROBLEMS. (Cr and hrs ar; prereq 5612)
Literature survey or research work on mining problems.

5700. SYSTEMS ANALYSIS FOR MINERAL ENGINEERS. (4 cr; prereq 5613, 5820, and GeoE 5437 or ♯; 3 lect and 2 rec hrs per wk)
Introduction to systems analysis, operations research techniques, modeling and simulation. Applications in mineral engineering. Life cycle concept of mining.

5710. ENVIRONMENTAL ASPECTS OF MINERAL ENGINEERING. (4 cr; prereq 5613 and 5820 or ♯; 4 lect hrs per wk)
Recognizing and minimizing the environmental problems posed by mining and metallurgical operations. Both the immediate working environment and the larger ecological impacts are considered.

5720. MINERAL PLANT ENGINEERING I. (4 cr; prereq 5612 or ♯; 3 lect and 3 lab hrs per wk)
Basic engineering principles in design and selection of mine, petroleum, and mill plant equipment. Calculations involving compressed air, pumping, transmission of gases and fluids, and power systems—mechanical, hydraulic, pneumatic, and electrical.

5722. MINERAL PLANT ENGINEERING II. (4 cr; prereq 5720 or ♯; 3 lect hrs and 3 lab hrs per wk)
Basic engineering principles in design and selection of mine plant equipment such as hoists, conveyors, railroad systems, etc. Calculation involving power transmission, drilling, hoisting, and transportation of crushed ore material.

5800. MINERAL PROCESSING I. (4 cr; prereq ♯; 3 lect and 3 lab hrs per wk)
Application of physical and chemical principles to mineral processing problems. Screening, size, reduction, size and gravity classification, electrical separation and magnetic separation.

5810. MINERAL PROCESSING II. (4 cr; prereq ♯; 3 lect and 3 lab hrs per wk)
Chemical, physical, and engineering aspects of flotation, hydrometallurgy, thickening and filtration. Integration of operations and processes on a plant basis.

5818. HYDROMETALLURGY. (4 cr; prereq ♯; 3 lect and 3 lab hrs per wk)
Application of physicochemical principles to leaching of metals, ores, and concentrates; to purification of leach solutions; and to recovery of metals. Integration of operations and processes on a plant basis.

5820. PRINCIPLES OF METALS EXTRACTION I. (5 cr; prereq 8 cr of inorganic chemistry)
Materials and heat balances in metallurgical processes. Chemical equilibrium and rates of reaction. Combustion of fuels and heat utilization. Phases in pyrometallurgical systems.

5825. METALLURGICAL HEAT TRANSFER AND FLUID FLOW. (4 cr; prereq 5820 or ♯; 4 lect hrs per wk)

Fluid flow and heat transfer concepts in metallurgical systems. Theory and correlation to industrial practice. Applications to temperature measurements, thermal insulation, and the heating and cooling of solid bodies.

5830. MICROSCOPY FOR MINERAL ENGINEERS. (3 cr; prereq ‡)
Petrographic and metallographic microscopic identification of minerals and ores. Elementary optics and the optical characteristics of nonopaque and opaque minerals. Application of microscopy to the mineralogical and textural factors which exercise fundamental control over beneficiation processes.

5910. METALLURGICAL UNIT PROCESSES. (4 cr; prereq 5825 or ‡)
Unit processes of chemical metallurgy are covered in chronological order; roasting, agglomeration, smelting, converting, refining, vaporization, and electrolytic methods.

5940. SPECIAL PROBLEMS IN EXTRACTIVE METALLURGICAL ENGINEERING. (Cr and hrs ar; prereq sr)
Laboratory investigation of problems in extractive metallurgy.

FOR GRADUATE STUDENTS ONLY

8330. ADVANCED CONCEPTS IN DRILLING OF ROCKS

8470-8471-8472. MINING RESEARCH PROBLEMS I, II, III

8601-8602-8603. SEMINAR: MINERAL ENGINEERING

8620. ADVANCED ENGINEERING DESIGN

8632. GRAVITY FLOW OF FRAGMENTED MATERIALS

8640. ADVANCED MINERAL ECONOMICS

8724. MINE ENVIRONMENT ENGINEERING

8730-8732. OPERATIONS ANALYSIS IN MINERAL ENGINEERING I, II

8830. ELECTRIC AND MAGNETIC SEPARATION OF MINERALS

8832. TECHNIQUES OF MINERAL PROCESSING RESEARCH

8838-8839. OPTIMIZATION AND CONTROL TECHNIQUES IN MINERAL PROCESSING I, II

8840. FLOTATION THEORY

8842. SURFACE CHEMISTRY OF MINERAL SUSPENSIONS

8921-8922-8923. RESEARCH IN EXTRACTIVE METALLURGICAL ENGINEERING

8925-8926-8927. SEMINAR: EXTRACTIVE METALLURGICAL ENGINEERING

8930-8932-8934. PHYSICAL CHEMISTRY OF HIGH TEMPERATURE METALLURGICAL REACTIONS I, II, III

Physics (Phys)

1014-1024. INTRODUCTORY PHYSICS: CONCEPTS IN PHYSICS. (4 cr per qtr, §other introductory physics courses; cannot be used as prereq for physics or biological science majors; prereq high school algebra and plane geometry; may be taken with or without accompanying lab 1015-1025; 3 lect hrs and 1 prob hr per wk)
Principles of physics. Mechanics, electricity and magnetism, waves, and 20th-century physics (relativity and quantum theory). Primarily for students interested in the ideas of 20th-century physics.

1015-1025. INTRODUCTORY PHYSICS LABORATORY. (1 cr per qtr; S-N only; prereq 1014 or ¶ for 1015...1024 or ¶ for 1025; 2 lab hrs per wk)
Laboratory experiments offered in conjunction with 1014-1024.

1031-1032. INTRODUCTORY PHYSICS: MEASUREMENT AND APPLICATIONS. (5 cr per qtr, §other introductory physics courses; prereq high school algebra and plane geometry; 4 class hrs and one 2-hr lab or prob session per wk)
Lectures, laboratory and problem sessions. Application of physics: mechanics, random processes, gases and fluids, electric circuits, waves, light, optical instruments, atoms and spectra, nuclei, radioactivity. Primarily for students interested in topics useful in technical areas.

1061. PHYSICS OF HUMAN MOTION. (4 cr; prereq 1 yr high school algebra; 3 lect discussions per wk and one 2-hr gym lab every 2 wks)
Basic concepts of classical mechanics applied to motion of human bodies in various forms of work, athletics, and dance. Physics of muscles. Eight labs, five in gym.

1071. INTRODUCTORY METEOROLOGY. (4 cr; prereq high school algebra and trigonometry; 5 lect hrs per wk)
Physics of atmospheric processes. Clouds, fronts, and cyclones. Weather forecasting. Man's influence on the atmosphere.

1075. INTRODUCTORY METEOROLOGY LABORATORY. (1 cr; S-N only; prereq 1071 or ¶; 2 lab hrs per wk)
Field experiments offered in conjunction with 1071.

1104-1105-1106. GENERAL PHYSICS. (5 cr per qtr; primarily for premedical students; prereq Math 1142 and high school trigonometry or Math 1008 for 1104...1104 for 1105...1105 for 1106; 4 lect, 1 quiz, 2 lab hrs per wk)
1104: Mechanics. 1105: Heat and electricity. 1106: Sound and light. Laboratory work is an integral part of course.

1121-1122. PHYSICS FOR ARCHITECTS. (5 cr per qtr; prereq Math 1211 or ¶; 4 lect and one 2-hr lab per wk)
General principles of physics useful to prearchitecture students. Mechanics, heat, electric circuits, gases, light, sound, properties of materials.

1271-1281-1291. GENERAL PHYSICS. (4 cr per qtr; prereq completion or concurrent regis in Math 1221 or 1321 or 1621 or equiv for 1271...completion or concurrent regis in Math 1231 or 1331 or 1621 or equiv for 1281; may be taken with or without accompanying lab 1275-1285-1295; 3 lect, 1 prob, and 1 quiz hr per wk)
Calculus-level general physics course. 1271: Mechanics. 1281: Heat, electricity. 1291: Magnetism, optics.

1275-1285-1295. GENERAL PHYSICS LABORATORY. (1 cr per qtr; S-N only; prereq 1271-1281-1291 or ¶; 2 lab hrs per wk)
Laboratory exercises in general physics.

3011. OSCILLATIONS. (4 cr; prereq 1291, Math 3211 or equiv; 3 lect and 1 prob session per wk)
Physical and mathematical study of the harmonic oscillator. Transient behavior; resonance; impedance; mechanical and electrical examples; coupled systems; traveling and standing waves in one dimension; Fourier series.

3012. WAVES AND OPTICS. (4 cr; prereq 3011; 3 lect and 1 prob session per wk)
Waves in two and three dimensions. Geometrical optics, physical optics. Standing waves; interference; diffraction; polarization; radiation. Examples emphasizing electromagnetic radiation.

3015. LABORATORY IN OSCILLATIONS AND WAVES. (1 cr; prereq 3011, 3012 or ¶3012; 3 lab hrs per wk)
Laboratory exercises in oscillations and waves.

3501. MODERN PHYSICS. (4 cr, §3511-3512-3513; prereq 1291 or 1106; 3 lect and 1 prob hr per wk)
Descriptive courses in modern physics; quantum mechanics, hydrogen atom, multielectron atoms, molecular structure, quantum statistics, thermal radiation, solid state physics, nuclear physics.

3505. PHYSICS LABORATORY. (1 cr; prereq 3501 or ¶; 2 lab hrs per wk)
Laboratory experiments in modern physics.

3511-3512-3513. MODERN PHYSICS. (4 cr per qtr; prereq 1291 or 1106, Math 1231 for 3511...Math 3221 or 3066 or equiv for 3512; 3 lect and 1 prob session per wk)
Introductory course in special relativity, quantum mechanics, atomic, molecular, solid state, and nuclear physics. Emphasis on experimental phenomena.

3515. PHYSICS LABORATORY. (1 cr; prereq 3513 or ¶; 3 lab hrs per wk)
Laboratory experiments in atomic, solid state, and nuclear physics.

3801. INTRODUCTION TO THE PHYSICS OF PHOTOGRAPHY. (5 cr; prereq high school algebra, some photographic experience; 3 lect, 1 discussion, and 2 lab hrs per wk)
Principles of optics and electricity applied to photographic processes. Image formation; intensity, color of illumination; exposure of photographic materials. Understanding technical literature as applied to pictorial photography (or tone reproduction); line reproduction and duplication.

3970. DIRECTED STUDIES. (1-5 cr; prereq ‡, △)
Independent, directed study in physics in areas arranged by the student and a faculty member.

5011-5012-5013.* MECHANICS, ELECTRICITY, AND MAGNETISM. (4 cr per qtr, §5021-5022, §5023-5024; prereq 1291, Math 3211, 3221 or equiv; 4 lect hrs per wk)
Theoretical mechanics and electricity and magnetism.

5021-5022.* INTRODUCTION TO ANALYTIC MECHANICS. (4 cr per qtr, §5011-5012-5013; prereq 3011, Math 3231 or equiv; 3 lect and 1 prob hr per wk)
Analytic course in Newtonian mechanics. Vectors and vector operators; angular momentum; central force problem; system of particles; tensors; rigid bodies; moving coordinate systems; continuous media; Lagrange's equations. Mathematics beyond the prerequisites developed as required.

5023-5024.* INTRODUCTION TO ELECTRIC AND MAGNETIC FIELDS. (4 cr per qtr, §5011-5012-5013; prereq 3011, Math 3231 or equiv; 3 lect and 1 prob hr per wk)
Classical theory of electric and magnetic fields making free use of vector algebra and vector calculus. Maxwell's equations for free space and material media. Wave solutions.

5025.* SPECIAL TOPICS IN ELECTRIC AND MAGNETIC FIELDS. (4 cr; prereq 5013 or 5024; 3 lect and 1 prob hr per wk)
Special topics selected by instructor.

5031-5032-5033.* TOPICS IN MATHEMATICAL PHYSICS. (4 cr per qtr; prereq two 5xxx-level math courses; 3 lect and 2 prob hrs per wk)
Mathematical techniques needed for physics. Application of mathematical methods to physical problems.

5051-5052-5053.* CLASSICAL PHYSICS. (4 cr per qtr; prereq 5013 or both 5022 and 5024, advanced calculus or ‡; 3 lect and 1 prob hr per wk)
Classical mechanics, special relativity, and classical electrodynamics. Applications of advanced mathematical techniques.

5090. PHYSICS OF MUSICAL INSTRUMENTS. (3 cr [no cr for physics grad students], §MuEd 5750; prereq ‡)
Seminar on physical characteristics of and processes in playing musical instruments. Nonmathematical; to improve performance and teaching skills. Electronic methods to sense and display cues to assist performance and teaching.

5091. PHYSICAL ACOUSTICS OF MUSIC. (5 cr [no cr for physics grad students]; prereq 1 yr high school algebra and upper division or grad standing in music or music education, or equiv background in music theory and practice as certified by inst; 3 lect, 1 discussion, and 3 lab hrs per wk)
Principles of physics and acoustics as they relate to musical sounds, musical instruments, and the electronic production and reproduction of musical sounds. Laboratory.

5101-5102.* INTRODUCTION TO QUANTUM MECHANICS. (4 cr per qtr; prereq 3512; 3 lect and 1 prob hr per wk)
Mathematical techniques of quantum mechanics. Wave packets; Schrodinger equation, angular momentum; radial equation; spin; perturbation theory; collision theory.

5120.* EXPERIMENTAL PHYSICS. (4 cr [may be repeated for cr]; prereq 3513, △; 6 lab hrs per wk)
Techniques and methods used in physics research laboratories. Experiments in high vacuum, mass spectroscopy, solid state, atomic, and nuclear physics.

5151-5152-5153.* QUANTUM MECHANICS. (4 cr per qtr; prereq 5102 or equiv, advanced calculus or ‡; 3 lect and 1 prob hr per wk)
Development from first principles. Schrodinger equation, angular momentum, scattering, matrix representations, spin, approximation methods, interaction with the electromagnetic field, identical particles, applications to atomic systems.

5162.* INTRODUCTION TO PLASMA PHYSICS. (4 cr; prereq 5011-5012-5013 or 5022 and 5024 or ‡)
Magnetohydrodynamics and properties of collisionless plasmas, applications to magnetic field of earth and sun and to plasma confinement. Transport phenomena and effects of collisions.

5201-5202.* THEMODYNAMICS, STATISTICAL MECHANICS. (4 cr per qtr; prereq 3501 or 3511, Math 3211 or 3411 or equiv; 3 lect and 1 prob hr per wk)
Basic laws of thermodynamics. Temperature, energy, and entropy; applications. Transport phenomena; principles of statistical mechanics.

5203.* INTRODUCTION TO SOLID STATE PHYSICS. (4 cr; prereq 5202 or ‡; 3 lect and 1 prob hr per wk)
Structure; thermal, magnetic, dielectric, and electronic properties of crystalline solids.

5231-5232-5233.* INTRODUCTION TO SOLID STATE PHYSICS. (4 cr per qtr; for grad and advanced undergrad students in physics, science, and engineering; 4 lect hrs per wk)

5231: Crystal structure and binding; diffraction; phonons; thermal and dielectric properties of insulators. 5232: Free-electron model; band structure; semiconductors; diamagnetism; paramagnetism; ferromagnetism and antiferromagnetism. 5233: Optical phenomena, lasers; superconductivity; surface properties; ferroelectricity.

5301.* INTRODUCTION TO NUCLEAR PHYSICS. (4 cr; prereq 5102 or equiv; 3 lect and 1 prob hr per wk)
Static properties and dynamic processes of atomic nuclei. Provides survey for nonspecialists; a first course for those intending to specialize in nuclear physics.

5351.* EXPERIMENTAL PARTICLE PHYSICS. (4 cr; prereq 3513; 3 lect hrs per wk and field trips)
Interactions of particles and photons with matter and radiation. Detectors for particles and photons used in elementary particle, nuclear, and cosmic ray physics.

5371.* INTRODUCTION TO ELEMENTARY PARTICLE PHYSICS. (4 cr; prereq 5102 or #)
Relativistic kinematics; mass, spin, isospin, and strangeness of elementary particles; SU3 classification; particle reactions and decays; experimental methods of detection and analysis.

5401.* INTRODUCTION TO CONTEMPORARY PROBLEMS IN COSMIC RAY AND SPACE PHYSICS. (4 cr; primarily for students specializing in other branches of physics; prereq #; offered alt yrs)
Cosmic rays; characteristics, motion in interplanetary and interstellar medium. X-rays and radio astronomy.

5441.* INTRODUCTORY DYNAMIC METEROLOGY I. (5 cr; prereq 1291 and Math 3231 or 5602 or #; 3 lect and 3 lab hrs per wk)
Fluid dynamics of large-scale weather systems; mathematical introduction to quasi-geostrophic model used in numerical weather prediction. Concurrent laboratory study of weather charts to illustrate application of theory offered.

5442.* INTRODUCTORY DYNAMIC METEOROLOGY II. (4 cr; prereq 5441 or #)
Energetics and general circulation of the atmosphere.

5451.* CLOUD PHYSICS. (3 cr; prereq Math 3211 or equiv, 1 yr general physics; 3 lect hrs per wk)
Composition of the atmosphere, past, present, and future. Thermodynamics of atmosphere with condensable water. Properties and growth of drops and ice crystals. Particles in the atmosphere.

5452.* CLOUD SYSTEMS. (3 cr; prereq Math 3211 or equiv, 1 yr general physics; 3 lect hrs per wk)
Circulation, energy balance of atmosphere. Radar techniques for analyzing cloud systems. Cloud structure and motion.

5453.* ELECTRICAL PROPERTIES OF CLOUDS. (3 cr; prereq Math 3211 or equiv, 1 yr general physics; 3 lect hrs per wk)
Structural, thermodynamic, and electrical properties of water and ice. Ions in the atmosphere. Generation of charge and its effects on cloud processes. Generation of lightning and properties of lightning discharges.

5551. TOPICS IN PHYSICS FOR BIOLOGY AND MEDICINE: MECHANICS AND MOLECULAR PHYSICS. (5 cr per qtr; prereq general physics and calculus)
Statics (forces in bones and joints). Graphical analysis. Statistical physics (entropy, reversibility, Boltzmann factor and Nernst equation, Brownian movement, free energy). Diffusion, bulk flow and osmosis.

5552. TOPICS IN PHYSICS FOR BIOLOGY AND MEDICINE: ELECTRICITY AND SIGNALS. (5 cr per qtr; prereq general physics and calculus)
Electricity and circuits (electrocardiogram, networks, nerve conduction); transducers and amplifiers; feedback and control; oscillators; signal analysis (Fourier analysis, correlation functions, power spectra).

5553. TOPICS IN PHYSICS FOR BIOLOGY AND MEDICINE: LIGHT, ATOMS, AND NUCLEI. (5 cr per qtr; prereq 5552 or familiarity with oscillators and signal analysis)
Optics (lenses and instruments; diffraction and resolution; polarized light). Atoms (dispersion, absorption, line spectra, molecular spectra, X-rays, nuclear radiation). Nuclei (nuclear size, mass, decay).

5804.* OPTICS LABORATORY. (4 cr; prereq 3012 or 5805 or #; two 3-hr labs per wk)
Optics experiments: modern optics, properties of lasers, spatial filters, light modulation, microwaves, Kerr cell, holography, Faraday effect, Zeeman effect, optical pumping, etc.

5805.* CONTEMPORARY OPTICS. (4 cr; prereq 3012 or #; 3 lect and 1 prob hr per wk)
Theory of lasers and their applications in holography, nonlinear optics, etc. Nonlinear optics. Optics of anisotropic media. Theory of image formation and spatial filtering. Properties of optical detectors.

5851.* ELECTRONIC MEASUREMENT. (5 cr; prereq 3011 or ♯; 3 lect and 3 lab hrs per wk)
Electronic measurement of physical properties. Energy and measurement; noise and bandwidth; processing of repetitive and random signals.

5852.* ELECTRONIC CONTROL. (5 cr; prereq 3011 or ♯; 3 lect and 3 lab hrs per wk)
Digital and analog control: digital logic; pneumatic, electromechanical, and semiconductor systems; *feedback; servosystems; mixed systems.*

5853.* ELECTRONIC COMPONENTS. (5 cr; prereq 3011 or ♯; 3 lect and 3 lab hrs per wk)
Electronic components, electrical behavior, and use in circuit design.

5923.* HISTORY OF 16TH- THROUGH 18TH-CENTURY PHYSICS. (4 cr; prereq general physics or ♯)
Internal conceptual developments in physics and astronomy from Scientific Revolution (Copernicus, Gilbert, Galileo, Bacon, Newton, Huygens, etc.) to end of the 18th century (Euler, Franklin, Coulomb, Laplace, etc.). Relationships of these developments to social, philosophical, and theological influences.

5924.* HISTORY OF 19TH-CENTURY PHYSICS. (4 cr; prereq general physics or ♯)
Internal conceptual developments in physics in 19th century (Young, Fresnel, Oersted, Ampere, Faraday, MacCullagh, Maxwell, Hertz, Lorentz, Lavoisier, Rumford, Dalton, Mayer, Joule, Helmholtz, Carnot, Clausius, Kelvin, Boltzmann, Mach, etc.). Relationships of these developments to social, philosophical, and theological influences.

5925.* HISTORY OF 20TH-CENTURY PHYSICS. (4 cr; prereq general physics or ♯)
Internal conceptual developments in relativity (Michelson, Lorentz, Poincare, Einstein, etc.), quantum mechanics (Planck, Einstein, Rutherford, Bohr, Sommerfeld, Ehrenfest, Pauli, Millikan, Compton, Heisenberg, de Broglie, Schrodinger, Born, etc.), and nuclear physics (Chadwick, Gamow, Fermi, etc.). Relationships of these developments to social, philosophical, and theological influences.

5950. SENIOR SEMINAR. (Cr ar; primarily for sr physics majors, △)

5990. *DIRECTED RESEARCH: ELEMENTARY PHYSICAL INVESTIGATION.* (Cr ar; prereq 3rd yr, △)
Problems, experimental or theoretical, of special interest to students. Written reports.

FOR GRADUATE STUDENTS ONLY

8000.* SEMINAR: THEORETICAL PHYSICS

8081-8082.* GENERAL RELATIVITY

8121.* ADVANCED QUANTUM MECHANICS

8122.* RELATIVISTIC QUANTUM MECHANICS

8123.* RELATIVISTIC QUANTUM FIELD THEORY

8131.* SYMMETRY AND ITS APPLICATIONS TO PHYSICAL PROBLEMS

8161.* ATOMIC AND MOLECULAR STRUCTURE

8163-8164.* PLASMA PHYSICS

8165.* ADVANCED TOPICS IN PLASMA PHYSICS

8200.* SEMINAR: SOLID-STATE AND LOW-TEMPERATURE PHYSICS

8211.* EQUILIBRIUM STATISTICAL MECHANICS

8212.* TRANSPORT THEORY

8216.* MANY-BODY THEORY

8221-8222-8223.* SOLID-STATE PHYSICS

8232.* MAGNETISM

8233.* *SUPERCONDUCTIVITY*

8234.* TECHNIQUES OF LOW-TEMPERATURE PHYSICS

8235.* LIQUID AND SOLID HELIUM

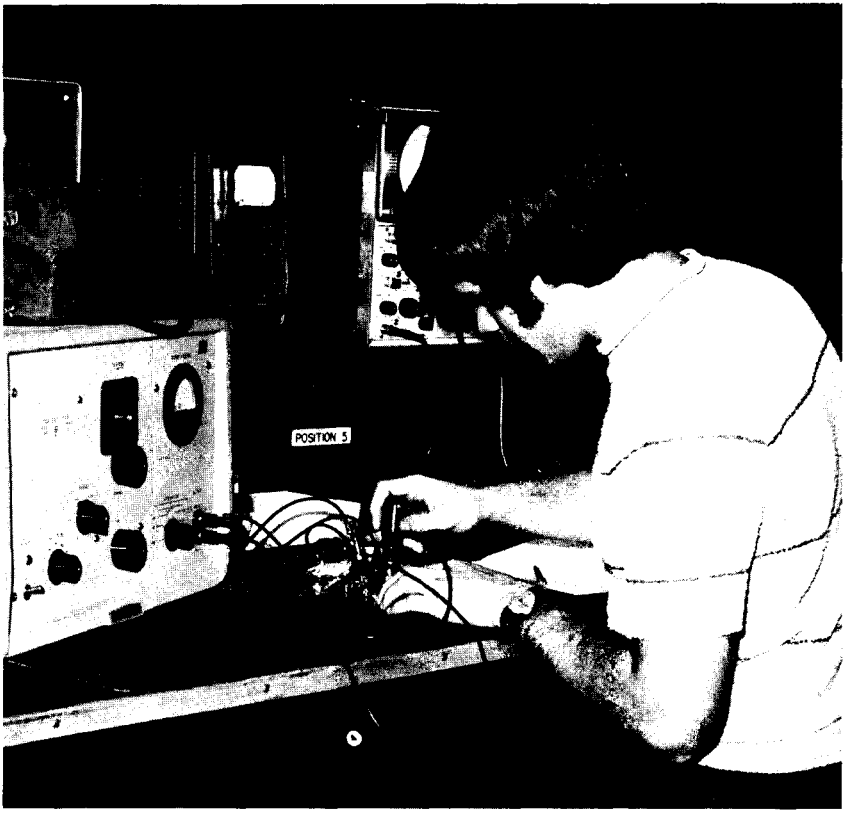
8236.* MAGNETIC RESONANCE IN SOLIDS

8238.* ADVANCED TOPICS IN SOLID-STATE AND LOW-TEMPERATURE PHYSICS

8300.* SEMINAR: NUCLEAR PHYSICS

8311-8312-8313.* NUCLEAR PHYSICS

8321.* ADVANCED TOPICS IN NUCLEAR PHYSICS
8360.* SEMINAR: MASS SPECTROSCOPY
8370.* SEMINAR: ELEMENTARY PARTICLE PHYSICS
8372-8373.* ELEMENTARY PARTICLE PHYSICS
8380.* ADVANCED TOPICS IN ELEMENTARY PARTICLE PHYSICS
8400.* SEMINAR: COSMIC-RAY AND SPACE PHYSICS
8411-8412.* COSMIC-RAY AND SPACE PHYSICS
8421-8422.* MAGNETOSPHERIC PHYSICS
8440.* SEMINAR: ATMOSPHERIC PHYSICS
8445.* ADVANCED TOPICS IN ATMOSPHERIC PHYSICS
8481-8482-8483.* ASTROPHYSICS
8484.* ORIGIN AND EVOLUTION OF THE SOLAR SYSTEM
8500. PLAN B PROJECT
8900.* SEMINAR: HISTORY OF 20TH-CENTURY PHYSICS
8950.* SEMINAR: PROBLEMS OF PHYSICS TEACHING AND HIGHER EDUCATION
8990.* RESEARCH IN PHYSICS



V. FACULTY—INSTITUTE OF TECHNOLOGY

In the faculty listing which follows, P.E. designates registration as a professional engineer and P.A. designates registration as a professional architect.

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Theodore A. Wilson

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Eugene Stolarik

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R. Vance Morey
Charles A. Onstad
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Earl A. Peterson
Alan Shapiro
John Warner

Instructor

Richard DeGeer
Keith Nier

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Office of the Assistant Dean, 105 Main Engineering Building

Aerospace Engineering and Mechanics, 107 Aeronautical Engineering Building

Architecture and Landscape Architecture, 110 Architecture Building

Chemical Engineering and Materials Science, 151 Chemical Engineering Building

Chemistry, 139 Smith Hall

Civil and Mineral Engineering, 112 Mineral and Metallurgical Engineering Building

Computer, Information, and Control Sciences, 114 Main Engineering Building

Electrical Engineering, 139 Electrical Engineering Building

Geology and Geophysics (Earth Sciences), 106 Pillsbury Hall

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Cover Photo: Ouroboros South, located at the University Research Station in Rosemount, is a working experiment in energy conservation and waste recycling; from conception to construction. the project exemplifies responsible environmental design. The School of Architecture and Landscape Architecture, recognizing that architecture and urban planning directly influence energy use, sponsors Project Ouroboros, named after the mythical dragon that survived by consuming its tail. The project is an active learning experience for architecture and mechanical engineering students, and a concrete example of alternative architecture and life-style for the general public.