University of Minnesota Bulletin

1981-83

UNIVERSITY OF MINNESOTA

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Institute of Technology

UNIVERSITY OF MINNESOTA

DIRECTORY OF DEPARTMENTAL OFFICES

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How to Use This Bulletin

This bulletin describes Institute of Technology programs, learning opportunities, procedures, degree and other requirements, and courses.

The *Class Schedule*, distributed with registration materials just before the registration period each quarter, lists course offerings with prerequisites, class hours, rooms, and instructors. Its opening and closing pages include registration instructions, final exam schedules, and other useful information.

All current and prospective students should also refer to the *General Information Bulletin.* Information about evening courses and summer school offerings is contained in the *Extension Classes Bulletin* and the *Summer Session Bulletin*, respectively.

Official Daily Bulletin—This column, published in the *Minnesota Daily* and posted on bulletin boards around campus, announces University courses, study opportunities, meetings, and activities. Students are expected to be aware of any information printed in the column that affects them.

CONTENTS

Institute of Technology students are responsible for all information contained in this bulletin that is pertinent to undergraduate study and to their particular field of study.

To New IT Students . . .

The Institute of Technology offers programs of study in the physical sciences and technology. It includes the Departments of Aerospace Engineering and Mechanics, Agricultural Engineering, Architecture and Landscape Architecture, Chemical Engineering and Materials Science, Chemistry, Civil and Mineral Engineering, Computer Science, Electrical Engineering, Geology and Geophysics (Earth Sciences), Mathematics, Mechanical Engineering, and Physics and Astronomy.

The 350 members of the IT faculty are energetic and dedicated to both education and the development of new knowledge. I hope that each of you will seek out and get to know members of the institute's faculty. You will find that they are leaders in their professional fields and concerned with the welfare of students. While I recognize that, under the pressure of studying and attending classes, you may feel that faculty members are somehow remote, I assure you that they are not. Any apparent barrier is easily overcome by taking the initiative to meet faculty members and talk to them about your goals or needs.

We hope that your studies of science and technology in IT will be rewarding. Our programs are designed to prepare you to contribute to society. Understanding science and technology can provide you with access to an all-powerful "genie." Implicit in the development of the genie is competence in a specialized area of study, and we encourage all students to work to their maximum abilities to develop a high level of competence in their chosen fields. Such achievement can provide you with the resources to advance the quality of society.

Because any social or organic system must work in harmony, we encourage students to seek experiences with other students and faculty members, as well as exposure to studies in other colleges. We hope that our students will acquire an appreciation for a balanced view of society. We are concerned, then, not only about the development of the genie but also with the humanity of the people who control the genie.

As science and technology provide instruments to improve society, they free it progressively from its servitudes and provide more opportunity for personal development. Through their studies, IT students can acquire the tools to contribute to these goals.

I hope that each of you will be enriched by your classroom experiences and your contacts with our outstanding faculty. We look forward to helping you in your quest for development.

Roger W. Staehle, dean

Institute of Technology

I. GENERAL INFORMATION

Degrees Offered

The Institute of Technology awards both undergraduate and graduate degrees.

Undergraduate Degrees—Bachelor's degrees are offered in architecture and landscape architecture, various branches of science, and major engineering fields. The specific degrees offered are:

Bachelor of Architecture
Bachelor of Environmental Design
Bachelor of Landscape Architecture
Bachelor of Science in Astrophysics
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 Statistics
Bachelor of Aerospace Engineering and Mechanics[1]
Bachelor of Agricultural Engineering
Bachelor of Chemical Engineering[1]
Bachelor of Civil Engineering[1]
Bachelor of Electrical Engineering[1]
Bachelor of Geo-Engineering[1]
Bachelor of Mechanical Engineering[1]
Bachelor of Metallurgical Engineering[1]
Bachelor of Mineral Engineering[1]

Graduate Degrees—IT and the Graduate School jointly offer a program leading to the master of engineering (M.E.) degree in any of the engineering disciplines. 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 very 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, which requires one calendar year to complete, 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 business, economics, statistics, geography, or political science. In addition, students complete a design project that requires the equivalent of four or five months of work under faculty supervision and often with the assistance of a working engineer.

Applicants are evaluated according to the following criteria:

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

[1] Program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology.

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

—Undergraduate grade point average; a GPA of 2.50 or better is required, and greatest consideration is given to upper division work.

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

Each IT department also offers M.S. and Ph.D. degree programs in a number of areas within its discipline. For detailed information about the various graduate programs, consult the *Graduate School Bulletin.*

Special Programs

Interdisciplinary Programs—Any IT student may plan an interdisciplinary program tailored to his or her specific interests. Although a degree is conferred by a single department, students may combine course work from several departments. A few examples of such programs are presented below:

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

Bioengineering—Study in biology, physiology, and chemistry as well as related engineering courses and project work provide background for this field.

Business Minor—Qualified students, after having earned the bachelor's degree in engineering and having completed electives in such areas as accounting, economics, and management, 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 engineering, chemical engineering, and physics.

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

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

Engineering Internships—Applied engineering training in selected industries is available during quarters of work experience that alternate with quarters of University studies. Students are registered and considered to be in full-time attendance during the work periods. Internships are usually designated for the last two years of study. Application for an internship program must be made before January 1 of the sophomore year. Students should contact their 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, at 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 1104-1105-1106-1107-1108-1109, or 1271-1275-1281-1285-1291-1295 (15 cr)

At least 27 cr, evaluated on A-N grading, in humanities, social science, foreign language, or other liberal arts areas (literature and humanities recommended)

Students considering careers in medical research or academic medicine should complete additional 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. P. Blackshear, Jr. (313 Mechanical Engineering): Mechanical Engineering

Prof. E. L. Cussler (216 Mines and Metallurgy): Chemical Engineering

Prof. R. Hobbie (233 Physics): Computer Science, Geology, Geophysics, Mathematics, Physics

Prof. J. Holte (258 Electrical Engineering): Electrical Engineering

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

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

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

Project Technology Power—The Institute of Technology participates in the national effort to overcome the underrepresentation of blacks, American Indians, Mexican Americans, and Puerto Ricans in engineering and other technical professions. To this end, an organization within IT called Project Technology Power is active at both the precollege and college levels. Through Project Technology Power IT sponsors motivational programs for minority students in the eighth, ninth, tenth, and eleventh grades in schools in Minneapolis and St. Paul. IT students and faculty members are encouraged to participate in the programs. At the college level, Project Technology Power encourages minority students to attend IT and serves IT students by offering several freshman scholarships, regularly scheduled tutoring, and a summer employment referral service.

The Project Technology Power office is located in 23 Lind Hall (373-2673).

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 two- and four-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 four 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, telephone (612) 373-2212; Naval Science, room 203, telephone (612) 373-2230; and Aerospace Studies, room 3, telephone (612) 373-2205.

Computer Facilities

Digital computers have become common working tools for most people in the areas of science and technology. In recognition of this fact, the Institute of Technology, in cooperation with University Computer Services, 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 a program and data, which are transmitted to a general purpose batch computer. After the program has been run, the output is returned and printed on a line printer at the laboratory where the job was submitted. Facilities in both types of laboratories are available to IT students at any time during the working day, and during evening and weekend hours when demand warrants. The facilities of 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 science 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 that may be entered at different levels is offered by the Department of Computer Science for students in the freshman year, both for those with an elementary background and those who have no prior training. These courses are designed to teach the student a more sophisticated level of programming, using both the interactive and batch systems, and to introduce other languages such as FORTRAN, PASCAL, Assembly Language, and SNOBOL. Thus all students should be 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.

The University Computer Center (UCC) has a variety of advanced computing equipment available to students. The primary batch processing equipment consists of a CDC Cyber 74/172 system with approximately 400,000 60-bit words of core storage. Interactive computing is available by means of a time-shared CDC 6400. Both systems are accessible through remote terminals.

A laboratory operated by the UCC is engaged in microprogramming experimentation, microcomputer system development, and image processing. The laboratory contains a PDP-11/40 with a writable control store, several Terak microcomputer systems that have PASCAL, FORTRAN, and BASIC processors, and Dicomed high-resolution digitizers and film recorders. The laboratory is staffed by graduate and undergraduate students, and the equipment is available for use by students.

In addition, the Department of Computer Science operates its own computer systems laboratory for instruction and research activities. The facilities available in this laboratory include PDP-11/60 and 11/40 systems (using the UNIX operating system), an Imlac interactive graphics system, and eight Terak microcomputers. There is also a VAX computer system on order. Another laboratory operated jointly by the UCC and the department is engaged in microprogramming experimentation, microcomputer systems development, and image processing. These facilities are all available to graduate students in computer science. Finally, substantial facilities associated with the recently formed Center for Microelectronic and Information Sciences are also available for use by students and faculty members. These facilities include CAD systems, chip production equipment, and analysis equipment.

The use of computers of all sizes and types is expanding so rapidly that it is difficult to predict all applications even a few years ahead. A major objective of IT is to ensure that all of

its graduates have experience with different computers during their undergraduate education so they will be thoroughly familiar with their use on the job.

Admission Information

Advising—Any student who wants to discuss her or his individual admission situation can arrange an interview through the Office of Student Affairs, 105 Lind Hall. Students should bring transcripts of high school and college work, test results, and any other pertinent information to the interview.

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 will be required beginning fall quarter 1982; they are now highly recommended.

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

Admission Without a Designated Major—Students undecided about a specific major in engineering or science should indicate "IT unclassified" on the application for admission. They are assigned a faculty adviser in the central advising office, 104 Lind Hall. Students may remain in this category for three quarters. Permission to continue for a fourth quarter must be requested by petition.

During the period in which students remain unclassified they are encouraged to take advantage of the many special programs that provide information about career opportunities in the various fields in IT. These programs are designed to help students choose a major.

IT unclassified students follow the same first-year academic program as that followed by IT students with a declared major. (A listing of the requirements common to all IT basic lower division curricula is found in section III of this bulletin.)

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

There are some restrictions on the acceptance of transfer credits by IT. Credits for a sequential technical course in which a student has earned a grade of D will be accepted for transfer only if the student earns a higher grade in the next course in the sequence. Credits for courses transferred from the General College are accepted only by petition; accepted credits may be applied to graduation requirements, but will not be used in the computation of the grade point average or of honor points.

Transfer students should apply and submit transcripts to the Office of Admissions 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 course work, as well as any previous course work at the University of Minnesota.

Admission as an Adult Special Student—Persons interested in completing individual courses or groups of courses to meet their own needs, rather than in pursuing degree programs, may be admitted as adult special students to individual IT departments. Applicants are usually required to have a bachelor's degree. Although adult special students are not considered degree candidates, they may subsequently begin degree work when recommended by the departments in which they have studied. In such cases, credit earned as an adult special student is accepted as degree credit when appropriate.

Students seeking adult special admission should apply and submit transcripts of all college work to the Office of Admissions well in advance of the quarter they wish to begin. Restrictions on admission of nonresident undergraduate students apply also to adult special students.

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. Those interested in beginning their studies in the fall quarter apply during the preceding winter or spring. A student admitted under this plan normally does not receive a high school diploma.

For More Information—Admission criteria and information about University-wide application procedures are detailed in the *General Information Bulletin.* Students should consult that bulletin in their school's counseling office, or they may request their own copy in person from the information booth in Williamson Hall or by phone or mail from the Office of Registration and Student Records, 110 Williamson Hall, 231 Pillsbury Drive S.E., University of Minnesota, Minneapolis, Minnesota 55455 (telephone 373-2153).

Financial Aids

The University offers three general types of financial aid to undergraduates: scholarships and grants, student loans, and college work-study. A student employment service to help students find jobs is also available. The financial aid programs are fully described in the *General Information Bulletin.* Students should consult this bulletin in their high school counseling office or the staff in the Office of Student Financial Aid, 210 Fraser Hall.

Various IT research facilities offer part-time research and other 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. Some are open to all IT students, and some are open to students in specific IT departments. Unless otherwise noted, one award is made each year. Students should read the Official Daily Bulletin column the first week of winter quarter each year for application information; this column is published in the *Minnesota Daily* and posted on bulletin boards around campus. Applications received by March 1 are given priority consideration.

Awards and Scholarships

ALL-COLLEGE

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

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

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

Harlow C. Richardson Scholarship: For undergraduates in the Institute of Technology who have demonstrated interest in the humanities. 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, electrical, metallurgical, and industrial engineering. A scholarship awarded to a freshman may be renewable for three additional years.

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

Twin Lakes Auxiliary of the M.S.P.E. Scholarship Fund: An initial gift of $150 from the Twin Lakes Auxiliary of the Minnesota Society of Professional Engineers established a scholarship fund to provide assistance to a promising engineering student, with preference given to women.

DEPARTMENTAL

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: For 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 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 by the College of Agriculture Scholarship Committee.

Architecture

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

Architectural Alliance Education Fund

Leon Arnal Fund

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 educational programs and scholarship aid for architecture students. Amount varies.

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

Minnesota Society of Architects Scholarship Fund: For educational programs and scholarship aid for architecture students. Amount varies.

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 have financial need. Amount varies.

Ralph Rapson F.A.I.A. and Associates 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 of Architecture and Landscape Architecture. Amount varies.

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

Chemical Engineering and Materials Science

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

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.

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

Pillsbury Scholarship: For 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: For 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, chemistry, 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

Bonestroo, Rosene, Anderlik and Associates Scholarships: For undergraduates in civil engineering. Awarded on the basis of academic ability, professional promise, and financial need.

Minnesota Public Works Association Scholarship: For undergraduates in civil engineering. Awarded on the basis of professional promise, interest in municipal engineering, and financial need.

Minnesota Surveyors and Engineers Society Transportation Scholarships: For undergraduates in civil engineering. Awarded on the basis of interest in transportation engineering, professional promise, and financial need. Students may apply to Personnel Office, Minnesota Department of Transportation, for summer employment.

Adolph A. Sommerfeld Scholarship Fund in Civil Engineering: For undergraduate and graduate students in civil engineering. Awarded on the basis of academic ability and financial need.

Electrical Engineering

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

Geology and Geophysics

American Metal Climax Foundation Fund: For fieldwork.

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

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

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

Standard Oil Company of California and Chevron Companies: To assist undergraduate seniors with educational expenses.

Mechanical Engineering

American Institute of Industrial Engineers, Twin Cities Chapter, Scholastic Award: For a sophomore or junior mechanical engineering student who is pursuing an industrial engineering option and who is a member of the student chapter of A.I.I.E. Contact the department for details.

Pillsbury Company Scholarships: See description under Electrical Engineering scholarships.

Rosemount Engineering Company Instrumentation Award: For a graduate or undergraduate student in mechanical engineering judged by the department to have made a meaningful contribution in the design and development of instrumentation at the University of Minnesota.

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 Twin Cities or Duluth campuses, or the Michigan College of Technology, Houghton, Michigan. Preference is given to those enrolled in mineral technology (mineral and metallurgical engineering), but other students in IT may also be eligible. Amount is $750. Entering students apply through their high school by January 1 each year; University students follow regular procedure. Two awards each year, renewable if the student maintains at least a 3.00 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 Fund, 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 her or his major department. During fall quarter, students consult with their adviser to plan their schedule for the rest of the year. During spring quarter, students meet again with their adviser 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.

Professional Counselors—Counselors are available to discuss questions about career plans or any personal problems students may have. Counseling appointments are scheduled in 105 Lind Hall.

Undergraduate Teaching Assistants—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. These teaching assistants are selected from junior and senior IT honor students who are willing and able to work with students who need aid. Tutoring assistance is provided in various locations—on campus, in residence halls, and at selected metropolitan high schools.

Teaching assistants are available during scheduled office hours Monday through Friday in 3 Lind Hall. They hold regularly scheduled hours, usually from 7 p.m. to 10 p.m. Sunday through Thursday, in Centennial, Comstock, Frontier, Territorial, Middlebrook, Pioneer, Sanford, and Bailey Halls.

Teaching assistants staff several metropolitan high schools, including Edina South View Junior High, Minneapolis Washburn, Mounds View, Sandburg Junior High, St. Paul Johnson, and West St. Paul Henry Sibley. The schedule at 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 Science, Mathematics, and Physics. These teaching assistants offer help with course work taught by the department with which they are associated and are available during scheduled hours, usually 9 a.m. to 4 p.m.

Inquiries about tuorial programs should be made to the director of lower division programs, 104 Lind Hall.

IT Career Planning and Placement—The IT Career Planning and Placement Office, located in 15 Experimental Engineering, has personnel available to assist graduating seniors and advanced degree candidates with career choices and career development.

A wide variety of companies, representing local, state, and national organizations, visits the Career Planning and Placement Office each year. The office schedules interviews

and maintains a library with information about companies and government agencies that are prospective employers. Assistance is also available to undergraduate and graduate students seeking summer employment.

The office maintains a résumé file for alumni and publishes a monthly newsletter listing positions available for experienced personnel.

A course is taught each fall quarter for students needing assistance in career decision making. The course, I of T 1222, Introduction to Careers in Science and Engineering, one or two credits, is open to all students.

The Career Planning and Placement Office also coordinates and supplies information about and applications for the Engineer In Training (EIT) examinations.

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 conducting 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 Institute of Electrical and Electronic Engineers. Additional professional societies include the Minnesota Society of the American Institute of Architects, School of Mineral and Metallurgical Engineering Society, University of Minnesota Flying Club, Geology Club, and 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 on the basis of scholarship, as measured by class rank, and character, as judged by peers and faculty members. 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: Alpha Epsilon (Agricultural Engineering), Chi Epsilon (Civil Engineering), Eta Kappa Nu (Electrical Engineering), Phi Lambda Upsilon (Chemistry), Pi Tau Sigma (Mechanical Engineering), and 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) during spring quarter. 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 members.

IT Student Board—The IT Student Board is the executive body of the students in the Institute of Technology. The board represents the students 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 required before an individual 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 do so. Many engineers have obtained a license to show their support for the concept of a legal recognition of the professional standing of the engineer. Many also obtain a license 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 specified 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
336 North Robert Street
St. Paul, Minnesota 55101

Continuing Education

Scientists and engineers frequently find the need to enhance their professional competence in response to technological change and the proliferation of newly reported research data. Others who change their professional interests in midcareer find the need to acquire training in areas different from those of their undergraduate specializations. In addition to on-the-job experience, technical reading, and attending professional meetings, continuing education studies offered by the University of Minnesota can help individuals accomplish these goals.

Because of the growing interest in postgraduate course work, IT and Continuing Education and Extension created the Office of Continuing Education for Engineers and Scientists. This office surveys the needs of technical specialists and responds by arranging quarter-length courses, special conferences, and workshops.

The office also maintains an Engineers Information Registry, which lists the names of professionals and their companies, job classifications, and areas of interest. This registry, along with input from advisory committees, companies, and professional societies, is used to determine areas of interest shared by practicing engineers and scientists. It also aids in identifying locations outside the metropolitan area where courses could be offered for the convenience of those enrolled.

Professional Development Recognition Program (PDRP)—This program, offered jointly by the Institute of Technology and Continuing Education and Extension, offers a

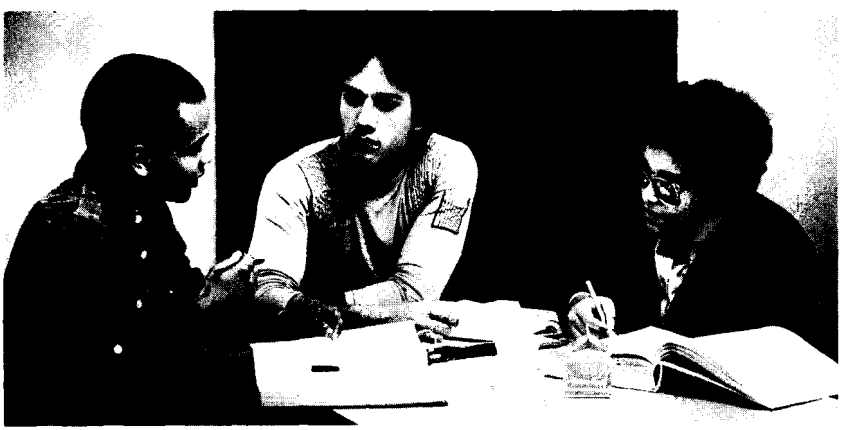
personalized, flexible plan for the continuing professional development of the degree holding engineer or scientist. Participants prepare a statement of their specific educational objectives and then meet with an IT faculty member to plan a program that will meet these goals.

The minimum number of credits required to complete a PDRP is 18. Up to 50 percent of this total may be satisfied through non-University work such as in-plant company programs and conferences and seminars offered by other recognized institutions.

With an average expenditure of 10 hours per week, a PDRP normally requires two calendar years to complete. Upon completion of the program requirements, participants receive a citation that states their self-chosen objectives and the steps taken to achieve them.

UNITE Instructional Television—Approximatey 20 courses each quarter are offered through UNITE (University-Industry Television for Education), an instructional television system for continuing education at the employee's worksite. These include both upper division and graduate courses as well as specially developed courses and seminars. Classes are held in specially equipped studio classrooms with on-campus students in attendance. The system is interactive, enabling students at all sites to talk with the instructor and to take part in class discussions. Participating companies help support the system through payment of a special fee based on the number of credits for which its employees are enrolled. This fee is separate from tuition, which is paid either by the student or the company, depending upon company policy. The growing list of organizations offering UNITE courses to their employees includes the Donaldson Company, FluiDyne, Honeywell, Inc., IBM Corporation, 3M Company, Northern States Power Company, Sperry Univac Defense Systems, Sperry Univac-Roseville, U.S. Bureau of Mines, and Physical Electronics, Inc.

Further information about continuing education opportunities for engineers and scientists may be obtained from the Director, Continuing Education for Engineers and Scientists, 320/322 Akerman Hall, 110 Union Street S.E., University of Minnesota, Minneapolis, Minnesota 55455; telephone (612) 373-3132.



Peer tutoring is one of the activities that Project Technology Power sponsors for IT minority students.

II. ACADEMIC POLICIES AND PROCEDURES

Grading

Grading System and Grade Point Average—The Institute of Technology uses the same grading and symbol system as the other collegiate units on the Twin Cities campus. Students should consult the *Class Schedule* for an explanation of the system.

Only credits taken on the A-N grading system are calculated in the grade point average. A 2.00 average or better is considered satisfactory work. Each letter grade carries the following grade points per credit: A = 4.00, B = 3.00, C = 2.00, and D = 1.00. The grade point average is determined by dividing the sum of the grade points earned by the sum of the credits completed.

The N grade is assigned when a student does not earn an S or a D or higher and is not assigned an I. It stands for no credit, carries no grade points, and is not used in calculating the grade point average.

S-N Grading—An IT student can elect the S-N grading option for any course offered on an S-N basis except those specifically designated by the student's major department to be taken on an A-N basis only. Each department has available a list of those courses or categories of courses that it restricts to A-N registration for its majors.

New students in the Institute of Technology may take only one course on S-N grading during their first quarter in residence (in addition to any course available only S-N).

An IT student may take no more than two courses per quarter or one course per summer term on S-N grading.

No more than 25 percent of the total University of Minnesota residence credits presented for graduation for a given curriculum may be taken S-N. This regulation does not apply to credits presented in excess of the minimum required.

Assuming that all other requirements and regulations are met, a student may change from A-N to S-N or from S-N to A-N through the second week of a quarter, but not thereafter. A change from or to S-N registration in a given course must be made on a cancel-add form.

S-N registration is indicated by inserting the number of course credits in the S-N column on the registration card.

Incompletes—The I grade is assigned when a student has completed all but a small portion of the work of a course and has made prior arrangements with the instructor to make up the work. An incomplete will become an N grade if not made up by the end of the next quarter in residence.

Withdrawals—The symbol W indicates official cancellation of a class without grade. IT students who withdraw from a course following the end of the second week of a quarter up through Study Day receive this symbol, regardless of their academic standing in the class at the time of cancellation. Cancellations processed during the first two weeks of a quarter do not appear on a student's record. A W received through the end of the sixth week of a quarter is *not* used in calculation of the honor point deficiency.

Auditing—The symbol V indicates that the student is a visitor in a course and is taking the course without credit. Courses audited may be taken for a grade and credit at a later time. A student may change from a credit/graded registration to an audit/nongraded registration up to the end of the sixth week of a quarter with the permission of the instructor. Students who audit courses pay regular tuition and fees.

Continuation Courses—The symbol X is reported in continuation courses in which a grade is not assigned until the entire sequence is completed. Upon completion of the sequence, a grade is submitted for each X on the academic transcript.

Transcripts—Student academic records are maintained on a computerized transcript system. For a description of the system, see the *General Information Bulletin.*

Academic Standards

Continuation in Sequences—IT students taking the following lower division sequence courses must earn a grade of at least C each quarter to continue in the sequence:

Chem 1004-1005, 3100-3101
Chem 1031-1032, 1133[1]
Chem 3301/3305, 3302/3306
Chem 3331, 3332/3335, 3333/3336
CSci 1100, 1101
EE 1510[2]
Geo 1001, 1002
Math 1201, 1211-1221-1231[3]
Math 1311-1321-1331[3]
Math 1611-1621[3]
Math 3211[3]
Math 3511, 3521, 3531
Math 3611, 3621
Phys 1121-1122
Phys 1271-1281-1291[4]
Phys 3511-3512-3513

Honor Points and Honor Point Deficiency—The Institute of Technology calculates honor points and an honor point deficiency (HPD), which are used to determine academic progress, as follows:

A = 2 per credit
B = 1 per credit
C = 0 per credit
S = 0 per credit
D = −1 per credit
N = −2 per credit
W (after sixth week) = −2 per credit

An I grade is not counted initially. If made up by the end of the next quarter in residence, the new grade will be counted on the basis of the above table. If not made up the I reverts to an N, and that grade carries a deficiency of 2 per credit.

Withdrawals after the end of the sixth week of a quarter are considered in the honor point deficiency calculation; the W is treated as an N in such cases.

Quarterly Honor Point Deficiency—A student will be placed on probation when the honor points earned for a given quarter fall in the negative range. If the honor point deficiency is 10 or more, the student may not again register in the Institute of Technology without the permission of the Scholastic Standards Committee of his or her major department.

[1]For continuation in the chemistry major sequence (Chem 3331) an IT student must have earned a C in Chem 1133.

[2]A C grade or better in EE 1510 is required for admission to EE 3010.

[3]In order to continue in additional mathematics courses (in particular Math 3211 or Math 3221) or sequences an IT student must earn at least a C grade in Math 1231 or Math 1331 or Math 1621. A student must earn at least a C grade in Math 3211 before taking Math 3231.

[4] For continuation in physics sequences, an IT student must earn at least a C grade in Phys 1291.

To obtain a decision on continuance, a student must complete an E-100 form (available in 105 Lind Hall) and must appear in person before the departmental Scholastic Standards Committee. The departmental committees normally meet only between quarters. This means a student with an HPD of 10 or more at the end of the fall quarter, for example, will be allowed to register for spring quarter classes only after his or her committee meets at the end of winter quarter and only if continuance is granted.

A student who is allowed to continue will normally be required to complete specified goals for the next quarter in residence, and these will be indicated on the E-100 form. If the goals are met, the student will be automatically continued at the end of the quarter. If the goals are not met, the student will be routinely dropped. A continued student will not be allowed to register for a future quarter unless his or her goals are met.

Cumulative Honor Point Deficiency—An IT student will not be allowed to again register in the Institute of Technology if her or his cumulative honor point deficiency is equal to or greater than 15, unless granted continuance by the departmental Scholastic Standards Committee. The cumulative calculation includes all work taken at the University of Minnesota beginning in fall quarter 1975. A student with an unsatisfactory cumulative HPD must appear before the Scholastic Standards Committee of his or her major department with an E-100 form. It is the responsibility of the committee to decide whether to continue or to drop the student.

Drop Status—A dropped student may not reenter day school classes or take IT evening classes through Continuing Education and Extension unless granted permission by the departmental Scholastic Standards Committee.

Repeating Courses—Students are allowed to repeat courses in which they received a grade of D, and only the last grade earned is then used in computing their grade point average and honor point deficiency.

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 Lind Hall.

Students who repeat a required course three times and do not earn a grade of C or higher will be subject to drop action by their departmental Scholastic Standards Committee.

ROTC Courses—Grades received in all ROTC courses will be entered on the student's transcript and will be counted in the grade point average and honor point deficiency calculations.

ROTC credits may be used to satisfy CLE requirements for those courses that have been certified as suitable for Group C (The Individual and Society) by the appropriate academic department of the University.

Changing Majors—To change majors within IT, students must petition requesting such a change. Forms are available in 105 Lind Hall. Petitions must be approved by the chair (or representative) of the department to which the student is transferring.

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 plan to enter.

Residency Requirement—A student earning a bachelor's degree must complete 45 credits after admission to IT, of which at least 30 credits must be completed in the senior year.

Dean's List—To qualify for the quarterly Dean's List, a student must complete a minimum of 12 credits with a grade point average of 3.50 or better. The credits may all be completed on A-N grading or on a combination of A-N and S-N grading.

Graduation—The bachelor's degree with professional designation will be recommended for students who earn a grade point average of 2.00 or better, who have no cumulative honor point deficiency, and who have completed all of the required work and the total number of credits specified for their curriculum. Students should file an Application for Degree at the Registration, Student Records, and Scheduling Office and pay the graduation fee approximately a year prior to graduation.

Graduation With Honors—Students with a grade point average of 3.50 or better in their undergraduate work are granted their degree "with distinction." Students with a grade point average of 3.80 or better in their undergraduate work are granted their degree "with high distinction."

Conduct and Discipline

The Institute of Technology assumes that all students enroll in its programs with a serious learning purpose, and expects them to be responsible individuals who demand of themselves high standards of honesty and personal conduct.

The Institute of Technology expects the highest standards of honesty and integrity in the academic performance of its students. Any attempt by a student to present work that she or he has not prepared, or to pass an examination by improper means, is regarded by the faculty as a serious offense, which may result in immediate expulsion of the student. Aiding and abetting a student in an act of dishonesty is also considered a serious offense.

IT reserves the right to dismiss at any time a student whom it deems undesirable for any reason. Unethical conduct, wherever it may occur, is considered sufficient grounds for dismissal. Unauthorized use of an instructor's or administrator's name on a University form or other paper is an example of conduct considered grounds for dismissal.

A student has the right to appeal any disciplinary action. Copies of the procedures for appeal are available in 105 Lind Hall upon request.

If a student's infraction involves both IT judicial proceedings and court proceedings, and if an IT decision might prejudice his or her court case, IT will hold its decision in abeyance until the court proceedings have been concluded.

Access to Student Educational Records

In accordance with regents' policy on access to student records, information about a student generally may not be released to a third party without the student's permission. The policy also permits students to review their educational records and to challenge the contents of those records.

Some student information—name, address, telephone number, dates of attendance, college and class, major, adviser, and degrees earned—is considered public or directory information. To prevent release of such information outside the University while in attendance at the University, a student must notify the records office on his or her campus.

Students are notified annually of their right to review their educational records. The regents' policy, including a directory of student records, is available for review at the information booth in Williamson Hall, Minneapolis campus, and at the records offices on other campuses of the University. Questions may be directed to the Office of the Coordinator of Student Support Services, 260E Williamson Hall, telephone (612) 373-2106.

III. CURRICULAR REQUIREMENTS

Changes—Academic requirements stated in this bulletin are subject to change at any time upon approval of the faculty. Notification of changes in requirements is distributed to students with their registration materials.

Liberal Education Requirements

Institute of Technology students, whatever their area of specialization, are expected to hold in common with all University students the search for a liberal education—one that enhances their powers of judgment and choice. A liberal education implies awareness of the intellectual instruments for acquiring and communicating knowledge, understanding of the ways in which engineers and scientists contribute to our knowledge of ourselves and our 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 by the All-University Council on Liberal Education (CLE). The IT minimum liberal education requirements, together with required courses in English, mathematics, and the physical sciences, exceed the basic all-University requirements of the Council on Liberal Education.

Liberal education course work should be planned to complement the student's subsequent professional studies. Students are encouraged to complete advanced level courses in some areas rather than a large number of unrelated beginning courses. Copies of recommended liberal education elective programs are available in departmental offices, and students are encouraged to consult these programs when choosing their electives.

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

1. Two courses (8 to 10 credits) of English composition or communication. If a student is exempt from freshman English, the 8 to 10 may be taken from Group A (excluding mathematics, computer science, and statistics), Group C, or Group D.
2. *Group C—The Individual and Society*
   Human experiences and behavior in social environments seen through modes of governance, societal structures and customs, patterns of interaction and communication, religious forces, philosophical and psychological concepts, and the perspectives of history. Requirement: three courses (12 to 15 credits).

   Afro 1015; 1021, 1022; 1025; 1036; 1441, 1442; 3001, 3002, 3003; 3011; 3013; 3061, 3062; 3072; 3075-3076†; 3081-3082†; 3091-3092†; 3098; 3099; 3340; 3401; 3455; 3501; 5001; 5002; 5072; 5101, 5102, 5103; 5401, 5402; 5551-5552; 5553

   Air 1201; 1202; 1203; 3302; 3303; 3401; 3402

   AmIn 1771; 3026; 3036; 3061; 3111; 3112; 3116; 3121; 3131; 3141; 3151; 3152; 3161; 3211; 3411; 3772; 3810; 5048; 5112; 5322; 5332; 5341; 5411; 5422; 5423

   AmSt All courses except 1920; 3920; 3970

   ANEJ 3117; 3501, 3502, 3505; 5501, 5502, 5505

   Anth All courses except 3592; 3960; 3970; 3980; 3991; 5161; 5331; 5392; 5413; 5910; 5920

   Arch 1001; 1002; 1003

   Chic 1105; 1106; 1107; 3112; 3113; 3114; 3116; 3118; 3211; 3212; 3221; 3324; 3330; 3335; 3345; 3615; 3617; 3711; 3712; 3991-3992-3993; 5711

   Chn 1032; 5463

   Clas 1001, 1002, 1003; 1004, 1005, 1006; 1011, 1022, 1033, 1041; 1042; 1055, 1066; 1012; 1019; 1042; 1043; 1061; 3007; 3008; 3041; 3042; 3051; 3070; 3071; 3072; 3073; 3145; 3219; 5004; 5005; 5006; 5007; 5008; 5013; 5014; 5017; 5018; 5020; 5061; 5070; 5071; 5072; 5073; 5073; 5085; 5086; 5089; 5110; 5145; 5794

   CJS All courses except 5001, 5002, 5003; 5103; 5106; 5113; 5114; 5121; 5150; 5201-5202; 5970; 5982

   CPsy All courses except 1970; 3330; 3980; 5310; 5970; 5990

   Econ All courses except 3105; 3951H-3952H; 3960; 3970; 5113; 5161-5162-5163; 5164-5165-5166; 5261-5262-5263; 5271-5272; 5431H; 5461-5462-5463; 5561-5562; 5631H; 5671-5672-5673; 5821H; 5861-5862-5863; 5970

   FoSt (SPAN) 3001-3002-3003 (may apply only 6 cr toward GrC)

Fren 3501; 3502; 3503; 3599; 3604
Geog All courses except 1425; 3311; 3431; 3451; 3511; 3531; 3551; 3950; 3970; 3990; 5011; 5423; 5445; 5502; 5512; 5521; 5522; 5531; 5701; 5900
Ger 3501; 3511; 3512; 3513; 5331; 5510; 5611
Grk 5794
Hebr 3131-3132
Hist All courses except 3020; 3150; 3607; 3608; 3813; 3827; 3828; 3868; 3961; 3970; 3990; 5011; 5012; 5100; 5617; 5764; 5764; 5765; 5766; 5772; 5773; 5784-5785; 5807; 5901, 5902, 5903; 5970
HSci 1711, 1712, 1713; 1811, 1812, 1813; 3201; 3202; 3203; 3711; 3712; 3713; 3825; 5111; 5242; 5825; 5924; 5925
Hum All courses except 1101; 3014; 3044; 3055; 3071; 3201, 3202; 3755; 3910; 3970; 3980; 5030; 5063; 5910
IntR All courses except 3091; 5831; 5901; 5902; 5903
Ital 3501; 3502; 3555; 5559; 5701-5702
Jour 1003; 1701; 3021; 3776; 5252; 5501; 5559; 5601; 5603; 5611; 5615; 5721; 5801; 5825
Jpn 1032
JwSt 1034; 3034; 3100; 3115; 3125; 3126; 3142; 3143; 3521; 5621
LAS 5101-5102†
Lat 5794
Lib 5101; 5221
Ling 1005
MidE 3005; 3036; 3511, 3512; 3525; 3541-3542-3543; 3545; 3551-3552; 3555; 5001; 5121; 5123; 5125; 5405; 5406; 5546
PA 3101, 3102; 3121; 3151; 5121; 5152; 5161, 5162; 5181; 5301; 5319; 5401; 5505; 5506; 5516; 5517; 5550; 5601-5062; 5691
Phil 1002; 1003; 1004; 1011; 1102; 1103; 1104; 1410; 3001, 3002, 3003, 3004; 3005; 3234; 3302; 3303; 3304; 3305; 3521; 3781; 5003; 5004; 5005; 5008; 5012; 5020; 5021; 5033; 5034; 5035; 5036; 5041; 5042; 5043; 5044; 5046; 5052; 5054; 5055; 5068; 5076; 5301; 5302; 5311; 5312; 5321; 5324; 5414; 5415; 5561, 5562; 5611; 5612; 5613; 5615; 5621; 5701; 5781
Pol All courses except 3085; 3109, 3110; 3810; 3970
Psy All courses except 3031; 3061; 3801; 3950; 3960; 3970; 3990; 5061; 5841; 5861; 5884; 5990
RelS All courses except 5960; 5970; 5980
Russ 3501, 3502, 3503; 5501
Scan 1504; 3501
Slav 1501; 3501, 3502, 3503
SoAS 1506; 3411; 3501, 3502; 3506; 3507; 3511; 5411; 5491; 5508; 5510; 5530; 5531-5532; 5533
Soc All courses except 1010; 1960; 3801; 3802; 3803; 3811; 3960; 3970; 3980; 3990; 3991; 3997; 3998; 5561; 5801; 5960; 5970
SPAN (see FoSt)
Spch 3211; 3401; 3402; 3431; 3625; 5211; 5222; 5231; 5232; 5233; 5402; 5403; 5405; 5421; 5422; 5431; 5441; 5451; 5602
SSci 3101; 3251, 3252; 3402
SW All courses except 3004; 3031-3032-3033; 3989; 3990; 5010
UrbS 3101, 3102, 3103; 3104
WoSt 1005, 1006; 1977; 3005; 3300; 5101; 5301; 5311

3. *Group D—Literary and Artistic Expression*

Accomplishment in music, literature, painting, sculpture, the theatre, the film: appreciation of the life of the imagination; interpretation of life through visual, oral, and literary expression. Requirement: two courses (8 to 10 credits).

Afro 1301; 3055; 3057; 3101, 3102; 3105; 3108; 3301; 5201; 5301; 5302; 5595; 5597
AmIn 1111; 3116; 3151; 3221; 3242; 3251
AmSt All courses except 1920; 3920; 3970
Arch 1021; 1022; 1023; 5051; 5052; 5053; 5054; 5055; 5056; 5061
ArtH All courses except 5521; 5950; 5960; 5970; 5990; 5991
ArtS All coursees except 3530; 3970; 3980; 5530; 5970
Chic 3507; 3508; 3510; 3511; 3513
Clas 3081; 3082; 3083; 3181; 3282; 3383; 5002; 5003; 5065; 5081; 5082; 5083; 5102; 5103; 5109; 5115; 5400
CICv 3940
CLit 5111, 5112; 5311; 5321; 5325; 5331, 5332; 5518; 5588; 5591
Comp 1111-1112; 1113-1114; 3101; 3104; 5101, 5102, 5103; 5104, 5105, 5106 (3085 may not be applied)
CSci 3002
Engl All courses except 3060; 3085; 3115; 3116; 3117; 3118; 3119; 3355; 3356; 3357; 3851; 3963; 3970; 3980; 5211; 5258; 5351; 5354; 5620; 5815; 5821; 5831; 5843; 5851; 5860; 5871; 5876
Foreign Languages—Any upper division foreign literature courses
Hum All courses except 3009; 3044; 3061; 3099; 3204; 3211, 3212; 3401; 3403; 3501, 3502, 3503; 3970; 3980; 5023; 5030; 5910
Jour 5171; 5221; 5606
MidE 3210
Mus All courses except 1052; 1053; 1340; 1351; 1602; 5253; 5330; 5340; 5540; 5667; 3970; 3980; 5364; 5365; 5950
Phil 3502; 5501; 5512; 5911
SoAS 1203; 5203
Spch 1104; 3201; 3203; 3204; 5204; 5221
Th All courses except 3412; 3980; 5321; 5540; 5950; 5970
WoSt 3103; 3501; 3502; 3631; 3701; 5100

4. Credits necessary to complete the 36-credit requirement.[1] These credits are in addition to the minimum required for each category. The credits may be taken in any of the above categories. They may include courses

[1] Engineering students must complete a minimum of 24 credits in Groups C and D. See Liberal Education Requirements for Students in Engineering Curricula below.

in the biological sciences and ecology, unless specifically excluded by the student's department. Comp 3085 and courses in astronomy, chemistry, computer science, geology, mathematics, physics, business, accounting, and related areas may *not* be used to fulfill liberal education requirements. CLEP examinations may be used for partial fulfillment of requirements. Students are strongly urged to take courses that examine the impact of science and technology on society and the environment.

The above-listed courses are examples only and do not include all of the courses that may be used to fulfill the requirements.

Courses required for a specific major curriculum that also meet the distribution requirements above may be applied toward the IT liberal education requirements.

Students are encouraged to take advanced level courses and deepen their knowledge of some area in which they are interested. The prerequisites for upper division courses are often quite minimal.

Normally, students are expected to fulfill the specific category requirements. However, students who feel that their education is better served by a certain amount of concentration in one category, even when this does not fulfill the letter of the distribution requirements, may petition to be exempted from the requirements for that category.

Liberal Education Requirements for Students in Engineering Curricula—Students in engineering programs must meet the liberal education requirements stated above. They must complete a minimum of 24 credits in the categories The Individual and Society, and Literary and Artistic Expression. These 24 credits cannot include any ROTC (Air, Mil, Nav) courses except those certified as suitable by the appropriate academic department of the University, any 1000-level introductory language courses, or any freshman composition courses.

Technology and Society—Every student in the Institute of Technology should have an appreciation of the role of technology in society in order to make the value judgments she or he must make as a professional and as a citizen. While this appreciation can be gained in many ways, students are encouraged to take suitable course offerings in IT and other University units to accomplish this goal. A list of suitable courses is available from the office of the director for student affairs and from IT faculty advisers.

First-Year Core Requirements

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 (Calculus I-II-III) or Math 1311-1321-1331 (Computer Calculus I-II-III).

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—Calculus I-II-III			
(or) Math 1311-1321-1331—Computer Calculus I-II-III	5	5	5
Comp 1001-1002—Introductory Composition			
(or) Comm 1001-1002—Communication	4	4	..

	Credits		
	f	w	s
Phys 1271-1281—General Physics	..	4	4
Phys 1275-1285—General Physics Laboratory	..	1	1
Elective[1]	4 or 5	..	4 or 5
	13 or 14	14	14 or 15

CORE B

Chemical Engineering, Chemistry, Materials Science

Math 1211-1221-1231—Calculus I-II-III			
(or) Math 1311-1321-1331—Computer Calculus I-II-III	5	5	5
Chem 1031-1032, 1133[2]—Chemical Principles I-II, Elementary Quantitative Analysis	5	5	5
Comp 1001-1002—Introductory Composition			
(or) Comm 1001-1002—Communication	4	4	..
Nontechnical Elective	..	..	4
	14	14	14

CORE C

Architecture, Environmental Design

Math 1211-1221—Calculus I-II			
(or) Math 1311-1321—Computer Calculus I-II	5	5	..
Comp 1001-1002—Introductory Composition			
(or) Comm 1001-1002—Communication	4	4	..
Arch 1021-1022-1023—History of Environmental Development	4	4	4
Phys 1121-1122—Physics for Architects	..	5	5
Nontechnical Elective	4	..	5
	17	18	14

CORE D

Landscape Architecture

See department curriculum.

Major Program Requirements

Aerospace Engineering and Mechanics

Aerospace engineering is a pioneering field that 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.

Aerospace engineering is a professional field that is constantly changing and that is concerned with 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 four-year program leading to the bachelor of aerospace engineering and mechanics (B.A.E.M.) degree is designed to provide this broad background.

[1]Elective may be in computer science, introduction to engineering, or a nontechnical area.

[2]Chem 1133 is required only for chemistry majors.

The required technical courses offer 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 or her study in an area of special interest. The available options are varied, permitting students to prepare for careers in such diverse fields 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 allows students to obtain practical work experience in industry in quarters (including summer) that alternate with University academic work during the last two years of study. The program operates in conjunction with the intern program of the Department of Mechanical Engineering as a program of the School of Mechanical and Aerospace Engineering. Prospective participants should contact the director of the program for information.

The department is actively involved in transportation studies, and students with an interest in the problems of urban and interurban transportation can participate in a special program in this area. The program includes a carefully selected group of elective courses offered by various departments that are designed to 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 problems arising from noise pollution and possible solutions to these problems can select special courses in acoustics, offered by this and other departments, to form a coherent program that emphasizes acoustical engineering.

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

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

LOWER DIVISION

	Credits
Comp 1001, 1002—Introductory Composition	
(or) Comm 1001, 1002, or 1003—Communication	8
Liberal Education Electives	12
Math 1211-1221-1231—Calculus I-II-III	
(or) Math 1311-1321-1331—Computer Calculus I-II-III	15
Math 3211-3221—Multivariable Calculus, Introduction to Linear Algebra and Linear Differential Equations	10
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
Chem 1014—Concepts of Chemistry	4
ME 1025—Engineering Graphics	4
CSci 1100, 1101—Introduction to FORTRAN Programming	
(or) CSci 3103, 3131—Introduction to Programming Languages and Problem Solving, FORTRAN Laboratory	5
EE 3000—Circuits	4
ME 3301—Thermodynamics	4
Phys 3501—Modern Physics	4
(or) Biol 1101—General Biology	
(or) EBB 3101—Ecology	
(or) Geo 5601—Limnology	
(or) Phsl 3055—Principles of Physiology	
(or) equivalent	
AEM 1001, 1005-1006—Aerospace Engineering Orientation and Survey	3
AEM 1011—Statics	2
AEM 3016—Deformable Body Mechanics	4
AEM 3036—Dynamics	4
Total Credits	98

UPPER DIVISION

	Credits
Liberal Education Electives	16
Required Technical Courses	46
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 5319—Dynamic Stability of Aerospace Craft (4)	
AEM 5515—Aerospace Structures I (4)	
AEM 5642, 5645, 5646—Laboratory I, II (6)	
ME 5342, 3305—Heat Transfer, Propulsion (8)	
Selected Required Technical Courses (select five of the nine listed)	20
AEM 5250 or 5516—Computational Fluid Mechanics or Aerospace Structures II (4)	
AEM 5321—Automatic Flight Control Systems (4)	
AEM 5329—Design I (4)	
AEM 5435—Introduction: Random Vibrations (4)	
AEM 5438—Intermediate Dynamics (4)	
AEM 5580—Mechanics of Elastic Solids I (4)	
AEM 5650—Aeroelasticity (4)	
AEM 5687—Acoustics (4)	
MatS 3400—Mechanical Properties: Materials (4)	
It is strongly recommended that MatS 3400 by taken either prior to or concurrently with AEM 5515 and AEM 5642.	
Other Required Course	2
Comp 3085—Technical Writing (2)	
Must be taken concurrently with AEM 5645.	
Technical Option	12
Technical electives should be selected from one of several recommended optional programs—see information in the departmental office.	
Electives	4
Total Credits	100

Agricultural Engineering

Agricultural engineering involves the application of engineering principles to food and fiber production and processing, rural living, and management of 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 soil, water, and energy resources wisely. These objectives are accomplished by developing and applying new and improved processes, machines, structures, and systems that achieve economic goals and also give full consideration to human and environmental factors.

Agricultural engineers serve not only the agricultural and food industries 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 outpaces 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 four years. It requires a minimum of 190 credits. Emphasis is on the engineering sciences and on engineering design. A general study of biology, agricultural science, communications, social science, and the humanities is included as well, since the agricultural engineer must be able to communicate and work with professionals in a variety of fields. The program is designed to provide students with a fundamental background for continued professional growth and prepare them 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. Students select special courses from a number of subject areas to give them a broad background in topics related to their specialization.

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

The first two years of the program provide the background necessary to complete the more advanced studies offered in the junior and senior years. They also provide a portion of the general educational studies essential to a balanced engineering education.

GENERAL REQUIREMENTS

	Credits
Mathematics	
Math 1211-1221-1231—Calculus I-II-III	15
Math 3211-3221—Multivariable Calculus, Introduction to Linear Algebra and Linear Differential Equations	10
Physical Sciences	
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
Chem 1004-1005—General Principles (or) Chem 1014—Concepts of Chemistry plus natural science elective	8-10
Agricultural and Biological Science	
Electives	8
Engineering Science	
ME 1025—Engineering Graphics	4
AEM 1015—Statics	4
AEM 1031—Computations in Agricultural Engineering	2
AEM 3016, 3036—Deformable Body Mechanics, Dynamics	8
AgEn 3052—Physio-Engineering in Agriculture	4
AgEn 3060—Analysis in Agricultural Engineering	4
CE 3400—Fluid Mechanics	4
EE 3002—Electric Machinery and Power Distribution (or) EE 3000—Circuits	4
ME 3301, 5342—Thermodynamics, Heat Transfer	8
Electives	8
Engineering Design	
AgEn 1071—Introduction to Agricultural Engineering	2
AgEn 5081, 5082, 5083, or 5084—Design	4
Agricultural Engineering Electives: AgEn 5060, 5070, 5072, 5130, 5140, 5330, 5340, 5540, 5550, 5730, 5740, 5910	16
Approved Engineering Design Elective	4
English Composition, Humanities, and Social Science	
English Composition or Communication	8
Electives to satisfy liberal education requirements	28
Technical or Professional Writing	4
Other Courses	
AgEn 1060—Agricultural Engineering Orientation (to be taken by freshman students only)	1
Computer Programming (AgET 1030, or CSci 1100 and 1101, or CSci 3103 and 3131)	3-5
Electives as needed to meet graduation requirement of 190 cr	

Electives are usually chosen to develop professional competence in a given area of specialization, but they can be used for broad professional preparation. Sample programs and lists of suggested electives are available at the department office or from individual advisers.

Architecture

(School of Architecture and Landscape Architecture)

Our environment exerts physical, emotional, and psychological influences on us and on our society. Unplanned and uncontrolled growth produces visual chaos, misuse of natural and other 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 areas have had a direct impact on the tasks of the architectural and environmental design professions. Many of the problems facing the world today fall within the areas of the architect's or designer's concern: inadequacy of housing, misuse of land and water resources, obsolescence of transportation systems, unplanned suburban sprawl, urban decay, and wasteful use of energy and materials. The urgency and critical nature of these problems demand a broader, more comprehensive approach to the education of architects, landscape architects, and environmental designers than in the past.

The spaces in which we live, move, work, and play are largely the product of our own devising. This process of devising and shaping 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 responsive 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 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 two four-year preprofessional degrees, the bachelor of environmental design and the bachelor of arts with a major in architecture, and one five-year professional degree, the bachelor of architecture.

Bachelor of Environmental Design (B.E.D.) Curriculum (four years in Institute of Technology)—This program normally requires one year of pre-environmental-design work followed by three years in the School of Architecture and Landscape Architecture. Students must complete a minimum of 192 credits of required and elective work.

This curriculum prepares students for continuation toward the B.Arch. degree, application for graduate study in architecture leading to the M.Arch. degree, or transfer into other disciplines such as urban design, city and regional planning, product design, or related fields.

Bachelor of Arts (B.A.) Curriculum (four years in College of Liberal Arts)—This program normally requires two years of pre-architecture work followed by two years of work in the School of Architecture and Landscape Architecture. Students must complete 180 credits of required and elective work.

Upon completion of the B.A. degree, students may (a) transfer to the Institute of Technology and after two 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 M.Arch. 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 related disciplines.

The B.A. program with a major in architecture is also offered through Continuing Education and Extension.

Bachelor of Architecture (B.Arch.) Curriculum (five years in Institute of Technology)—This program normally requires one year of pre-architecture work followed by four years

in the School of Architecture and Landscape Architecture. Students must complete a minimum of 250 credits of required and elective work. The curriculum is intended for students who plan 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 required by laws of the various states.

Students will not be permitted to register in Arch 5122 until they have completed an approved graduation check sheet. Prior to registering for Arch 5123, students must present evidence that they have completed a minimum of 800 hours of practical experience in an architectural or planning office and have completed all required course work.

Master of Architecture (M.Arch.) Program—Programs in architectural design and urban design leading to the M.Arch. degree are open to students who meet the entrance requirements of both the Graduate School and the School of Architecture and Landscape Architecture. See the *Graduate School Bulletin* or the director of graduate studies in architecture for details.

Special Programs

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

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

Computer Application (in collaboration with the University Computer Services)—Students carry out projects involving application of computer programming and computer graphics to architecture, landscape architecture, and planning.

Community Advocacy Design—Students work as University Year for Action interns on a variety of design projects in rural and urban communities.

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

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

Admission Procedure

To enter the architecture program, students must submit an application on Form AR 110 by May 1 of the year of desired admission. Admission to the program is permitted only in the fall quarter unless advanced standing is granted. Students should apply to the University of Minnesota if not already a University of Minnesota student. Forms may be obtained from the Office of Admissions, 240 Williamson Hall, 231 Pillsbury Drive S.E., University of Minnesota, Minneapolis, Minnesota 55455.

To be considered for admission to the architecture program, a student must:

1. Have completed a minimum of 45 quarter credits (31 by the time of application).
2. Have fulfilled the following prerequisites with a minimum grade of C.
   2 quarters of English composition (Comp 1001-1002 or equivalent) .... 8 credits
   2 quarters of calculus (Math 1211-1221 or equivalent)[1] .....10 credits
   2 quarters of physics (Phys 1121-1122 or equivalent)[1] .....10 credits
   3 quarters of environmental history (Arch 1021-1022-1023)[2] .....12 credits

[1] Students should note that the architecture curriculum requires two quarters each of calculus and physics. Since admission to the architecture program is limited, students may wish to substitute math and physics sequences that are acceptable for admission to other IT disciplines. Laboratory work is required for all physics sequences.

[2] Students not enrolled on the Twin Cities campus must take this sequence before graduation, but it is not required for entry.

3. Submit an official transcript of all college work taken at the University of Minnesota and other colleges to date.
4. Submit a one- or two-page letter stating reasons for selecting the School of Architecture and Landscape Architecture, interests, motivation, experiences in architecture, and any information that might be valuable in assessing the application.
5. If desired, submit a portfolio including art or design work, drawings, paintings, photographs of sculpture or ceramics, environmental reports, slides, or other appropriate work. The portfolio must be a bound 8½-by-11-inch booklet. It must be submitted to the school office by May 1, along with a self-addressed, postage paid return envelope. The portfolio allows the student to demonstrate design abilities, graphic communication skills, organizational skills, and commitment to or insights into design and architecture.

Applicants may make an appointment with a counselor in the School of Architecture and Landscape Architecture before applying to discuss individual experience, professional development, motivation, or other pertinent information. Relevant data will be noted on the application.

Students are selected on the basis of overall grade point average, college work completed, and art and design skills. Criteria for art and design skills are outlined on the application form. Preference for admission is given to Minnesota, Wisconsin, and North Dakota residents.

All students must begin Arch 3081 (Architectural Design I) in the fall quarter unless advanced standing is granted. Since the School of Architecture and Landscape Architecture can admit a limited amount of students, only those students who successfully meet the admission criteria will be allowed to register for Arch 3081. Additionally, promotion from one level of the design sequence to the next is by design faculty approval. Students who have interrupted their enrollment in the design course sequence for two years or more will be readmitted only if space is available and must reapply to the school approximately one month before the end of the quarter preceding the one in which they wish to enter.

Course Requirements

The pre-architecture and pre-environmental-design program, which is completed by all students, is one year in length. It prepares students for the required course work in the School of Architecture and Landscape Architecture.

In both the B.E.D. and B.Arch. degree programs, each required course must be passed with a minimum grade of C. Courses in the pre-architecture and pre-environmental-design program are considered part of the respective curricula.

The school will consider substitutions for any required courses in the curriculum upon petition to the director of scholastic standards. Permission for a substitution must be requested before the quarter the required couse would normally be taken.

PRE-ARCHITECTURE AND PRE-ENVIRONMENTAL-DESIGN PROGRAM

	Credits		
Comp 1001-1002—Introductory Composition or Communication	4	4	...
Arch 1021-1022-1023—History of Environmental Development	4	4	4
Math 1211-1221—Calculus I-II	5	5	...
Phys 1121, 1122-1123, 1124—Physics for Architects	...	5	5
CLE Electives	4	...	5
	17	18	14

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 of desired admission.

BACHELOR OF ARCHITECTURE[1]

First-Year Design

	Credits		
Arch 3061-3062[2]—Building Systems	4	4	...
Arch 3081-3082-3083[2]—Architectural Design	6	6	6
AEM 3092-3093—Statics and Mechanics of Materials	4	4	...
ArtS 1107-1108-1109[2]—Drawing for Architects	2	2	2
CLE Electives	...	...	10
	16	16	18

Second-Year Design

Arch 3064-3065[2]—Environmental Management and Control	4	4	...
Arch 3091-3092-3093[2]—Architectural Design	6	6	6
CE 3600-3601-3602[2]—Structural Design	4	4	4
ArtS 3140[2]—Drawing and Painting (for architects)	2	2	2
CLE Electives	...	...	5
	16	16	17

Third-Year Design

Arch 5051 through 5061—Architectural History (any three)	4	4	4
Arch 5111-5112-5113[2]—Architectural Design	6	6	6
Arch 5115-5116[2]—Structure and Form in Architecture	4	4	...
Electives (theory, law, preservation, methods, CLE)	3	3	8
	17	17	18

Fourth-Year Design

Arch 5121-5122[2]—Architectural Design	9	9	...
Arch 5123[2]—Architectural Thesis	...	...	12
Arch 5126[2]—Professional Practice	...	...	4
Arch 5137-5138[2]—Planning	4	4	...
Electives (theory, law, preservation, history, methods)	4	4	...
	17	17	16

BACHELOR OF ENVIRONMENTAL DESIGN[1]

First-Year Design

Arch 1001-1002-1003—Environmental Design	4	4	4
Arch 3081-3082-3083[2]—Architectural Design	6	6	6
AEM 3092-3093—Statics and Mechanics of Materials	4	4	...
ArtS 1107-1108-1109[2]—Drawing for Architects	2	2	2
CLE Electives	...	...	5
	16	16	17

Second-Year Design

Arch 3061-3062[2]—Building Systems	4	4	...
Arch 3067—Integrated Design Systems	...	...	4
Arch 3091-3092-3093[2]—Architectural Design	6	6	6
CE 3600-3601-3602[2]—Structural Design	4	4	4
ArtS 3140[2]—Drawing and Painting (for architects)	2	2	2
	16	16	16

[1]See the yearly handout, available in the architecture department office, for any changes in program requirements.

[2]Offered only after admission to School of Architecture and Landscape Architecture.

Third-Year Design

	Credits		
Arch 3064-3065[1]—Environmental Management and Control	4	4	...
Arch 5051 through 5061—Architectural History (any three)	4	4	4
Arch 5111-5112-5113[1]—Architectural Design			
(or) 18 credits environmentally related electives	6	6	6
CLE Electives	4	...	4
	18	14	14

Astronomy

(School of Physics and Astronomy)

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

A double major in astrophysics and physics can be completed.

GENERAL REQUIREMENTS

(Based on 180 credits)

	Credits
Liberal Education (see Physics listing)	36
Mathematics (see Physics listing)	33-37
Astrophysics and Physics	
Ast 3051, 5161, 5162—Astrophysics	12
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
Phys 3011-3015—Oscillations, Oscillations and Waves Lab	5
Phys 3511-3512-3513—Modern Physics	12
Phys 5021-5022—Introduction to Analytic Mechanics	8
Phys 5023-5024—Introduction to Electric and Magnetic Fields	8
Ast 5990—Directed Research	3
Free electives to total 180 credits	44-48
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—Introduction to Astronomy and Lab, Topics in Modern Astrophysics
Ast 5163—Galactic and Extragalactic Astronomy
Phys 5101-5102—Quantum Mechanics
Phys 3201—Thermodynamics
Phys 5801—Modern Optics
Phys 5121-5122-5123—Methods of Experimental Physics

Suggested Technical Electives

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

[1]Offered only after admission to 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 that emphasizes basic and engineering sciences, the chemical engineer is considered the universal engineer.

Chemical engineers work on a wide variety of projects: basic and applied research, development work, design and modification of processes and equipment, and plant operation. Some enter sales, engineering, marketing, and management. Because of the breadth and flexibility of the chemical engineering curriculum, it is chosen by some students who plan to pursue 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 or she may work 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. Chemical engineers are particularly well suited for dealing with problems associated with disposal of industrial wastes and other forms of pollution that are of a chemical nature, as well as with 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, students must normally complete required and elective course work totaling 200 credits (although the minimum, in special cases, may be 191 credits). Students must satisfy the IT minimum liberal education requirements (a total of 36 credits including at least 3 in biological science) as part of a pre-chemical-engineering program (96 to 105 credits) and complete a coherent degree program of science and technical courses (86 to 104 credits). Both predegree and degree curricula are outlined on the following pages.

The student, together with her or his adviser, plans the degree program in two stages: a one-year plan is submitted at the start of the third year, and, ordinarily, a complete four-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. Sample programs that illustrate these possibilities are available from the departmental office, 151 Amundson Hall. Advisers and the department's director of undergraduate studies can be contacted through the same office.

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

Cooperative Programs—Coop programs combining work with academic study may be arranged by a student with an appropriate employer when a job offers professional training in the field of study. Such arrangements can receive departmental approval and cooperation.

Two work-study schedules are recommended: 1) work summers (June 16 through September 15) through third year, continue working during fall and winter quarters of fourth year, return to University for spring quarter, work summer, return to University for fall and winter quarters of fifth year, and have option to graduate at the end of winter quarter of that year; or 2) work summers through third year, continue working through following academic year and following summer, return to University for fifth year, and graduate at end of the spring quarter of that year.

To facilitate schedule one, the department will allow substitutions for required courses in the spring quarter of the fifth year that have as prerequisites courses to be completed in the previous fall and winter quarters.

To preserve educational continuity and student status, coop students working during the regular academic year may register during work quarters for one credit of Special Projects (ChEn or MatS 5902f, 5903w, 5904s). Written reports must be submitted to the adviser to earn these credits. Two credits of Special Projects courses may be used to satisfy one of the two-credit laboratory courses required for the bachelor's degree.

Transfer Students—Students intending to transfer from another campus or school should take courses available to them that are equivalent to those required for this curriculum. Students with questions about a proposed transfer are encouraged to write or visit the Department of Chemical Engineering and Materials Science, 151 Amundson Hall, 421 Washington Avenue S.E., University of Minnesota, Minneapolis, Minnesota 55455.

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—Calculus I-II-III	5	5	5
Chem 1031-1032—Chemical Principles I-II	5	5	...
Phys 1271, 1275—General Physics, Laboratory	...	...	5
Liberal Education Electives (quarters of registration may be *rearranged with* Comp 1001-1002)	...	0-4	4-8

Second Year

Chem 3331, 3332, 3335, 5126—Introductory Organic Chemistry I, II with Laboratory (II), Modern Analytical Chemistry	5	5	4

	Credits		
	f	w	s
Chem 5533—Quantum Chemistry	...	...	4
Phys 1281-1291—General Physics: Heat and Electricity, Magnetism and Optics	4	4	...
Phys 1285-1295—General Physics Laboratory	1	1	...
Math 3211, 3221—Multivariable Calculus, Introduction to Linear Algebra and Linear Differential Equations	5	5	...
ChEn 5001—Mathematical Methods in Chemical Engineering and Materials Science	...	...	3
Electives[1]	4	4	4

Note that the lower division curriculum in chemical engineering is the same as the lower division curriculum in chemistry, except that a course in biology is included. The lower division curriculum in chemical engineering differs from those in other engineering fields because more chemistry course work is required.

Also note that the required lower division biological science elective fulfills both chemical engineering and liberal education requirements.

UPPER DIVISION

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]	3	...	...
ChEn 5401—Chemical Engineering Laboratory	...	...	2
Chem 5534—Chemical Thermodynamics	4	...	...
ChEn 5201—Thermodynamics and Materials States	...	4	...
ChEn 5202—Chemical Engineering Thermodynamics and Kinetics	...	...	4
MatS 5011—Introduction to Science of Materials	4	...	...
Chem 5535, 5538—Statistical Mechanics and Reaction Kinetics with Laboratory	...	5	...
Liberal Education Electives	0-4	3-5	4-8

Fourth Year

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

[1]Electives include at least four credits of computer science and one quarter of an approved biological science course. The computer science credits may be chosen from: CSci 3103 and 3131; CSci 1100 and 1101; and CSci 3101 (offered through extension and summer session only).

[2]For transfer students only.

[3]Programs normally include at least three laboratory courses.

[4]Recommended technical electives include the following: For a metallurgy/materials science emphasis, AEM 1011, 3016; for a mathematics emphasis, Math 3231; for a mechanical engineering emphasis, ME 1025; for an electrical engineering emphasis, EE 3000.

Chemistry

The chemistry curriculum includes courses in chemistry, physics, mathematics, English, and German that cover the background necessary for a successful career in this field. After the required courses have been completed there are no restrictions on the remaining courses the student chooses.

Specific requirements are:

1. A minimum of 180 credits for graduation. All required courses including German but excluding freshman English must be taken A-N.
2. Freshman English (8 credits) or exemption.
3. One year of German (15 credits) to acquire ability to read the literature of the field in German.
4. One year of calculus-based physics (15 credits).
5. Five quarters (25 credits) of mathematics.
6. Sixty credits of chemistry.
7. Minimum liberal education requirements (36 credits). Eight credits of English, if taken, and 8 credits of German may be included in this total.
8. Electives (35-40 credits), chosen by the student in consultation with his or her adviser, but otherwise without restriction.

The department will consider substitutions for any item in the required curriculum upon petition to the director of undergraduate studies. Permission for any substitution must be requested before the quarter a required course would normally be taken.

Electives—The required chemistry, mathematics, and physics courses are presented in the recommended schedule below. The English and German courses are included in the electives listing in the schedule.

In addition to advanced courses in the conventional fields of chemistry—analytical, inorganic, organic, and physical—students are encouraged to take the following chemistry courses:

3499—Senior Thesis
3970—Directed Study
5522, 5523, 5524—Physical Biochemistry
5580—Physical Chemistry of Polymers
5610—Principles of Polymer Science
5801, 5802, 5803—The Chemistry of Industry

Other areas recommended for consideration for elective work are:

Astronomy
Biochemistry
Biology
Botany
Chemical Engineering
Computer Science
Ecology
Economics
Food Science and Nutrition
Genetics and Cell Biology
Mathematics
Medicinal Chemistry
Microbiology
Physics
Physiological Chemistry
Physiology
Plant Physiology
Zoology

LOWER DIVISION

First Year

	Credits f	w	s
Chem 1031-1032, 1133—Chemical Principles I-II, Elementary Quantitative Analysis	5	5	5
Math 1311-1321-1331—Computer Calculus I-II-III (or) Math 1211-1221-1231—Calculus I-II-III	5	5	5
Electives (quarters of registration may be rearranged with Comp 1001-1002)	4-8	4-8	4-8

Second Year

	Credits f	w	s
Chem 3331, 3332, 3333—Introductory Organic Chemistry I, II, III	5	3	3
Chem 3335, 3336—Introductory Organic Chemistry Laboratory II, III	...	2	2
Math 3211, 3221—Multivariable Calculus, Introduction to Linear Algebra and Linear Differential Equations	5	5	...
Phys 1271-1281-1291—General Physics	4	4	4
Phys 1275-1285-1295—General Physics Laboratory	1	1	1
Electives	0-3	0-3	4-8

UPPER DIVISION

Third Year

Chem 5534—Chemical Thermodynamics	4	...	...
Chem 5535, 5538—Statistical Mechanics and Reaction Kinetics, Physical Chemistry Laboratory	...	4, 1	...
Chem 5533, 5536—Quantum Chemistry, Laboratory	...	...	4, 2[1]
Chem 5133—Chemical Instrumentation and Analysis	...	...	5
Electives	9-13	9-13	4-8

Fourth Year

Chem 5731, 5732—Inorganic Chemistry I, II	3[1]	3[1]	...
Chem 5734, 5735—Inorganic Chemistry Laboratory I, II	2[1]	2[1]	...
Electives	9-13	9-13	14-18

Civil Engineering

(Department of Civil and Mineral Engineering)

Civil engineering deals with the science and art of engineering, applied to solving problems related to the human environment and natural resource needs.

Students interested in developing and applying scientific and technological innovations, as well as in providing service to others, will find a strong appeal in civil engineering. This field requires high professional 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 professional 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. 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, pollution control facilities, water resources projects, private and public utility enterprises, and other civil works.

The bachelor of civil engineering (B.C.E.) degree program requires a minimum of 194 credits. The first two years of the curriculum are similar to the first two years of the curricula in other IT engineering departments. Students may transfer to civil engineering from another IT engineering department, another University campus or college, or another academic institution. Students who transfer to the program after completing the first two years at another institution must complete a course in statics (AEM 1015), which is a

[1] A student who wishes to complete the required chemistry courses in the first 3 years may take Quantum Chemistry (5533 and 5536) in the third quarter of the second year and Inorganic Chemistry (5731, 5732, 5734, and 5735) in the first two quarters of the third year.

prerequisite for many third-year CE courses, prior to entering the University if they expect to complete the program in two additional years. The last two years of the civil engineering program emphasize engineering science and engineering practice.

Principal fields within civil engineering are:

Structural Engineering—The design and analysis of buildings, bridges, industrial facilities, and other structures built with concrete, steel, reinforced or pre-stressed concrete, wood, and other materials.

Geotechnical Engineering—The analysis of the properties of soils and rocks and applications to the design of foundations, retaining walls, roads, slopes, dams, and tunnels.

Water Resources Engineering—The application of fluid mechanics and hydrology as well as other basic knowledge to the design and operation of water resources systems, including hydrologic analysis; hydraulic design of channels, pipelines, pumping stations, dams and reservoirs; hydrothermal power development; environmental transport processes; sedimentation; coastal engineering and harbor development; irrigation and drainage; and wastewater disposal. The St. Anthony Falls Hydraulic Laboratory, a part of the Department of Civil and Mineral Engineering, is the site of water resources research.

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

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

Surveying and Mapping—The art and science of locating points and objects on, above, and under the surface of the earth for planning, design, and construction. This field includes geodesy, photogrammetry, and land surveying.

General requirements and senior elective program courses for the bachelor of civil engineering degree are listed below, followed by a sample curriculum illustrating how these requirements can be combined. By selecting appropriate courses for the senior elective program, students can specialize in an area of interest. For further information contact the Director of Undergraduate Studies, Department of Civil and Mineral Engineering, 103 Experimental Engineering, 208 Union Street S.E., University of Minnesota, Minneapolis, Minnesota 55455.

A limited number of civil engineering students may enter an engineering intern program after completing approximately five quarters of study. Participants alternate study quarters with two six-month work periods, for which they earn four credits each period. For further information contact the Director of the Civil Engineering Intern Program, Department of Civil and Mineral Engineering, 103 Experimental Engineering, 208 Union Street S.E., University of Minnesota, Minneapolis, Minnesota 55455.

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

GENERAL REQUIREMENTS

	Credits
Math 1211-1221-1231, 3211, 3221—Calculus I-II-III, Multivariable Calculus, Introduction to Linear Algebra and Linear Differential Equations	25
Phys 1271-1275-1281-1285-1291-1295—General Physics, General Physics Laboratory	15
Chem 1004-1005 or 1031-1032—General Principles	10
Geo 1001 or 1001H or 1111—Physical Geology	5
CE 1001—Civil Engineering Orientation	1
CSci 3103, 3131; or 1100, 1101—FORTRAN Programming	4 or 5

	Credits
Stat 3091—Probability, Statistics	4
CE 3500—Introduction to Environmental Engineering Problems and Analysis	4
AEM 1015—Statics	4
AEM 3016—Deformable Body Mechanics	4
CE 3100—Introduction to Surveying and Mapping	4
CE 3200—Introduction to Transportation Engineering	4
CE 3300—Soil Mechanics	4
CE 3301—Soil Mechanics Laboratory	1
CE 3400—Fluid Mechanics	4
CE 3700—Introduction to Construction Materials	4
CE 5002—Engineering Economics	2
CE 5401—Water Resources Engineering	4
CE 5405—Hydrology and Hydrologic Design	4
CE 5505—Water Quality and Treatment (or) CE 5500—Analysis and Design of Water Supply Systems (or) CE 5501—Analysis and Design of Wastewater Systems	4
CE 5600—Linear Structures	4
CE 5611—Design of Reinforced Concrete Structures (or) CE 5610—Design of Metal Structures	4
Technical Elective—one course chosen from EE 3000—Circuits, EE 3002—Electric Machinery and Power Distribution, or ME 3301—Thermodynamics	4 or 5
Liberal Education Electives[1]	36
Free Electives[2]	5 or 7
Total Credits	166

SENIOR ELECTIVE PROGRAM

(28 credits)

The senior elective program provides additional training in one or more areas. Courses for the program are listed below. Four areas of emphasis are available: structures and geotechnical engineering, water resources and environmental engineering, transportation, and surveying. Courses in each area of emphasis are divided into two categories: design oriented (A) and engineering oriented (B). Four courses must be completed in category A; at least three of these must be in one area of emphasis. Three courses must be completed in category B. One of the courses CE 5097, 5098, or 5099, Advanced Design, Analysis, Research, or Tutorial in Civil Engineering, may be substituted for a course in category A. One of the courses CE 5001, Contracts and Specifications; CE 5004, Structural and Construction Considerations for Earth Sheltered Buildings; or CE 5703, Construction Project Management, may be used as a category A course in any area of emphasis. Students who maintain a grade point average of 3.30 or higher are permitted to choose up to 8 credits of 8000-level courses as part of their senior elective program.

1. *Structures and Geotechnical Engineering*	Credits
A. CE 5301—Applied Soil Mechanics	4
CE 5302—Applied Rock Mechanics	4
CE 5601—Matrix Analysis of Structures	4
CE 5610—Design of Metal Structures[3]	4
CE 5611—Design of Reinforced Concrete Structures[3]	4
CE 5612—Intermediate Design of Metal Structures	4
CE 5613—Intermediate Reinforced Concrete Design	4
CE 5615—Prestressed Concrete	4
CE 5617—Design of Masonry Structures	4
CE 5701—Cemented Materials: Properties, Evaluation, and Mixture Design	4
CE 5702—Manufacture and Quality Control of Construction Materials	4

[1]One course should be in economics.

[2]Technical electives are recommended. Physical education credits are not acceptable. Credits earned through the engineering intern program will be included in these electives. Students who have not taken graphics in high school should complete ME 1025—Engineering Graphics.

[3]Students emphasizing structures must complete CE 5610 and CE 5611. One of these courses satisfies part of the core curriculum requirement, while the other satisfies part of the senior elective program, category A.

	Credits
B. AEM 3036—Dynamics	4
AEM 5580—Introduction to Solid Mechanics	4
AEM 5581—Mechanics of Elastic Solids	4
CE 5300—Theory of Geomechanics	4
CE 5425—Groundwater Mechanics	4
EE 3002—Electric Machinery and Power Distribution	4
Geo 5002—Structural Geology	4
Geo 5251—Geomorphology	4
GeoE 5347—Computer Applications in Geo-Engineering	4
Math 3231—Vector Analysis	4
Math 5512—Differential Equations	4
Math 5567—Fourier Series and Boundary Value Problems	4
ME 3301—Thermodynamics	4
2. *Water Resources and Environmental Engineering*	
A. CE 5402—Hydraulic Analysis With Computer Applications	4
CE 5410—Open Channel Hydraulics	4
CE 5420—Introduction to Water Resources Management	4
CE 5425—Groundwater Mechanics	4
CE 5500—Analysis and Design of Water Supply Systems[1]	4
CE 5501—Analysis and Design of Wastewater Systems[1]	4
CE 5510—Solid Waste Management	4
CE 5511—Hazardous Waste Engineering	4
B. Biol 3013—Microbiology	4
CE 5300—Theory of Geomechanics	4
CE 5435—Intermediate Fluid Mechanics	4
Chem 3301, 3302—Elementary Organic Chemistry	8
Chem 5520, 5521—Elementary Physical Chemistry	6
CSci 5301—Numerical Analysis	4
EE 3000—Circuits	4
EE 3002—Electric Machinery and Power Distribution	4
ME 3301—Thermodynamics	4
Geo 3101—Surficial Geologic Processes	5
Geo 5601—Limnology	4
Geo 5611—Groundwater Geology	4
GeoE 5437—Computer Applications in Geo-Engineering	4
3. *Transportation*	
A. CE 5200—Geometric Design of Highways	4
CE 5201—Highway Traffic Characteristics	4
CE 5202—Airport Design	4
CE 5210—Introduction to Transportation Systems Analysis	4
CE 5212—Transportation Productivity and Energy Consevation	4
CE 5304—Highway and Airport Pavements	4
CE 5701—Cemented Materials	4
CE 5702—Manufacture and Quality Control of Construction Materials	4
B. CSci 5301—Numerical Analysis	4
Econ 5231—Introduction to Econometrics	4
EE 5750—Topics in Systems Analysis	3
Geog 5372—Metropolitan Analysis I	4
Geog 5373—Metropolitan Analysis II	4
Geog 5383—Transportation Geography	4
IEOR 5040—Operations Research	4
IEOR 5710—Transit System Analysis and Design	4
IEOR 5711—Transit System Analysis and Design	4
Stat 5021—Statistical Analysis I	4
Stat 5022—Statistical Analysis II	4
4. *Surveying*	
A. CE 3103—Field Surveying	3
CE 5100—Land Surveying	4
CE 5102—Site and Route Engineering	4
CE 5103—Land Planning and Subdivision Design	4
B. CE 5101—Geodesy	4
CE 5104—Photogrammetry	4
CE 5105—Survey Adjustments	4
CSci 5301—Numerical Analysis	4
FR 5262—Remote Sensing of Natural Resources	4
GeoE 5437—Computer Applications in Geo-Engineering	4

[1]Students emphasizing environmental engineering must complete CE 5500 and CE 5501.

SAMPLE PROGRAM

First Year

f	Credits	w	Credits	s	Credits
Math 1211	5	Math 1221	5	Math 1231	5
Comp 1001	4	Comp 1002	4	Phys 1271, 1275	5
Chem 1004	5	Chem 1005	5	Geo 1001	5
CE 1001	1	CSci 1100	2	CSci 1101	2
	15		16		17

Second Year

Math 3221	5	Math 3211	5	Stat 3091	4
Phys 1281, 1285	5	Phys 1291, 1295	5	CE 3100	4
AEM 1015	4	AEM 3016	4	Econ 1001	4
CE 3500	4	ME 1025	4	CE 3400	4
	18		18		16

Third Year

CE 3700	4	CE 5505	4	CE 3200	4
CE 3300	4	CE 5600	4	CE 5610	4
CE 5401	4	CE 5405	4	CE 5002	2
EE 3002	5	CLE	4	CLE	4
				CE 3301	1
	17		16		15

Fourth Year

CE(A)	4	CE(A)	4	CE(A)	4
CE(A)	4	CE(B)	4	CE(B)	4
CE(B)	4	CLE	4	Elective	3
CLE	4	CLE	4	CLE	4
	16		16		15

Master's Degree Programs

Because of the rapid development in technology, many students prepare themselves for advanced professional work by completing graduate study. Students who have a maximum of nine credits to complete for their baccalaureate degree, and who have a satisfactory academic record, may be admitted to study for a master's degree program; and nine credits earned during the last term of undergraduate study may be applied to the master's program. Two master's degree programs, the M.S. and M.C.E., are available. Each requires about one year to complete. Information about these programs will be provided by the director of graduate studies of the department.

Computer Science

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 earned 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 programs are designed to give a student a broad foundation in the basic subjects of computer science. By means of an upper division option and a choice of alternatives in the required courses, the curriculum allows a student to develop a concentration within computer science or in interdisciplinary areas involving the applications of computers. This should prepare a student for a variety of industrial and governmental positions involving use of the computer or for graduate work in the field.

The four-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 complete approved electives. A minimum of 187 or 188 credits are required for graduation.

All IT courses in the required program as well as the 32 credits that constitute the upper division option must be taken on A-N grading unless particular courses are offered only on S-N.

Transfer Students—After the sophomore year, students who have completed elementary physics and a higher level programming language may enter the program as juniors, assuming that their liberal education course work is roughly equivalent to that required by the Institute of Technology. Most transfer students have not studied the material covered in CSci 3104, 3105, 3106, and 3107; however, a program can be worked out in which these courses are taken during the summer and the junior year. All transfer students should visit the departmental office for information.

LOWER DIVISION

	Credits
Freshman English or Communication	8
Math 1211-1221-1231—Calculus I-II-III (or) Math 1311-1321-1331—Computer Calculus I-II-II	15
Math 3142, 3211 (or) Math 3511, 3211 (for students with better than average mathematical ability) (or) Math 3511, 3521 (for students with high mathematical ability)	9 or 10
Stat 3091—Probability, Statistics (or) Stat 5121—Theory of Statistics[1]	4
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
CSci 3001—Perspectives on Computers and Society	4
CSci 3103, 3134—Introduction to Programming and Problem Solving, Pascal Laboratory	5
CSci 3105, 3106—Fundamentals of Algorithms and Languages I, II	8
CSci 3107—Introduction to the Structures and Programming of Computer Systems	4
CSci 3400—Discrete Structure of Computer Science	4
Liberal Education Electives	20
Total Credit Minimum	96 or 97

UPPER DIVISION

Engl 3085—Technical Writing	4
Liberal Education Electives	8
Electives	24
Required Technical Courses:	
CSci 5102—Structure and Programming of Software Systems II	4
CSci 5106—Higher Level Languages	4
CSci 5121—Data Structures	4
CSci 5201—Introduction to Computer Architecture	4
CSci 5301—Numerical Analysis	4
CSci 5400—Introduction to Automata Theory	4
Upper Division Option	
Elective courses that form a coherent program in computer science or application areas; for example, computer design, electrical engineering, health sciences, management information systems, mathematics of computation, software design, theory of computation, data base systems. These courses may be selected from additional 5000-level CSci courses and adviser-approved courses from other departments. Normally at least 16 credits must be from computer science.	
See option program *information available in departmental office*	32
Total Credit Minimum	92

[1]Students intending to complete additional work in statistics must take Stat 5121 rather than Stat 3091.

Electrical Engineering

The electrical engineering program seeks to prepare its graduates to deal with beginning engineering assignments and to provide a foundation for continued professional development.

The electrical engineering curriculum offers students an opportunity to concentrate in a number of specialized areas or in related interdisciplinary studies. These areas include control and communications engineering, bioengineering, computers and other digital systems, energy conversion and power systems, microelectronic devices and circuit design, and physical electronics.

An honors program and an engineering intern program are available to qualified upper division students. The honors program offers an opportunity for greater depth of study through special recitation sections, an individual honors project completed under faculty guidance, and increased elective choice. The engineering intern program offers industrial work experience and some financial support through alternate quarters of on-campus study and off-campus industrial assignment during a two-year period.

The degree of bachelor of electrical engineering (B.E.E.), granted after completion of the four-year curriculum, requires completion of a minimum of 190 quarter credits. Further information about the B.E.E. program can be obtained by requesting a copy of the *EE Curriculum Guide* from the Department of Electrical Engineering, 139 Electrical Engineering, 123 Church Street S.E., University of Minnesota, Minneapolis, Minnesota 55455.

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

LOWER DIVISION

	Credits
Liberal Education Electives, including 8 cr of freshman composition or communication	18
Math 1211-1221-1231, 3211, 3221, 3231—Calculus I-II-III, Multivariable Calculus, Introduction to Linear Algebra and Linear Differential Equations, Vector Analysis	29
Natural Sciences	
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
Chem 1014—General Principles of Chemistry	4
Phys 3501—Modern Physics (or other appropriate science elective)	4
EE 1000—Introduction to Electrical Engineering	1
CSci 1100-1101—FORTRAN Programming	4
EE 1510—Elements of Electrical Engineering	5
Technical Elective (AEM 3036 or Stat 3091 or ME 3301)	4
Electives	10
Total Credits	94

UPPER DIVISION

EE 3010-3011-3012—Circuits, Signals, and Systems I-II-III	12
EE 3050-3051-3052—Electronics I-II-III	12
EE 3100-3101—Electromagnetic Fields I-II	8
EE 3400-3401-3402—Junior EE Laboratory	8
EE 5100—Electromagnetic Fields III	4
EE 5101—Electromagnetic Fields Laboratory	1
Comp 3085—Technical Writing	3
Senior Technical Program	28
Electives (including liberal education courses to complete the CLE requirements)	20
Total Credits	96

Geo-Engineering

(Department of Civil and Mineral Engineering)

Geo-engineering is concerned with the application of engineering and geological principles to the problems of analysis and design in those engineering activities directly related to the earth and 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. Concerns may include 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. Activities may include analysis and design in the exploration and development of minerals, mineral valuations, and application of geochemical, geophysical, and geological 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, involving environmental studies, geothermal energy, water resources, underground transit systems, and similar concerns.

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. 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 to allow the student to obtain a limited degree of specialization in one of the fields with which geo-engineers are concerned. It also offers a good foundation for graduate study.

The four-year program leads to the degree of bachelor of geo-engineering (B.Geo.E.). A minimum of 192 credits are required for graduation.

The following program includes the required courses and a recommended schedule. It can be modified, in consultation with the faculty adviser, to meet individual student interests. The program also includes field trips. The final program must be approved by the adviser for graduation.

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

LOWER DIVISION—ALL OPTIONS

First Year

	Credits		
	f	w	s
Math 1211-1221-1231—Calculus I-II-III	5	5	5
Chem 1004-1005—General Principles of Chemistry	5	5	...
Comp 1001-1002—Introductory Composition	4	4	...
Phys 1271—General Physics	...	...	4
Phys 1275—General Physics Laboratory	...	...	1
Liberal Education Electives	4	...	4

Second Year

Math 3221—Introduction to Linear Algebra and Linear Differential Equations	5	...	...
Phys 1281-1291—General Physics	4	4	...
Phys 1285-1295—General Physics Laboratory	1	1	...
AEM 1015—Statics	...	4	...
AEM 3016—Deformable Body Mechanics	...	...	4

	Credits		
	f	w	s
Stat 3091 or ME 3900—Statistics	...	...	4
CSci 1100—Introduction to FORTRAN Programming	...	2	...
CE 3400—Fluid Mechanics	...	...	4
ME 1025—Engineering Graphics	4	...	...
Liberal Education Electives	4	4	4

UPPER DIVISION—GEOMECHANICS INTEREST

Third Year

MinE 5611, 5612, 5613—Mineral Resources I, II, III	4	4	4
GeoE 5216—Geo-Engineering	...	3	...
GeoE 5300—Theory of Geomechanics	...	4	...
CE 5301—Applied Soil Mechanics I	...	...	4
GeoE 5302—Applied Rock Mechanics II	...	...	4
Geo 1111, 3401—Physical Geology, Introductory Mineralogy	5	5	...
Geo 3103—Structural and Field Geology	...	...	5
CE 3300—Elements of Soil Mechanics	4	...	...
CE 3100—Surveying	4	...	...
CE 3301—Soil Mechanics Laboratory	...	1	...

Geology Summer Field Trip (4 weeks or more) 6

Fourth Year

GeoE 5262—Geo-Engineering Analysis	...	...	4
GeoE 3012—Geo-Engineering Surveying	...	...	2
GeoE 5437—Computer Applications in Geo- and Mineral Engineering	4	...	...
Geo 5611—Groundwater Geology	...	...	4
Geo 5512—Principles of Seismic Exploration	...	3	...
Geo 5513—Principles of Electrical Exploration	...	...	3
CE 5600—Linear Structural Systems	...	4	...
Technical Electives	4	5	4
Liberal Education Electives	8	4	...

UPPER DIVISION—EXPLORATION INTEREST

Third Year

MinE 5611, 5612, 5613—Mineral Resources I, II, III	4	4	4
MinE 5800—Mineral Processing	4	...	...
GeoE 5216—Geo-Engineering	...	3	...
Geo 1111, 3401—Physical Geology, Introductory Mineralogy	5	5	...
Geo 3103—Structural and Field Geology	...	...	5
CE 3100—Surveying	...	...	4
Liberal Education Electives	4	4	4

Geology Summer Field Trip (4 weeks or more) 6

Fourth Year

GeoE 5180—Geochemical Exploration	3	...	...
GeoE 5437—Computer Applications in Geo- and Mineral Engineering	4	...	...
GeoE 5262—Geo-Engineering Analysis	...	...	4
GeoE 3012—Geo-Engineering Surveying	...	...	4
MinE 5642—Mineral Economics	...	3	...
MinE 5830—Microscopy for Mineral Engineers	...	...	3
Geo 5351—Metal Sulphide Deposits	4	...	...

	Credits f	w	s
Geo 5512—Principles of Seismic Exploration	...	3	...
Geo 5513—Principles of Electrical Exploration	...	...	3
CE 3300—Elements of Soil Mechanics	4	...	...
Technical Electives (geology or geo-engineering)	...	4	...
Technical Electives	...	8	...
Geology Electives	...	...	4

Geology and Geophysics

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

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 include private industry, research institutions, universities, and governmental agencies. An advanced degree is generally necessary for research and development work or teaching.

The undergraduate curriculum is designed to provide a strong foundation in physics, mathematics, and chemistry. The geophysics program emphasizes the first two. The geology program is built around a core of seven basic courses taken during the second and third years. Some students select a geology or geophysics major simply to obtain this broad science base.

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; and magnetic, thermal, and electrical properties applied to topics ranging from continental drift to mineral exploration.

Selection of a degree program should be made during the second year, although a later decision is possible. Both degree programs offer a good foundation for students preparing for graduate work or for those planning to enter professional work with a baccalaureate degree.

GENERAL REQUIREMENTS

	Credits
CLE requirements	36

Specific courses required of all students. These should be taken on A-N grading except Comp 3085 or 3090.

Freshman Year: Spring: Geo 1111—Introductory Physical Geology (5 cr)

Sophomore Year: Fall: Geo 3112—Earth History (5 cr)
Winter: Geo 3401—Introductory Mineralogy (5 cr)
Spring: Geo 3102—Petrology (5 cr)

Junior Year: Fall: Geo 3100—Sedimentary Petrology (5 cr)
Winter: Geo 3101—Surficial Geologic Processes (5 cr)
Geo 5501—Geophysical Methods in Geology (4 cr)[1] (will be offered first time winter quarter 1982)
Spring: Geo 3103—Structural Geology (5 cr)

Summer After Junior Year: Geo 5110—Field Camp (9 cr)

Geology Majors	48
Geophysics Majors	44
Math 1211, 1221, 1231, 3211 (should be taken as early as possible, preferably beginning in the freshman year)	20
Phys 1271, 1275, 1281, 1285, 1291, 1295 (should be taken early if possible)	15
Chem 1004, 1005 (should be taken early, preferably in the freshman year; Chem 1004 is a prerequisite for Geo 3401)	10
Comp 3085 or 3090—Advanced Writing (should be taken late in junior or early in senior year)	4

[1]Not required for geophysics majors.

	Credits
Free Electives	
Geology Majors	20
Geophysics Majors	18
Subtotal, Geology Majors	153
Subtotal, Geophysics Majors	147

ADDITIONAL REQUIREMENTS FOR IT GEOLOGY MAJORS

These courses should be taken on A-N grading, unless available only on S-N. Specific courses should be chosen in consultation with the adviser.

Additional cognate sciences *to total at least 24 credits*, including:	
Math 3221 (recommended for most students) or Stat 3091	4 or 5
Chem 1006 and 5520, or Chem 5520 or Geo 5303 (or) Chem 3301, 3302 (or) BioC 1301, 1302	9 or 10
Additional science credits chosen from: Physics (3000 level or above; 3501 recommended) Mathematics (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 Computer Science (no more than 4 cr at 1000 level can be applied) Other science courses, as suitable, with departmental consent	9-11
Minimum Requirements	24
Additional geology or geophysics electives, to be chosen from 5000 level or above. Geo 3099 may be used, but 8098 may not	12
Subtotal	36
Total Credits Required for Geology Major	189

ADDITIONAL REQUIREMENTS FOR IT GEOPHYSICS MAJORS

Phys 3501, 3505, 3011	9
Math 3221	5
Geophysics chosen from Geo 5500 series courses	9-12
Geology, mathematics, physics, electrical engineering, chemistry, or computer science courses chosen in consultation with the adviser, from the following: Geo 3099, 5253, 5351, 5303, 5611, 5652 Math 3231, 3142, 5512, 5457-5458-5459, 5567, 5568 Stat 3091 Phys 5021-5022, 5023-5024 EE 3100-3101 Chem 5520-5521 CSci 1100, 1101, or 3101	16-19
Subtotal	42
Total Credits Required for Geophysics Major	189

Other courses from these departments may be chosen with the adviser's consent.

Industrial Engineering/Operations Research

(Department of Mechanical Engineering)

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

Industrial engineering is concerned with the design, improvement, and installation of integrated systems of labor, 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 produced by such industrial systems. The industrial engineer studies product designs to adapt them for production, determines an optimal system for 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—Advanced Mechanical Engineering Laboratory	
ME 5260—Engineering Materials and Processing	
ME 5254—Design Morphology With Applications	
Liberal Education Electives	18
Coherent Elective Program	22

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 to students who meet the entrance requirements of the Graduate School. See the *Graduate School Bulletin* for specifics.

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 that results from the development of land for specific human use.

The landscape architect is concerned with a wide range of projects: 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. 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, 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, and others. 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 recommendations.

Bachelor of Landscape Architecture (B.L.A.) Program—This five-year program emphasizes the design process and developing skill in its application. The B.L.A. program is offered jointly by the College of Agriculture and the Institute of Technology. The program is designed to provide the basic professional training for the practice of landscape architecture and to allow for exploration of one or more areas of professional interest. It leads to the professional degree bachelor of landscape architecture.

A total of 230 credits are required for graduation. Of this total, 132 credits are completed in the upper division. The upper division work includes a sequential design-course program that takes a minimum of three years to complete.

It is recommended that all students complete a minimum of 800 hours of 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.

Bachelor of Environmental Design (B.E.D.) Program—This nonprofessional program is offered only through the Institute of Technology. It is designed to allow the student to explore a broad range of environmental courses as well as complete two years of professional courses in landscape architecture. Upon completion of the B.E.D. degree requirements, a student may continue on for the professional B.L.A. degree, enter a professional master's degree program, or transfer to another discipline such as city design, city and regional planning, or an area of the social or natural sciences.

A total of 192 credits are required for the B.E.D. degree. It is recommended that all students also complete 400 hours of summer work in landscape architecture. Individualized study programs may be arranged with approval of the faculty.

In both degree programs, required core courses must be passed with a minimum grade of C. These courses are: LA 3071, 3072, 5226, 1025, 1026, 3101, 5261, 5263, 5265, 5117, 5118; 5119; Hort 1021, 1022; and all design courses.

Admission Procedures

To enter the landscape architecture program students must submit an application. Admission to the program is permitted only in the fall quarter unless advanced standing is granted. The deadline for submitting an application is May 1 of the year of desired entry. The procedure and requirements are as follows:

1. Apply to the University of Minnesota if not already a University of Minnesota student. Forms may be obtained from the Office of Admissions, 240 Williamson Hall, 231 Pillsbury Drive S.E., University of Minnesota, Minneapolis, Minnesota 55455; or the Office of Admissions, 130 Coffey Hall, 1420 Eckles Avenue, University of Minnesota, St. Paul, Minnesota 55108.
2. Before an application will be considered, a student must have completed a minimum of 75 credits of required pre-LA courses; courses taken the quarter of current enrollment may be included. This total must include at least 8 credits in basic English or communications, 10 credits in physical and biological sciences, 8 credits in mathematics, 6 credits in social sciences, 12 credits in studio arts or design, and 8 credits in landscape architectural, environmental, or design theory.
3. Complete the landscape architecture program application form (available from the Department of Horticultural Science and Landscape Architecture, St. Paul; the School of Architecture and Landscape Architecture, Minneapolis; or either Office of Admissions identified above).

4. Submit a letter of intent stating the reasons for selecting landscape architecture as a profession. This letter, generally consisting of one or two pages, should give an account of the student's reason for becoming interested in the field and in becoming a landscape architect, experience in landscape architecture or related fields (art, horticulture, architecture, engineering, construction, etc.), experience or participation in other interests (travel, hobbies, avocations, etc.) and perception of herself or himself in the role of a landscape architect.
5. Submit an official transcript of all college work completed to date at the University of Minnesota and other colleges. Generally, a student must have a grade point average of 2.50 or higher for admittance.
6. Submit a portfolio of art or design work, environmental or design reports, photographs of sculptural work, slides, or similar examples of creative work. It is suggested that the portfolio be a bound 8½-by-11-inch booklet. A portfolio that is larger than 24 by 36 inches will not be accepted. Material not enclosed in a carrying case is also unacceptable. Any slides must be in an 8½-by-11-inch transparent slide carrier. It is recommended that the student bring the portfolio to the interview with the faculty member.
7. Interview or correspond with at least two landscape architecture faculty members prior to the May 1 application deadline. Specific times for interviews should be arranged with the individual instructors. The interview or correspondence is used to judge the student's commitment to finish the landscape architecture design program and to determine the student's enthusiasm for landscape architecture and sensitivity to people and the environment. It allows the student to demonstrate his or her design, communication, and organizational skills. From the interview the faculty members will judge the student's insight into landscape architecture, maturity, dedication and sincerity, self-confidence, demonstrated design abilities, and potential.

Applicants are encouraged to visit the design studios and talk to students who are in the program and to find out as much about the profession as they can.

The landscape architecture faculty votes on each applicant. The applicant is either admitted to the program, rejected, or assigned pre-landscape-architecture status. Approval for admission is based on consideration of the following:

1. The student's academic standing and grade point average.
2. The student's maturity and experience.
3. The student's letter of intent.
4. The estimated design potential of the student.
5. The availability of staff and space.

Applicants will be notified by letter of the admission decision not later than June 1. Those admitted must notify the landscape architecture program chair of their intention to attend by July 1, or their place will be forfeited. Those not accepting the opportunity must reapply if they wish to enter the program at a later date.

BACHELOR OF LANDSCAPE ARCHITECTURE

LOWER DIVISION (IT and IAg)

	Credits
Core Course Requirements	98
Communications	
Basic Composition (8)[1]	
Speech (4)[1]	

[1] Courses should be selected, in consultation with the adviser, to complete the Council on Liberal Education requirements specified by the student's college.

Mathematics (two courses or 8 credits in mathematics, statistics or computer science; college algebra or higher mathematics must be one of the two courses)[1]
Physical and Biological Sciences (18)[1]
The Individual and Society (16)[1]
Literary and Artistic Expression (8)[1]
Studio Arts (12)[1]
Landscape Architecture Theory (select two) (8):
LA 1001
LA 1002
LA 1003
LA 1024
LA 1031
Landscape Architectural History (8)
LA 1021, 1022
Landscape Architecture Technology (8):
AgET 1400
Soil 1122

Following substantial completion of the above requirements the student must apply for admission to the program before May 1 of the year of desired entry.

UPPER DIVISION (IT and IAg)

	Credits
Core Course Requirements	92
Hort 1021, 1022	
LA 3071, 3072	
LA 3081-3082-3083	
LA 3091-3092-3093	
LA 5110	
LA 5226	
LA 1025	
LA 1026	
LA 3101	
LA 5117, 5118, 5119	
LA 5261, 5263, 5265	
Rhet 3551	
Design Option and Option Support Requirement	28
Elective Requirements	12

BACHELOR OF ENVIRONMENTAL DESIGN

LOWER DIVISION (IT only)

Core Course Requirements	85
Basic Composition (8)	
Math 1211-1221-1231	
Biology and Botany (10)	
Physical Geology (5)	
Physical Geography (5)	
ArtH 1001	
ArtS 1107, 1108, 1109	
LA 1001, 1002, 1003	
LA 1021, 1022, 1023	
Soil 1122	
AgET 1400 or CE 3100	
Elective Requirements[1]	12

Following substantial completion of the above requirements the student must apply for admission to the program before May 1 of the year of desired entry.

[1] Courses should be selected, in consultation with the adviser, to complete the Council on Liberal Education requirements specified by the student's college.

UPPER DIVISION (IT only)

	Credits
Core Course Requirements	72
Hort 1021, 1022	
LA 1025, 1026, 3101	
LA 3071, 3072, 3075	
LA 3081-3082-3083	
LA 3091-3092-3093	
LA 5117, 5118	
LA 5261, 5263	
Ecology (4)[1]	
Elective Requirements[1]	24

Mathematics

The School of Mathematics offers programs leading to the bachelor of mathematics (B.Math.) degree through the Institute of Technology and the bachelor of arts (B.A.) degree through the College of Liberal Arts. Information about the B.A. program can be found in the *College of Liberal Arts Bulletin.*

The course of study for the B.Math. degree is very flexible and can be adapted to satisfy a wide variety of interests and needs. Programs can emphasize diverse fields of interest such as applied mathematics, computer science, or actuarial science; sample curricula for some of these specializations are available in 127 Vincent Hall. The program also offers good preparation for graduate study.

In addition to the prescribed courses listed below, a student must complete the minimum liberal education requirements of the Institute of Technology. A total of 186 credits are required.

Majors are required to see a mathematics adviser at least once each year to plan their programs for the following year; appointments can be made in 127 Vincent Hall. Appointments can also be made with the mathematics placement director to discuss job opportunities and requirements.

All courses in the major must be taken on A-N grading.

MATHEMATICS REQUIREMENTS

1xxx Level—one freshman sequence: calculus of functions of a single variable
- Math 1211-1221-1231—Calculus I-II-III
- (or) Math 1311-1321-1331—Computer Calculus I-II-III
- (or) Math 1511-1521-1531—Honors Calculus I-II-III
- (or) Math 1611-1621—Accelerated Calculus I-II

3xxx Level—one sophomore sequence: multivariable calculus, some linear algebra, and some ordinary differential equations

Math 3511-3521-3531; 3211, 3142, 3066; 3211, 3221, 3231; 3211, 3221, 3675; or 3611-3621-3631. Majors with high ability are urged to take 3511-3521-3531.

5xxx Level—at least 48 credits including

One Analysis Sequence
- Math 5601-5602-5603—Advanced Calculus
- (or) Math 5612-5613-5614—Introduction to Analysis
- (or) Math 5601-5602, 5612—Advanced Calculus, Introduction to Analysis

One Algebra Sequence
- Math 5262-5263-5264—Modern Applied Algebra
- (or) Math 5282-5283-5284—Fundamental Structures of Algebra
- (or) Math 5242-5243—Linear Algebra With Applications or 5232-5233—Computer-Oriented Linear Algebra together with 5244—Group Theory or one of 5262 or 5282 when the content is not linear algebra

One Sequence for Depth (approval of director of undergraduate studies required for selection of any other sequence)
- Math 5162-5163-5164—Mathematical Logic
- (or) Math 5341-5342-5343—Introduction to Topology
- (or) Math 5375-5376-5377—Differential Geometry
- (or) Math 5457-5458-5459—Methods of Applied Mathematics

[1] Courses should be selected, in consultation with the adviser, to complete the Council on Liberal Education requirements specified by the student's college.

(or) Math 5473-5474-5475—Approximation Theory and Theory of Numerical Analysis
(or) Math 5521-5522-5523—Introduction to Ordinary Differential Equations
(or) Math 5571-5572-5573—Elementary Partial Differential Equations
(or) Math 5681-5682-5683—Introduction to Probability
(or) Math 5701, 5702, 5703—Combinatorics, Graph Theory, Algorithms
Stat 5131-5132-5133—Theory of Statistics

OTHER TECHNICAL REQUIREMENTS

One course in computer science
Phys 1271-1281-1291—General Physics; the associated lab courses Phys 1275-1285-1295 are recommended but not required
Technical Elective: any three 3xxx- or 5xxx-level technical courses that form a coherent part of the student's program and have calculus as a prerequisite (approval of math adviser required for selection of courses)

Mechanical Engineering

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

The department program is designed to provide preparation for a career in mechanical engineering or for graduate work. A strong background in the basic sciences of mathematics, physics, and chemistry, balanced with courses in engineering science and applied engineering, is emphasized. Through electives, each student has an opportunity to develop a program of study that reflects his or her particular area of interest.

Degree Requirements—The four-year curriculum requires 190 quarter credits and leads to the bachelor of mechanical engineering (B.M.E.) degree.

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

Elective Programs

Interdisciplinary programs involving work in other departments are available. Students are encouraged to work with their adviser in formulating a cross-disciplinary program to meet their particular objectives.

The mechanical engineering program consists of a minimum of 28 liberal education elective credits, a coherent technical elective program of approximately 24 credits, and 4 free elective credits. Thus the student has the responsibility of selecting 56 credits of course work. Students should work closely with their adviser in planning their elective work. A list of suggested programs is available in the Advising and Information Center, 121 Mechanical Engineering. Some of the available areas of specialization are listed below:

Power and Propulsion
Design and Controls
Thermodynamics and Heat Transfer
Materials Engineering
Environmental Engineering
Industrial Engineering/Operations Research
Bioengineering
Solar Energy
Nuclear Engineering
Electrical Engineering Emphasis
Transportation Emphasis

Graduate Study in Mechanical Engineering

Designated master's degree programs in mechanical engineering (M.M.E.) and industrial engineering (M.I.E.) are offered by the Institute of Technology through the Graduate School. Information about these programs is available in the department office, 125 Mechanical Engineering. In addition, M.S. and Ph.D. programs with a major in mechanical or industrial engineering are open to students who meet the entrance requirements of the Graduate School.

Special Programs in Mechanical Engineering

Coherent Elective Program—The coherent elective program in mechanical engineering offers students the opportunity to pursue interdisciplinary study involving several departments as well as work in the community and industry. Information about this program is available in 121 or 125 Mechanical Engineering. A brief description of a number of the interdisciplinary study opportunities is presented below:

Bioengineering—Project work in bioengineering is available. In addition, students can combine elective work in biology, physiology, chemistry, fluid flow, and similar areas with related engineering courses to prepare for work or graduate study in bioengineering. Students preparing for work in bioengineering may also plan their studies 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 a variety of closely related areas. In addition, propulsion courses relating to vehicle transport as well as a course in urban transportation are offered.

Environmental Engineering—The 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, and related areas 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 two years of study. Completion of the major part of the lower division academic curriculum with a satisfactory grade point average is required for admission. Application must be made in January of the sophomore year. The program provides applied engineering training in selected established industries during quarters of supervised assignments that alternate with quarters of University studies. Participants register at the University during work periods and are considered regular full-time students.

The B.M.E. degree is awarded upon satisfactory completion of the required mechanical engineering curriculum work as well as four quarters of 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 are selected on the basis of scholastic ability, 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 the program may also apply for the engineering intern program in mechanical engineering. For further information, see the Industrial Engineering/Operations Research program description.

Preparation for Other Programs—By careful selection of liberal education electives and coherent program electives, the student can prepare for subsequent study in a number of other fields including business, law, and medicine.

Course Requirements

The lower division program includes course work in basic and engineering science preparatory for studies in the upper division. The upper division program includes course work in additional engineering science and applied engineering subjects such as measurements and design. Further details and information about alternate course selections, coherent elective programs, areas of specialization, and changes in course or credit requirements, as well as supplemental departmental brochures, are available in 121 Mechanical Engineering or from the adviser.

LOWER DIVISION

	Credits
Freshman English or Communication	8
Math 1211, 1221, 1231, 3221, ME 3900[1]—Calculus I, II, III, Introduction to Linear Algebra and Linear Differential Equations, Engineering Statistics	24
Phys 1271, 1281, 1291—General Physics	12
Phys 1275, 1285, 1295—General Physics Laboratory	3
Chem 1014, MatS 3400[1] and an additional course in chemistry, biology, ecology, geology, mathematics, or physics	12
Introduction to Engineering[1] ME 1025—Graphics; CSci 3103, 3131—Introduction to FORTRAN Programming; ME 1001—Introduction to Mechanical Engineering (optional)	9
Engineering Science AEM 3036—Dynamics; AEM 3016—Deformable Body Mechanics; EE 3000—Circuits[1] CE 3400 or AEM 3200—Fluid Mechanics; AEM 1011—Elements: Statics	18
Liberal Education Electives (approximately)	8
Total Credits	94

UPPER DIVISION

Basic Engineering Program 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	40
Laboratory Program ME 3701-3702—Basic Measurements Laboratory I, II (4) ME 3703-3704—Advanced Mechanical Engineering Laboratory (4)	8
Liberal Education Electives (sufficient to complete liberal education requirements)	20
Coherent Elective Program[2]	24
Free Electives	4
Total Credits[3]	96

[1]For a complete description of the lower division program, alternate course selections, and suggested scheduling, students should obtain the curriculum brochure in 121 Mechanical Engineering.

[2]See information about coherent elective programs under the heading Special Programs in Mechanical Engineering, and obtain the program brochure in 121 Mechanical Engineering.

[3]Credit and course requirements are subject to change by faculty action.

Metallurgy/Materials Science

(Department of Chemical Engineering and Materials Science)

Metallurgists and materials engineers select and develop metals and alloys, ceramics, and plastics to meet diverse engineering needs. Products composed of these materials 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 and test the performance of new products and their component parts.

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

Industry/Organization	*Metallurgical Engineering Tasks*
aircraft	create fatigue, fracture, corrosion, and heat resistant materials for use in products such as landing gear or 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 for electronic circuitry
consumer advocates	analyze material failures and recommend solutions for increased product reliability
energy	develop reliable materials for coal gasification or fission reactors as well as unique compounds for energy storage, conversion, and transmission
medical-dental	create and evaluate potential prosthetic materials
nuclear	develop reliable materials for long-term containment of 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 circumvent existing time-environment barriers in aerospace and ocean space exploration

The curriculum is based on a foundation of mathematics, physics, and chemistry course work, plus specialized professional course work in areas such as materials science, physical and mechanical metallurgy, thermodynamics, polymer engineering and corrosion, and related laboratory studies.

Degree Requirements—To receive the bachelor of metallurgical engineering (B.Met.E.) degree, 200 credits are normally required (although the minimum, in special cases, may be 195). Students must complete the IT minimum liberal education requirements (a total of 36 credits including at least 4 in biological science), the pre-metallurgical-engineering program (91 to 100 credits), and a coherent program of science and technical course work (91 to 100 credits).

Suggested lower division and upper division curricula are outlined below. Students, together with an adviser, plan their degree program in two stages: a one-year plan is submitted at the beginning of the third year, and, ordinarily, a complete four-year program is submitted for certification by the department by the beginning of the fourth year. Degree programs may emphasize metallurgy or materials science and may be oriented toward graduate work or professional employment after graduation. Sample programs are available from advisers or from the departmental office, 151 Amundson Hall.

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

Transfer Students—Normally, students intending to transfer from another campus or school with lower division standing in general engineering have satisfied most course requirements or have equivalent course work to offer. For specific information, prospective transfer students should write or visit the Department of Chemical Engineering and Materials Science, 151 Amundson Hall, 421 Washington Avenue S.E., University of Minnesota, Minneapolis, Minnesota 55455. Students can obtain certification of completion of the lower division requirements at the time of transfer.

LOWER DIVISION

First Year

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

Second Year

Phys 1271, 1281, 1291—General Physics	4	4	4
Phys 1275, 1285, 1295—General Physics Laboratory	1	1	1
Math 3211, 3221—Multivariable Calculus, Introduction to Linear Algebra and Linear Differential Equations	5	5	...
EBB 3101—Ecology for Students of Physical Science (or biology alternative)	...	4	...
AEM 1002, 3016—Statics and Deformable Body Mechanics	2	...	4
Technical Electives	4-5	...	0-5
Liberal Education Electives	0-4	0-4	4-8
Total Credits, Lower Division Program			95-105

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

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

UPPER DIVISION

Third Year

	Credits		
	f	w	s
MatS 5011-5012-5013—Introduction to Materials Science	4	4	4
Chem 5534—Chemical Thermodynamics	4	...	...
CSci 1001, 3131 Introduction to FORTRAN, FORTRAN Laboratory	2	2	...
MatS 5101, 5102—Thermodynamics and Kinetics	...	4	4
MatS 3501, 3521—Quantitative and X-Ray Metallography	...	3	3
MinE 5818—Hydometallurgy (or) MinE 5820—Principles of Metal Extraction	...	4	...
MinE 5910—High Temperature Metallurgical Processes	...	4	...
Technical Electives	4	0-4	...
Liberal Education Electives	...	0-4	0-4

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—Introduction to Polymers	4	...	...
(or) MatS 5630—Polymer Physical Properties	...	...	4

	Credits f	w	s
MatS 5450—Corrosion of Metals (or) Chem 5535—Statistical Mechanics and Reaction Kinetics (or) Phys 3501—Modern Physics	...	4	0-4
AEM 5580—Mechanics of Elastic Solids (or) ME 5207—Experimental Stress Analysis	4	...	...
Technical Electives	...	4	0-4
Liberal Education Electives	0-4	3-4	3-4
Total Credits, Upper Division 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 (including coal and industrial minerals), 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, size 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 the disciplines and processes of mineral production and mineral and metal extraction. This field of study is closely allied with geoengineering.

The undergraduate curriculum includes preparation in basic sciences, engineering, geology, and economics. There is some overlap between the disciplines of mineral production and mineral and metal extraction, since the production engineer and the extractive engineer must be knowledgeable about 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 mineral engineering courses in the program address the environmental aspects of the mineral industry. The program also includes field trips.

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

The four-year curriculum leads to the degree of bachelor of mineral engineering (B.Min.E.). A total of 196 credits are required for graduation.

The following schedule lists the required courses. It can be modified, in consultation with a faculty adviser, to meet the interests and needs of the individual student. The final program must be approved by the Undergraduate Studies Committee for graduation.

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

Note: Courses for which the credits are listed in brackets are for students with a processing interest. Courses for which the credits are listed in parentheses are for students with a production interest.

LOWER DIVISION

First Year

	Credits f	w	s
Math 1211-1221-1231—Calculus I, II, III	5	5	5
Chem 1004-1005, 1006—General Principles of Chemistry, Principles of Solution Chemistry	5	5	[4]

	Credits		
	f	w	s
Comp 1001-1002—Introductory Composition	4	4	...
Phys 1271—General Physics	...	...	4
Phys 1275—General Physics Laboratory	...	...	1
Liberal Education Electives	4	4	(4)
	18	18	14

Second Year

Math 3221—Introduction to Linear Algebra and Linear Differential Equations	5	...	...
Phys 1281-1291—General Physics	4	4	...
Phys 1285-1295—General Physics Laboratory	1	1	...
AEM 1015—Statics	...	4	...
AEM 3016—Deformable Body Mechanics	...	...	4
Stat 3091 or ME 3900—Statistics	...	...	4
Geo 1111—Introduction to Physical Geology	...	...	5
CE 3400—Fluid Mechanics	...	...	4
ME 1025—Engineering Graphics	4	...	...
Liberal Education Electives	4	8	...
	18	17	17

UPPER DIVISION—
MINERAL DEVELOPMENT, PRODUCTION, AND ECONOMICS INTEREST

Third Year

MinE 5611, 5612, 5613—Mineral Resources I, II, III	4	4	4
MinE 5437—Computer Applications	4	...	...
MinE 5720—Mineral Plant Engineering I	4	...	...
Geo 3103—Structural and Field Geology	...	...	5
Geo 3401—Introductory Mineralogy	...	5	...
ME 3301—Thermodynamics	...	4	...
CE 3100—Introduction to Surveying and Mapping	...	...	4
CE 5600—Linear Structural Systems	...	4	...
Electives	4	...	4
	16	17	17

Summer

MinE 5619—Engineering Field Study ..... 3 credits

Fourth Year

MinE 5630—Surface Mining	4	...	...
MinE 5650, 5652—Mineral Engineering Design I, II	...	4	4
MinE 5640—Introduction to Economics of the Mineral Industries	...	4	...
GeoE 5302—Applied Rock Mechanics	...	...	4
MinE 5800—Mineral Processing I	4	...	...
CE 3300—Elements of Soil Mechanics	4	...	...
Technical Electives	4	8	...
	16	16	16

UPPER DIVISION—
MINERAL PROCESSING AND EXTRACTIVE METALLURGY INTEREST

Third Year

MinE 5611, 5612, 5613—Mineral Resources I, II, III	4	4	4
MinE 5800, 5810, 5820—Mineral Processing I, II, Principles of Metals Extraction	4	4	4

	Credits		
	f	w	s
Geo 1111, 3401—Physical Geology, Introductory Mineralogy	5	5	...
MinE 5825—Metallurgical Heat Transfer	...	4	...
MinE 5830—Microscopy for Mineral Engineers	...	...	3
EE 3002—Electrical Machinery	5	...	...
Liberal Education Electives	...	...	7
	18	17	18

Summer

MinE 5619—Engineering Field Study ..... 3 credits

Fourth Year

Chem 5520, 5521—Elementary Physical Chemistry	3	3	...
MinE 5700—Systems Analysis	...	...	4
GeoE 5437—Computer Applications	4	...	...
MatS 3400—Mechanical Properties	4	...	...
MinE 5650, 5652—Mineral Design I, II	...	4	4
MinE 5710—Environmental Aspects of Mineral Engineering	...	...	4
MinE 5815—Mineral Processing III	...	3	...
MinE 5818—Hydrometallurgy	...	...	4
MinE 5910—Metallurgical Unit Processes	5	...	...
MinE 5920—Metallurgical Processes	...	2	...
Liberal Education Electives	...	5	...
	16	17	16

Physics

(School of Physics and Astronomy)

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 another area such as biology, medicine, law, or business. Students interested in a career as a high school teacher may wish to consider the four-year program in the College of Education leading to a B.S. degree with a major in physical science. This program leads to teaching licensure. Information about physics programs is available in the undergraduate office, 148 Tate Laboratory of Physics.

Normally, students who fail to earn A or B grades in the freshman mathematics and physics courses will have difficulty pursuing a physics major.

Because of the varied interests of students pursuing this degree program, 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 when planning their program. Sample programs emphasizing various areas of interest are available in the undergraduate office.

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

If a student must complete English composition courses at the University of Minnesota, the number of credits required for graduation may increase by as much as eight credits.

If a student has not had three years of foreign language study in high school, he or she must complete the third quarter of a foreign language at the college level. College-level language courses usually carry five credits per quarter, and of those five credits, three are

added to the graduation requirements and two may be applied toward the liberal education requirements described below. For a student who must take three language courses (15 credits) at the college level, this means that nine additional credits are required for graduation and six credits are applied toward the liberal education requirements.

To summarize, the number of credits required for graduation can vary as follows:

	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 composition credits may not be counted toward the 36 liberal education credits required (see below).

GENERAL REQUIREMENTS

(Based on 180 credits)

	Credits
Liberal Education	36
Of these 36 credits, at least three courses (12-15 credits) must be in Group C (The Individual and Society), and at least two courses (8-10 credits) must be in Group D (Literary and Artistic Expression). The remaining courses may be in any category but not in the areas of computer science, mathematics, or the physical sciences. At least two of the courses must be at the 3000 or 5000 level.	
Mathematics	
Math 1211-1221-1231 (or) Math 1311-1321-1331 (or) Math 1611-1621	15
Math 3211-3221-3231 (or) Math 3511-3521-3531 (or) Math 3611-3621	10-15
Two additional courses at 5000 level	8
Physics	
Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
Phys 3011—Oscillations	4
Phys 3015—Laboratory in Oscillations and Waves	1
Phys 3201—Thermodynamics (or equivalent)	4
Phys 3511-3512-3513—Modern Physics	12
Phys 3515—Modern Physics Laboratory	1
Phys 5021-5022—Introduction to Analytic Mechanics	8
Phys 5023-5024—Introduction to Electric and Magnetic Fields	8
Phys 5101—Introduction to Quantum Mechanics	4
Phys 5121-5122-5123—Methods of Experimental Physics	13
Electives to total 180 credits	37-41
Subtotal	180
English and/or Foreign Language as required	0-17
Total Credits	180-197

SAMPLE PROGRAM

First Year

Phys 1271-1281-1291—General Physics	12
Phys 1275-1285-1295—General Physics Laboratory	3
(or) Phys 1271-1281—General Physics	8
(and) Phys 1275-1285—General Physics Laboratory	2
Math 1211-1221-1231—Calculus I, II, III	15
English Composition (if required), Foreign Language (if required), and/or Liberal Education Electives	15-25

(Students may wish to consider Phys 1071, 1075—Introductory Meteorology, Laboratory or Ast 1021, 1025—Introduction to Astronomy, Laboratory as first-year electives.)

Second Year

Phys 1291, 1295—General Physics, Laboratory (if not completed)	5
Phys 3011-3015—Oscillations, Laboratory	5
Phys 3201—Thermodynamics	4
Phys 3511-3512-3513-3515—Modern Physics, Laboratory	13
Math 3211-3221-3231—Multivariable Calculus, Introduction to Linear Algebra and Linear Differential Equations, Vector Analysis	14
Foreign Language (if required) and/or Liberal Education, Technical Electives	4-15

Third Year

	Credits
Phys 5021-5022—Analytic Mechanics	8
Phys 5023-5024—Electricity and Magnetism	8
Phys 5121-5122-5123—Methods of Experimental Physics	13
Math 5xxx, 5xxx	8
Liberal Education, Technical, Physics or Astronomy Electives	8-18

Fourth Year

Phys 5101—Introduction to Quantum Mechanics	4
Physics or Astronomy, Math, Technical, and Liberal Education Electives	41-48

Physics or astronomy electives might be selected from, but need not be limited to, the following:

Ast 3051—Introduction to Astronomy and Astrophysics
Ast 5161—Astrophysics of Diffuse Matter
Ast 5162—Astrophysics of Condensed Matter
Ast 5163—Galactic and Extragalactic Astronomy
Phys 5031-5032-5033—Topics in Mathematical Physics
Phys 5051-5052-5053—Classical Physics
Phys 5102—Introduction to Quantum Mechanics
Phys 5124—Methods of Experimental Physics: Experimental Project
Phys 5162—Introduction to Plasma Physics
Phys 5202-5203—Statistical Mechanics, Transport Theory
Phys 5231-5232-5233—Introduction to Solid State Physics
Phys 5301—Introduction to Nuclear Physics
Phys 5351—Experimental Particle Physics
Phys 5371—Introduction to Elementary Particle Physics
Phys 5401—Introduction to Contemporary Problems in Cosmic Ray and Space Physics
Phys 5441-5442—Introduction to Dynamic Meteorology
Phys 5451, 5452, 5453—Cloud Physics
Phys 5461—Physics and Chemistry of the Earth's Upper Atmosphere
Phys 5551, 5552, 5553—Topics: Physics for Biology and Medicine
Phys 5801—Modern Optics
Phys 5805—Contemporary Optics
Phys 5924, 5925—History of Physics

Electives—The curriculum includes 37 to 41 credits of unspecified electives. Because the specified physics courses represent a minimum requirement, most students will want to take some of their unspecified electives in physics or allied areas.

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

Electives Suggested for Students Interested in Graduate Study in Physics

Continuation of Introduction to Quantum Mechanics (Phys 5102)
Specialized courses in physics (e.g., nuclear, solid state, elementary particle, plasma, optics)
Topics in Mathematical Physics (Phys 5031-5032-5033)
Statistical Mechanics (Phys 5202-5203)
Methods of Experimental Physics: Experimental Project (Phys 5124)
Classical Physics (Phys 5051-5052-5053)
Quantum Mechanics (Phys 5151-5152-5153)
Astronomy (Ast 3051, 5161, 5162, 5163)
Mathematics
Chemistry
Computer Programming
History of Physics

Electives Suggested for Students Interested in Industrial Employment or Graduate Study in Engineering

Methods of Experimental Physics: Experimental Project (Phys 5124)
Introduction to Solid State Physics (Phys 5231-5232-5233)
Chemistry
Computer Science
Specialized courses in physics
Technical Writing (Comp 3085)
Electrical Engineering

Aerospace and Engineering Mechanics (fluid mechanics, elasticity, acoustics)
Topics in Physics for Biology and Medicine (Phys 5551, 5552, 5553)
Materials Science
Geophysics

Electives Suggested for Students Interested in Graduate Study in Other Professional Schools

Biology, Dentistry, or Medicine
- Topics in Physics for Biology and Medicine (Phys 5551-5552-5553)
- Biology
- Biophysics
- Physiology

Meteorology
- Meteorology (Phys 1071, 1075, 5441-5442, 5461)
- Cloud Physics (Phys 5451, 5452, 5453)

Business School
- Computer Programming
- Economics
- Statistics

Statistics

Statistics deals with methods and theories of data collection, tabulation, and analysis and interpretation, and with the use of data for inference and decision making in industrial, scientific, and governmental enterprises. Students considering professional careers as statisticians should have an aptitude for mathematics and the ability to reason logically. Statistics majors are encouraged to acquire a thorough knowledge in a second academic area such as some branch of engineering or computer science.

The School of Statistics offers a four-year curriculum leading to the bachelor of statistics (B.Stat.) degree.

The School of Statistics includes the Department of Applied Statistics and the Department of Theoretical Statistics. While a program may emphasize work in theory or in applications, all programs include some concentration on both theory and applications.

In addition to the prescribed courses listed below, a student must complete the minimum liberal education requirements for the Institute of Technology and approved electives. A total of 186 credits are required for the degree. Programs are flexible and can be planned to emphasize such interests as industrial engineering, operations research, computer science, or actuarial science.

Students wishing to plan a program in statistics should make an appointment with the director of undergraduate studies in 270 Vincent Hall.

LOWER DIVISION

	Credits
Calculus of a Single Variable	
Math 1211-1221-1231	15
(or) Math 1311-1321-1331	15
(or) Math 1611-1621	10
Elements of Computer Programming	
CSci 1100-1101	4
(or) CSci 3101	4
Multivariable Calculus, Linear Algebra	
Math 3511-3521	9
(or) Math 3211, and 3221 or 3142	9 or 10
(or) Math 3611-3621	10
Physics and Chemistry	
Phys 1271-1275-1281-1285-1291-1295	15
Chem 1014	4
Statistics	
Stat 3091	4

UPPER DIVISION

	Credits
Stat 5021-5022—Statistical Analysis	10
Stat 5131-5132-5133—Theory	12
Stat 5302—Applied Regression	4
Statistics Electives—12 credits chosen from:	
Stat 5201—Sampling Methodology in Finite Populations	4
(or) QA 5171—Statistical Methods for Sample Surveys	4
Stat 5301—Designing Experiments	4
(or) IEOR 5550-5551—Design and Analysis of Experiments	8
Stat 5401—Introduction to Multivariate Methods	4
Stat 5421—Analysis of Categorical Data	4
Stat 5601—Nonparametric Methods	4
IEOR 5531—*Industrial Sampling Techniques*	4
Technical Electives—20 credits of adviser approved, 5000-level technical courses that form a coherent program in statistics and related areas; e.g., computer science, mathematics, industrial engineering, operations research, management science. *The following courses are suggested:*	
CSci 5001—Linear Programming Algorithms	4
CSci 5002—Nonlinear Programming	4
CSci 5101-5102—*Structure and Programming of Software Systems*	8
CSci 5104—System Simulation	4
CSci 5301-5302—Numerical Analysis	8
EE 5702—Stochastic Processes and Optimum Filtering	3
IEOR 5000—Industrial Engineering Analysis	4
IEOR 5010—Work Analysis	4
IEOR 5030—Quality Control and Reliability	4
IEOR 5040, 5441-5442—Operations Research	12
IEOR 5361—Inventory and Production Control	4
Math 5612-5613-5614—Analysis	12
Math 5681-5682-5683—Probability	12

An IT student evaluates data while testing a computer program in the Lind Hall computer science laboratory.

IV. COURSE LISTINGS

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

* Courses in which graduate students may prepare Plan B projects.

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

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

¶ Concurrent registration is allowed (or required) in the course listed after the paragraph mark.

Consent of the instructor is required prior to registration.

△ Consent of the division, department, or school offering the course is required prior to registration.

H Honors section of a regular course.

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

A hyphen between course numbers (e.g., 3142-3143-3144) indicates a sequence of courses that must be taken in the order listed.

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

Courses numbered 8000 or above are open to graduate students only, except by special permission of the dean of the Graduate School.

If a course prerequisite statement specifies a class rank (e.g., 3rd year), no one below that rank may register for the course without special permission from the Scholastic Standards Committee.

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

Special Interest Courses for IT Students

Comp 3085. CONFERENCE COURSE IN ADVANCED WRITING. (1-4 cr; prereq completion of freshman English)
Theory and practice in technical and professional writing.

EBB 3101. ECOLOGY FOR ENGINEERS AND PHYSICAL SCIENTISTS. (4 cr, §1003, §3001, §Biol 1104; not open to biology majors; prereq Math 1231)
The scientific basis for the past and continued existence of life on the earth.

IofT 1020. LEADERSHIP, MANAGEMENT DEVELOPMENT. (1-3 cr; prereq △)

IofT 1222. CAREER PLANNING AND OCCUPATIONAL CHOICE. (1 cr; S-N only; 2 hrs per wk)
Opportunity to learn how to make vocational decisions, gather information about technical careers, become acquainted with the world of work, and assess personal skills, interests, and values.

IofT 3101. INTRODUCTION TO ENVIRONMENTAL TECHNOLOGY. (4 cr; prereq high school physics or chemistry)

IofT 3222. WOMEN AND CAREERS IN TRADITIONALLY MALE FIELDS. (1 cr; S-N only; 2 hrs per wk)
Information about women and careers in medicine, engineering, biological sciences, law, physical sciences, business management, mathematics-computer science, and architecture. Status of women in these fields from early 1900s to present. Guest lectures by women professionals. Life-style alternatives for women with careers.

IofT 5211. INFORMATION SOURCES FOR SCIENCE AND TECHNOLOGY. (2 cr)

IofT 5501. PLASMA CHEMISTRY. (4 cr; prereq #)

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.

Aerospace Engineering and Mechanics (AEM)

1001. AEROSPACE ENGINEERING ORIENTATION. (1 cr; prereq 1st-qtr fr 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.

1011. ELEMENTS OF STATICS. (2 cr; no cr for CE majors; prereq Phys 1271; 1 lect and 2 rec hrs per wk)
Force vectors, resultants, components; particle equilibrium. Moments of forces; the couple. Mechanical systems and the free-body diagram. Equilibrium equations for the rigid body and simple trusses and frames. Coulomb friction.

1015. STATICS. (4 cr, §1011; prereq Phys 1271, Math 1231)
Force and moment vectors; resultants. Principles of statics. Applications to simple trusses, frames, and machines. Distributed loads. Hydrostatics. Properties of areas. Laws of friction.

3016. DEFORMABLE BODY MECHANICS. (4 cr; prereq 1011 or 1015, ¶Math 3221)
Uniaxial loading and deformation. Stress and strain at a point. Forces and moments in beams. Centroids and second moments. Material behavior; linear elasticity. Torsion. Bending of beams of symmetrical section.

3036. DYNAMICS. (4 cr; prereq 1011 or 1015, ¶Math 3221)
Review of particle dynamics. Mechanical systems and the rigid-body model. Kinematics and dynamics of plane systems.

3092. STATICS AND MECHANICS OF MATERIALS I. (4 cr; prereq Math 1221, Phys 1121)
Forces, equilibrium, and free-body diagrams. Analysis of statically determinate plane trusses and frames. Bending of statically determinate beams. Bending stress and shear stress in beams.

3093. STATICS AND MECHANICS OF MATERIALS II. (4 cr; prereq 3092; includes lab period per wk)
Statically indeterminate problems in axial force and beam bending. The three-moment principle for continuous beams. Combined direct and bending stresses. Column buckling. Laboratory tests of mechanical properties of construction materials and of simple structural configurations.

3200. INTRODUCTION TO ENGINEERING FLUID MECHANICS. (4 cr, §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.

3401. INTRODUCTION TO DYNAMICAL SYSTEMS. (4 cr, §ME 3201; prereq 3036)
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; prereq mathematics including vector analysis; 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 theorems to fluid flow. Flow about cylinder. Potential flow in two and three dimensions. Dynamics, Euler equation, Bernoulli 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.

5206. AERODYNAMICS OF LIFTING SURFACES. (4 cr; prereq 5200...knowledge of FORTRAN recommended or #)
Pressure distributions, forces, and moments on airfoils and wings of finite span. Analysis of potential flow by thin airfoil theory, lifting line theory, and panel methods. Viscous effects and their relation to design variables.

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.

5250. COMPUTATIONAL FLUID MECHANICS. (4 cr; prereq FORTRAN and 5200 or #)
Methods for solving practical problems in aerodynamics that require use of large high speed computers. Emphasis on utilization of methods and results rather than on mathematical analysis.

5270. ATMOSPHERIC FLUID DYNAMICS. (4 cr; prereq some background in viscous flow such as 5202 or #)
The large- and small-scale motions, structure, and physical mechanisms in our atmospheric environment.

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 3401 and 5206)
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. Routh 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.

5329. FUNDAMENTALS OF AIRCRAFT DESIGN. (4 cr; prereq 5300 or #; 1 lect and 1 lab per wk)
Aircraft design considerations, mission analysis, estimates of weights and wing loading, airfoil and platform selection, fuselage and tail sizing, propulsion system sizing, material selection, control surface placement and sizing. Students prepare a conceptual design of an aircraft.

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

5359. DECELERATION OF AEROSPACE CRAFT. (4 cr; prereq 3036, 5200)
Aircraft approach and landing run with parachutes, reverse pitch propellers and jet thrust reversers. Terrestrial and reentry trajectories. Systems for aerial delivery and space recovery. Aircraft antispin parachutes. Aerodynamic characteristics of parachutes. Screen drag of porous sheets. Interaction between screen drag and aerodynamic characteristics of parachutes.

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 ASTRODYNAMICS. (4 cr; prereq 5438; 4 lect hrs per wk)
Fundamental concepts of the two-body problem. Celestial coordinates, orbital elements. Spacecraft attitude dynamics. Attitude maneuvers and control. Orbit maneuvers and introduction to the three-body problem.

5435. INTRODUCTION TO RANDOM VIBRATIONS. (4 cr; prereq 3401 or ME 3201)
Concepts of probability theory, random variables, and statistical averages. Elements of stochastic system theory. Response of one- and two-degree-of-freedom mechanical systems to nondeterministic inputs. Fatigue failure criteria, acoustic excitation.

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 equations, and applications, multiple-degree-of-freedom dynamical systems.

5440. INTERMEDIATE DYNAMICAL SYSTEMS. (4 cr; prereq 3401, ME 3201 or #)
Frequency domain analysis techniques. Elementary feedback control concepts, time domain analysis of simple mechanical systems.

5515. AEROSPACE STRUCTURES I. (4 cr; prereq 3016)
Elastic analysis of components important to aerospace structures. Plane-stress analysis of composites. Torsion and bending of thin-walled structural members. Castigliano method for trusses and beams. Stability and buckling.

5516. AEROSPACE STRUCTURES II. (4 cr; prereq 5515 or #)
Consideration of structures examined in 5515 in view of design problems, inelastic behavior, and solution on the computer of moderate-sized examples.

5580. INTRODUCTION TO THE MECHANICS OF SOLIDS. (4 cr; prereq 3016 or #)
Linear theory of strain and stress in two dimensions. Stress-strain relations (plane stress) for elastic and perfectly plastic materials. Plane-stress beam solutions; St. Venant principle. Rotationally symmetric solutions in plane stress. Three-dimensional strain, stress, and constitutive relations. Simple exact solutions. Plane stress and plane strain as three-dimensional problems.

5581, 5583. MECHANICS OF SOLIDS II, III. (4 cr per qtr; prereq 5580 or # for each)
Virtual work, minimum potential and complementary energy with applications. Torsion of prismatic bars, thermoelasticity. Waves and vibrations. Plastic limit analysis for plane stress and simple structures; creep and relaxation phenomena, linear viscoelasticity; approximate solution techniques based on energy methods; technical theory of curved bars, plates, and shells.

5642. ELEMENTARY AEROMECHANICS LABORATORY. (2 cr; prereq 5200 or equiv, 3016; 2 hrs per wk)
Basic measurement techniques in aeromechanics. Material properties, manometers, Pitot tubes, strain gages. Simple experiments illustrating basic principles of aeromechanics.

5645, 5646. AEROMECHANICS LABORATORY I, II. (2 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.

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. (1-4 cr per qtr; prereq #)
Topics of current interest. Individual projects.

5810, 5811, 5812. PROBLEMS IN FLUID MECHANICS. (1-4 cr per qtr; prereq #)

5838, 5839. SUMMER ENGINEERING EMPLOYMENT. (1-4 cr per qtr; prereq completion of 3rd yr and #)
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

(For course descriptions, see the *Graduate School Bulletin*)

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

8201, 8202, 8203. FLUID MECHANICS I-III

8207. STABILITY OF FLUID MOTIONS I

8208. STABILITY OF FLUID MOTIONS II

8209. ROTATING FLUIDS

8216, 8217. THEORY OF TURBULENCE I, II

8220. RHEOLOGICAL FLUID MECHANICS I

8221. RHEOLOGICAL FLUID MECHANICS II

8230. ADVANCED GAS DYNAMICS

8240. PERTURBATION METHODS IN FLUID MECHANICS

8260-8261. NONLINEAR WAVES IN MECHANICS I, II

8285-8286. SELECTED TOPICS IN RAREFIED GAS DYNAMICS

8410. ADVANCED DYNAMICS

8411. LINEAR SYSTEMS

8412. NONLINEAR SYSTEMS

8413-8414-8415. 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. THEORY OF VISCOELASTICITY

8541. 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 CSci 1100-1101 or 3101, Math 1231; 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 through lectures, readings, demonstrations, and classroom discussions. Identification of 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.

3052. PHYSIO-ENGINEERING IN AGRICULTURE. (4 cr; prereq AEM 3016 or AEM 3016; 3 lect and 3 lab hrs per wk)
Mechanical and hydraulic properties of porous media, moisture relations; strength parameters for structural and mechanical design. Soil-machine action involved in tillage and traction. Energy and water balance in the soil-plant system. Plant structure and growth. Engineering and management requirements.

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. (2 cr per qtr)
Required of students in the engineering intern program during the employment periods.

5060. PROCESSING. (4 cr; prereq 3052, 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.

5072. FINITE ELEMENT METHOD: FUNDAMENTALS AND APPLICATIONS. (4 cr; prereq differential equations and sr status or #; 4 lect hrs per wk)
Basic theory and principles of implementation of the finite element method for a number of fundamental engineering areas. Applications in heat transfer, fluid mechanics, solid mechanics, radial and axisymmetric field problems, and time-dependent field problems.

5081, 5082, 5083, 5084. DESIGN. (4 cr per qtr; prereq completion of appropriate AgEn sr level courses or #; 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 . (4 cr; prereq thermodynamics, 3060 or #; 4 lect hrs per wk)
Fundamental requirements for handling food products. Separation processes in the food industry. Storage of foods. Optimization techniques, experimental design, project management methods, and engineering economics for the food industry.

5140. THERMAL PROCESSES FOR FOOD. (4 cr; prereq heat transfer, 5060 or #; 3 lect and 3 lab hrs per wk)
Engineering principles of thermal processing of food, pasteurization, microwave heating, heat exchange, evaporation, refrigeration and freezing. Process design and evaluation.

5191-5192. SPECIAL PROBLEMS IN AGRICULTURAL ENGINEERING. (2-5 cr per qtr; prereq #)
Individual study project at an advanced level involving application of engineering principles to a specific problem.

5330. AGRICULTURAL MACHINERY. (4 cr; prereq ME 3203 and knowledge of actions of agricultural mechanisms as assessed by instructor; 3 lect and 3 lab hrs per wk)
Principles of operation and performance characteristics of agricultural machines. Forces operating 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 3052 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 3052 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 3052, 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. Determinate 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 3052, Chem 1005 or 1014; 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.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

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)
Interaction of human beings and their 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.

1010. INTRODUCTION TO ARCHITECTURE, DRAWING. (4 cr; 8 lab hrs per wk)
Basic drawing techniques, freehand drawing and sketching, perspective, shades, and shadows.

1021f. HISTORY OF ENVIRONMENTAL DEVELOPMENT: ARCHITECTURE AND LANDSCAPE ARCHITECTURE. (4 cr, §LA 1021; 4 lect hrs per wk)
Introduction to the philosophy and principles of architecture and landscape architecture as an art; survey of environmental history from the ancient periods through the medieval age.

1022w. HISTORY OF ENVIRONMENTAL DEVELOPMENT: ARCHITECTURE AND LANDSCAPE ARCHITECTURE. (4 cr, §LA 1022; 4 lect hrs per wk)
Continuation of Arch 1021 from the Renaissance through the modern eras; focuses on forces and individuals that shaped the form of architecture and landscape architecture in the 19th and 20th centuries in America and Europe.

1023s. HISTORY OF ENVIRONMENTAL DEVELOPMENT: PLANNING. (4 cr, §LA 1023; 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. ARCHITECTURAL GRAPHICS. (2 cr per qtr; restricted to students in pre-architecture and architecture. . .others #; 2½ lab hrs per wk)
The skills, media, and techniques of architectural graphics communication, including perspective systems, shade and shadow, color, freehand drawing, and organizing presentation material.

3061-3062. BUILDING SYSTEMS. (4 cr per qtr; prereq 3081 or ¶3081 or #; 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, 3083 or #; 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 or CLA students, △; 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 World War II.

5057. ASIAN ARCHITECTURE. (4 cr; prereq 1021; 3 lect and 1 seminar hrs per wk)
Selected topics from the history of architecture and urban design in West, South, and East Asia.

5061. LATE MODERN ARCHITECTURE. (4 cr; prereq 1021; 3 lect and 1 seminar hrs per wk)
Developments, theories, and stylistic movements in architecture from World War II to the present time.

5101, 5102, 5103. TUTORIAL WORK IN HISTORY OF ARCHITECTURE. (4 cr; prereq 12 upper division cr in history 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 5061 or #; 4 seminar hrs per wk)
Contemporary architecture from the beginning of modern movement until the present time with emphasis on 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 5061 or #; 4 seminar hrs per wk)
Survey of Scandinavian architectural history with emphasis on the origin and development of modern architecture in Denmark, Finland, Norway, and Sweden.

5106. SEMINAR: AMERICAN ARCHITECTURE. (4 cr; prereq 5056 or 5061 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 contributions of Louis H. Sullivan, Frank Lloyd Wright, Eliel and Eero Saarinen, Walter Gropius, Mies van der Rohe, Louis Kahn, Ralph Rapson, Robert Venturi, Frank Gehry, Michael Graves, and others.

5111-5112-5113. ARCHITECTURAL DESIGN. (6 cr per qtr; prereq 3093, 3064-3065 or ¶3064-3065, CE 3600-3601-3602 or ¶CE 3600-3601-3602; 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 3093, CE 3602; 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 studied 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 3602; 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 plan during qtr prior to thesis writing 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 3rd-yr design or ¶3rd-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.

5127, 5128. LAW FOR ARCHITECTS. (4 cr per qtr; prereq 3093 or △; 2 lect hrs per wk)
Legal subject matter relevant to the work of architects and design professionals.

5129. LAW FOR ARCHITECTS SEMINAR. (4 cr; prereq 3093 and 5128 or #; 4 hrs per wk)
Third course in series. Case studies of legal subject matter relevant to the work of architects and design professionals; individual research assignments.

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.

5137. PLANNING: URBAN FUNCTION AND STRUCTURE. (4 cr; prereq #)
Economic, technological, and social factors that 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.

5141. HISTORIC PRESERVATION PROCESS. (4 cr; prereq 1021 or #; 4 lect hrs per wk)
Philosophy and theory of historic preservation, historic origins, descriptive analysis of buildings, building documentation, technology of building conservation, historical archaeology, economic considerations, preservation law, guidelines for preservation, neighborhood conservation, international preservation, and case studies of representative preservation projects.

5142. HISTORIC BUILDING RESEARCH AND DOCUMENTATION. (4 cr; prereq 5141 or #; 2 lect and 2 lab hrs per wk)
Philosophy, theory, and methods of historic building research, descriptive analysis of buildings, building documentation, historical archaeology and architectural taxonomy.

5143. HISTORIC BUILDING CONSERVATION. (4 cr; prereq 5141 or #; 2 lect and 2 lab hrs per wk)
Historic building systems, materials and methods for their conservation; introduction to use of contemporary systems in historic buildings.

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

5155. URBAN DEVELOPMENT PROCESS. (3 cr; prereq #)
History of urban development programs in the United States including urban renewal, new communities and community development, review of relevant legislation; economics and politics of the urban development process.

5156. URBAN DEVELOPMENT PROCESS. (3 cr; prereq #)
Comparative study of major urban development projects drawing upon American and European experience. The process through which development projects are planned and carried out.

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

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

5173. ENERGY AND URBAN FORM. (3 cr; prereq 5171 or #; 3 lect hrs per wk)
The role of energy as a determinant of urban form.

5850. TOPICS IN THEORY. (2 cr; prereq #)
Special topics in architecture examined in a philosophical and theoretical context.

5852. ARCHITECTURE: THEORY AND PHILOSOPHY. (3 cr; prereq 3093 or #; 2 lect hrs per wk)
Architecture examined within a general philosophical context: its nature, role, purpose, meaning; its definition; and its mode of operation as a discipline and in relation to other fields.

5853. ARCHITECTURE AS THOUGHT AND DESIGN PROCESS. (3 cr; prereq 3093 or #; 2 lect hrs per wk)
Architecture as a thought, creative, and transformational process; underlying attitudes, paradigms, models, and strategies and tools, and their potential, limitations, implications, formal outcome, and meaning.

5854. THE LANGUAGE OF ARCHITECTURE: SEMIOTICS, SYMBOLISM, AND METAPHOR. (3 cr; prereq 3083 or #; 2 lect hrs per wk)
Communicative dimensions of architecture, especially as they relate to linguistic analogies. Broad historical perspective including current aspects of subject.

5855. TYPOLOGY AND ARCHITECTURE: THEORIES OF ANALYSIS AND SYNTHESIS. (3 cr; prereq 3083 or #; 2 lect hrs per wk)
Theoretical traditions and development of the use of typology in architecture. Works of Laugier, Quatremere De Quincy, Viollet-Le-Duc, Ledoux, Durand, Camillo Sitte, and Le Corbusier. Recent developments and theoretical positions of the "neorationalist" and "contextual" arguments for contemporary applications of typology.

5856. ARCHITECTURE: FORM AND MEANING. (3 cr; prereq 3093 or #; 2 lect hrs per wk)
Architectural form, order, and meaning relative to architecture as an aesthetic, social, environmental, and technical object. Current theories and concepts; their potential and implications.

5950. TOPICS IN ARCHITECTURE. (Cr ar; prereq 3093 and 3067 or #)
Special topics of concern to the field.

5951. ARCHITECTURE AND BEHAVIOR. (3 cr; prereq 3083 or #; 4 lect hrs per wk)
The relation between people and built environments: theoretical basis for exchange between designers and behavioral scientists, impact of knowledge of behavior on design process (design/evaluation/programming cycle), behavioral findings, problems of implementation. Guest lecturers and reading of materials from related disciplines.

5952. PROGRAMMING FOR ARCHITECTURAL DESIGN. (3 cr; prereq 3093 or #; 3 lect hrs per wk)
Principles of programming explored through case study method. Guest lecturers discuss how principles are applied in architectural practice. Students develop program for a specific academic design problem: examination of precedents, site selection, function analysis and relationship diagrams, assumptions examination, form options, and design directives.

5953. HOUSING AND VALUES. (3 cr; prereq upper division or grad student; 3 lect/discussion hrs per wk)
Meanings and values attached to housing in different cultures, at various stages in the life cycle, and in differing climatic situations. Impact of housing heritage on housing choice, and potential impact of emerging constraints (such as energy availability) on current and future housing decisions.

5954. ARCHITECTURE AND BEHAVIOR RESEARCH METHODS. (3 cr; prereq 3083 or #; 4 lect hrs per wk)
Use of behavior research in architectural practice: evaluation of buildings, architectural programming methods, application of findings in architectural design. Students design and implement a small behavioral research project.

5958. ENERGY AND ARCHITECTURE. (4 cr; prereq 3093 or #; 2 lect and 2 lab hrs per wk)
Relationship of conservation, passive solar, and active solar strategies in design of small buildings. Exercises and case studies provide hands-on experience with systems, calculating techniques, and evaluative methods as a basis for understanding space-heat requirements.

5959. LIGHTING DESIGN TECHNIQUES. (2 cr; prereq 3083 or #; 2 lab hrs per wk)
Design of architectural lighting effects to enhance perception and give direction to space through practice drawing and modeling skills exercises.

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

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

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. Occasional nighttime observing sessions required. Some algebra and trigonometry, at high school level used.

1015Hw,s. HONORS COURSE: DESCRIPTIVE ASTRONOMY LABORATORY. (1 cr, §1025; S-N only; prereq △; 1 lab hr per wk)

1021f. 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.

1025Hf. 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. Occasional nighttime observing sessions required.

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 extragalactic universe. How information is obtained; conclusions that can be inferred from observations through applications of elementary physics to astronomical problems.

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.

5163. GALACTIC AND EXTRAGALACTIC ASTRONOMY. (4 cr; prereq 3051 and Phys 3511 or #)
The Milky Way, physical properties of galaxies, distance scale, distance-red-shift relation, clusters of galaxies, peculiar galaxies, radio galaxies and quasars, cosmology.

5970. DIRECTED STUDIES. (1-5 cr; prereq #, △)
Independent, directed study in observational and theoretical astrophysics in areas arranged by the student with a faculty member. Primarily intended for senior astrophysics majors.

5990. DIRECTED RESEARCH. (3 cr minimum; prereq #, △)
Independent research in observational or theoretical astrophysics under the direction of a faculty member. Intended for senior astrophysics majors.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

8200.* SEMINAR: ASTROPHYSICS AND SPACE PHYSICS

8481, 8482, 8483.* TOPICS IN ASTROPHYSICS

8990. RESEARCH IN ASTRONOMY AND ASTROPHYSICS

Phys 8081-8082.* GENERAL RELATIVITY

Phys 8161.* ATOMIC AND MOLECULAR PHYSICS

Phys 8163-8164.* PLASMA PHYSICS

Phys 8400.* SEMINAR: COSMIC RAY AND SPACE PHYSICS

Phys 8411-8412.* COSMIC RAY AND SPACE PHYSICS

Phys 8421-8422.* SOLAR AND MAGNETOSPHERIC PHYSICS

Chemical Engineering (ChEn)

5001. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING AND MATERIALS SCIENCE. (3 cr; 3 lect hrs per wk)
Introduction to the analysis of representative chemical engineering problems by mathematical methods.

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 5101; 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; prereq 5101, Chem 5534 or #; 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.

5203. STATE AND TRANSPORT PROPERTIES. (4 cr; prereq 5101, 5102, 5103, 5201, 5202 or equiv)
Evaluation, correlation, estimation, and application of thermodynamic properties of pure substances, solutions, two-phase mixtures, and reactive mixtures. Group contributions and generalized correlations. Computer-aided calculation of thermodynamic properties including those of vapor-liquid systems and reaction systems at elevated pressures.

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.

5302. APPLIED REACTOR ANALYSIS. (4 cr; prereq 5301 or equiv)
Practical chemical reaction systems and the reactors for them. Catalysis and its role in the chemical industry. Analysis of functioning chemical reaction systems involving ammonia synthesis, polymerization reactors, combustion, and sulfur dioxide removal.

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. (4 cr; prereq 5501 or #; 3 lect and 2 design lab hrs per wk)
(Continuation of 5501) Computer-aided design of unit operations, chemical reactors and integrated plants; operability characteristics of chemical processes; design for optimum operability (safety, reliability, control).

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)
Advanced topics in chemical process control; synthesis of control structures; multivariable control schemes, optimal control and estimation; computer-aided real-time process control.

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.

5640. POLYMERIZATION REACTOR ENGINEERING. (4 cr [available to grad students for 3 cr]; prereq chemical engineering reactor design course or #; 3 lect and 1 ar lab hr per wk)
Introduction to analysis and design of polymerization reactors. Topics include mathematical modeling techniques, chain-growth and step-growth polymerization, copolymerization, molecular weight distributions, composition and sequence distributions. Emphasis on application of results. Laboratory offers experience with polymerization processes and molecular weight measurements.

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
Modeling and analysis of biosystems. Thermodynamics, transport and transfer, biochemical reactions, growth and death processes 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.

5756. BIOENGINEERING LABORATORY. (1 or 2 cr; prereq 5752 or 5755 or #)
Experiments to demonstrate techniques of biochemical and biomedical industrial processes.

5757. PRINCIPLES OF ARTIFICIAL INTERNAL ORGAN DESIGN. (3 cr; prereq #; 3 lect hrs per wk) Keller
Survey of those artificial internal organs important in the maintenance of homeostasis with emphasis on the general principles and particular problems involved in their design, including blood compatibility, access, and alternative approaches to replacing natural organ functions.

5761. FLOW OF FLUIDS IN POROUS MEDIA WITH APPLICATIONS TO OIL RECOVERY. (3 cr; 3 lect hrs per wk) Davis, Scriven
Survey of fluid mechanics, interfacial phenomena, transport processes, and statistical aspects, with application to petroleum production and chemical and thermal processes of enhanced recovery.

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

(For course descriptions, see the *Graduate School Bulletin*)

8004. PHYSICAL RATE PROCESSES

8005. PHYSICAL RATE PROCESSES

8101. INTERMEDIATE FLUID MECHANICS

8102. PROBLEMS IN FLUID MECHANICS

8103. TENSORS AND FIELD THEORY WITH APPLICATIONS

8104. INTERFACES AND INTERFACIAL PHENOMENA

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. PHYSICAL AND CHEMICAL 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 EQUILIBRIUM AND NONEQUILIBRIUM PROCESSES

8701. ANALYSIS OF CHEMICAL ENGINEERING PROBLEMS

8702. ADVANCED TOPICS IN CHEMICAL ENGINEERING

8750. ADVANCED CHEMICAL PROCESS DESIGN

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—All course offerings are intended for students who have taken high school chemistry. Completion of at least one course in high school chemistry is a *prerequisite* for Chem 1004 or 1031. High school chemistry is recommended preparation for all other courses, and students who lack this background will be at a serious disadvantage.

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

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

1003. PHYSICAL WORLD, CHEMISTRY. (5 cr, §any other college chemistry course; prereq 1 yr high school algebra... high school chemistry recommended; a terminal course...cannot be used as prereq for any other advanced chemistry course; 4 lect, 1 rec, 1 2-hr lab per wk)
Fundamental concepts of chemical bonding, structure of matter, and forces in the physical world. Scientific methods and principles contribute to understanding of the environment and problems faced in improving it. Labs to illustrate.

1004-1005†. GENERAL PRINCIPLES OF CHEMISTRY. (5 cr per qtr, §1001-1002, §1003, §1008, §1014, §1031-1032; primarily for non-chemistry majors; prereq placement index of Y or predicted mathematics GPA of 1.90 on ACT or Math 0009 or college course in algebra, high school chemistry...high school physics and 4 yrs high school mathematics 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)
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.

1008. PHYSICAL WORLD, CHEMISTRY. (4 cr, §any other college chemistry course; prereq 1 yr high school algebra... high school chemistry recommended; a terminal course...cannot be used as prereq for any other advanced chemistry course)
Fundamental concepts of chemical bonding, structure of matter, and forces in the physical world. Scientific methods and principles that contribute to understanding the environment and problems faced in improving it.

1014. CONCEPTS OF CHEMISTRY. (4 cr, §1001, §1003, §1004, §1008, §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.

1031-1032†. CHEMICAL PRINCIPLES I AND II. (5 cr, §1001-1002, §1003, §1004-1005, §1008, §1014; prereq chemistry or chemical engineering major or #, 4 yrs high school mathematics, high school chemistry, placement index of Y or predicted mathematics GPA of 1.90 on ACT or Math 0009 or college course in algebra...1 yr high school physics recommended; 4 lect, 1 lab discussion, and one 3-hr lab per wk)
Stoichiometry, development and use of structural concepts, energetics, geometry of molecules, bonding, and the behavior of the gaseous and liquid states, the solid state, theory of solutions, equilibrium, gas and condensed phases, behavior and nature of the solution process, acids and bases.

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.

3100. QUANTITATIVE ANALYSIS LECTURE. (3 cr, 3100-3101†; for non-chemistry majors; prereq 1005 or 1032)
Introduction to the theory of quantitative chemical analysis.

3101. QUANTITATIVE ANALYSIS LABORATORY. (2 cr. 3100-3101†; for non-chemistry majors; prereq 3100 or ¶3100; 8 lab hrs per wk)
Introductory laboratory in quantitative chemical analysis.

3301. ELEMENTARY ORGANIC CHEMISTRY I. (4 cr, §3331; for non-chemistry majors; prereq 1005 or 1032 or equiv; 4 lect hrs per wk)
Important classes of organic compounds, both aliphatic and aromatic, together with some heterocyclic compounds.

3302. ELEMENTARY ORGANIC CHEMISTRY II. (4 cr; prereq 3301, 3305 or ¶3305; 4 lect hrs per wk; if 3305 is taken concurrently, a passing grade is required for 3305 in order to receive cr for 3302)
Continuation of 3301.

3303. ELEMENTARY ORGANIC CHEMISTRY III. (4 cr; prereq 3302, 3306 or ¶3306; 4 lect hrs per wk; if 3306 is taken concurrently, a passing grade is required for 3306 in order to receive cr for 3303)
Basic principles with emphasis on organic reaction mechanisms. Intended to coordinate the knowledge acquired in the preceding two quarters.

3305. ELEMENTARY ORGANIC CHEMISTRY LABORATORY I. (2 cr; prereq 3301 or ¶3301; 1 lab conf, 4 lab hrs per wk)
Introduces the various techniques utilized in the preparation of typical organic substances.

3306. ELEMENTARY ORGANIC CHEMISTRY LABORATORY II. (2 cr; prereq 3302 or ¶3302; 1 lab conf, 4 lab hrs per wk)
Introduces the various techniques utilized in the preparation of typical organic substances.

3331. INTRODUCTORY ORGANIC CHEMISTRY I. (5 cr, §3301; for chemistry and chemical engineering majors; prereq 1133 or 1 yr college chemistry; 5 lect hrs 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, 3332-3335†; prereq 3331; 3 lect hrs per wk)
A survey of the reactions of organic compounds; nucleophilic substitution and addition; electrophilic substitution and addition; elimination reactions; molecular rearrangements; oxidation and reduction.

3333. INTRODUCTORY ORGANIC CHEMISTRY III. (3 cr; prereq 3332; 3 lect hrs 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 LAB. (2 cr, 3332-3335†; prereq 3332 or ¶3332 [¶3332 is recommended]; two 4-hr labs per wk)
A laboratory course to accompany 3332.

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

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

3970. DIRECTED STUDY. (Cr ar; prereq #)
On- or off-campus learning experiences, individually arranged between a student and chemistry faculty member, in areas not covered by regular courses.

3991, 3992, 3993. SPECIAL TOPICS IN CHEMISTRY. (Cr ar; prereq #)
Areas of current research. Primarily for third- and fourth-year chemistry majors.

5122. ADVANCED ANALYTICAL CHEMISTRY. (4 cr; prereq 1 yr organic chemistry, course in thermodynamics)
Equilibria in aqueous and nonaqueous systems.

5126. MODERN ANALYTICAL CHEMISTRY. (4 cr; primarily for chemical engineering majors; prereq 3332 and 3335; 2 lect and two 3-hr labs per wk)
Strategies and techniques for solving modern analytical problems. The use of modern instruments in analysis.

5127. ANALOG AND DIGITAL INSTRUMENTATION. (5 cr; prereq Phys 1291, Math 1231 or 1331 or equiv or #; 4 lect and one 4-hr lab per wk)
Basic principles and applications of electronic circuitry; servo systems, operational amplifiers, feedback control, oscillators, digital gates, and converters for signal processing and control of chemical measurement systems.

5128. THE SMALL COMPUTER IN THE CHEMICAL LABORATORY. (5 cr; prereq 5127 or #; 3 lect and two 4-hr labs per wk)
Applications of the laboratory computer to the control of chemical instrumentation and acquisition of data. Hardware (interfacing) and software (assembly language programming) aspects of automating the chemical experiment.

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.

5139. CHROMATOGRAPHY AND SEPARATION SCIENCE. (4 cr; prereq 5133 or equiv or #; 3 lect and one 4-hr lab per wk)
Fundamental and practical aspects of gas liquid chromatography, modern liquid chromatography, electrophoresis and other techniques used for analysis and separations.

5211. ADVANCED CHEMICAL KINETICS. (4 cr; prereq 5535 or equiv)
Factors that 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.

5212. CHEMICAL DYNAMICS IN SOLUTION. (4 cr, §8212; prereq undergrad physical chemistry course with a section on kinetics or #)
Substitution reactions; electron-transfer reactions; electrode reactions; linear free energy relationships; structure of intermediates; ion pairing, solvent effects, ionic strength; diffusion-controlled processes; cage effects.

5301. SPECTRAL METHODS FOR ORGANIC QUALITATIVE ANALYSIS. (4 cr, §8302; prereq 3303 or 3333 or equiv; 3 lect and 1 conf hrs per wk)
Practical application of nuclear magnetic resonance, mass, and ultraviolet and infrared spectral analysis to solution of organic structural problems.

5302. ORGANIC SYNTHESIS. (4 cr; prereq 3303 or 3333 or equiv; 8 lab and 2 conf hrs per wk)
Reactions of typical functional groups and introduction to modern laboratory methods of organic synthesis.

5305. INTERMEDIATE ORGANIC CHEMISTRY. (4 cr; prereq 3303 or 3333 or equiv; 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. APPLICATIONS OF MOLECULAR ORBITAL THEORY IN ORGANIC CHEMISTRY. (4 cr; prereq 5536 or Phys 3501 or #)
Application of quantum mechanics to organic reactions and photochemistry.

5342. CHEMISTRY OF NATURAL PRODUCTS. (3 cr; prereq 3303 or 3333 or equiv; offered 1980-81 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 3333 or equiv; offered 1981-82 and alt yrs)
Steroidal hormones, their isolation, proof of structure, synthesis, and action.

5344. HETEROCYCLIC COMPOUNDS. (3 cr; prereq 3303 or 3333 or equiv; offered 1981-82 and alt yrs)
Typical classes of heterocyclic compounds, their chemical and physical properties and uses, synthesis.

5365. ORGANIC QUALITATIVE ANALYSIS. (4 cr; prereq 3303 or 3333 or equiv; 8 lab and 2 conf hrs per wk)
Reactions of typical functional groups and introduction to methods of organic structure determination.

5520-5521. ELEMENTARY PHYSICAL CHEMISTRY. (3 cr per qtr; prereq 1 yr college chemistry, Phys 1291 or ¶Phys 1291 or Phys 1106, 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...BioC 5001 or Biol 3021 desirable)
Physical chemistry of equilibrium and transport phenomena in solution with application to biochemical systems. Macromolecular solutions, phase transitions, cooperative binding, conformational transitions, protein polymerization, micelle formation, sedimentation equilibrium and velocity, translational and rotational diffusion, viscosity.

5523. PHYSICAL BIOCHEMISTRY: STRUCTURE AND INTERMOLECULAR FORCES. (4 cr, §BioC 5523; prereq 2 qtrs physical chemistry...BioC 5001 or Biol 3021 desirable)
Methods of structure determination for biological macromolecules. Scattering and diffraction, optical and magnetic resonance spectroscopy. Application to proteins, nucleic acids, and synthetic analogs.

5524. BIOPHYSICAL CHEMISTRY: DYNAMICS. (4 cr, §BioC 5524; prereq 2 qtrs physical chemistry, BioC 5752...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, §5533; intended for beginning grad students not specializing in physical chemistry; prereq Phys 1291 or equiv plus Math 3211 or equiv or #)
Postulates of quantum mechanics. Introduction to wave functions, solutions of the Schrödinger equation, variation and pertubation theory, modern techniques for calculating bound state wave functions and electronic energies of molecules.

5533. QUANTUM CHEMISTRY. (4 cr, §5531; prereq 1 yr college chemistry, Phys 1291 or ¶Phys 1291, or 1106 with #, Math 3211)
Principles of quantum mechanics with applications to atomic and molecular structure and to spectroscopy.

5534. CHEMICAL THERMODYNAMICS. (4 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. (2 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 5531 or 5533 or equiv for 5571)
An examination of various types of molecular spectroscopy from the standpoint of how structural 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 5535 or 5534 or #; offered 1981-82 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, §8610, §MatS 5610; prereq physical chemistry or MatS 5011 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 and crystalline state, rubber elasticity, flow and viscoelasticity, environmental degradation.

5731. INORGANIC CHEMISTRY I. (3 cr; prereq 5533; 3 lect 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. (3 cr; prereq 5731; 3 lect hrs per wk)
(See 5731) Emphasis on transition metal compounds where *d* electrons are important. Topics of current interest such as boron hydrides, inert gas compounds, organometallic compounds, and biologically important metal compounds.

5734. INORGANIC CHEMISTRY LABORATORY I. (2 cr; prereq 5731 or ¶5731 or #; 1 lect and 3 lab hrs per wk)
Laboratory to accompany 5731.

5735. INORGANIC CHEMISTRY LABORATORY II. (2 cr; prereq 5734, 5732 or ¶5732 or #; 1 lect and 3 lab hrs per wk)
Laboratory to accompany 5732.

5751. PHYSICAL INORGANIC CHEMISTRY I. (4 cr; prereq 5732 or equiv or #)
Physical methods and concepts applied to inorganic and organometallic systems including NMR, IR, UV-VIS, ESR, Mössbauer and mass spectroscopy, magnetic measurements, X-ray crystallography.

5752. PHYSICAL INORGANIC CHEMISTRY II. (4 cr; prereq 5751 or equiv or #)
Solution thermodynamics and kinetics applied to inorganic and organometallic systems; determination of reaction mechanisms; symmetry and ligand field concepts.

5761. ORGANOMETALLIC CHEMISTRY. (4 cr; prereq 5732 or equiv or #)
Synetheses, reactions, structures, and other important properties of main group and transition metal organometallic compounds; treatment in terms of modern electronic and structural theory; emphasis on their use as stoichiometric and homogeneous catalytic reagents in organic and inorganic systems.

5762. SURVEY OF THE CHEMISTRY OF THE TRANSITION METALS. (4 cr; prereq 5732 or equiv or #)
Reactions and properties of the transition metals and their compounds. Modern coordination chemistry including magnetic and spectroscopic properties and qualitative ligand field theory.

5763. SURVEY OF THE CHEMISTRY OF THE NONTRANSITION ELEMENTS. (4 cr; prereq 5732 or equiv or #)
Reactions and properties of the nontransition elements, including the rare gases, and their compounds.

5801, 5802, 5803. THE CHEMISTRY OF INDUSTRY. (4 cr per qtr; prereq chemistry sr or grad student or #)
The relation between basic chemical theory and chemical technology including programs of economics, ecology, and resources.

5991, 5992, 5993. SELECTED TOPICS IN CHEMISTRY. (Cr ar; prereq sr, △)
Topics of current interest in chemistry. Consult department for details for a particular quarter.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

8100. GENERAL SURVEY OF ANALYTICAL CHEMISTRY

8104. OPTICAL METHODS OF ANALYSIS

8129. SURVEY OF MODERN INSTRUMENTAL ANALYSIS

8133. MODERN ELECTROANALYTICAL TECHNIQUES, PRINCIPLES, AND PRACTICES

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

8290. SEMINAR: CHEMICAL DYNAMICS

8300. GENERAL SURVEY OF ORGANIC CHEMISTRY

8301. ADVANCED ORGANIC CHEMISTRY I

8302. INTERPRETATION OF ORGANIC SPECTRA

8303. DETERMINATION OF MECHANISMS OF ORGANIC REACTIONS

8304. ADVANCED ORGANIC CHEMISTRY II

8305. ADVANCED ORGANIC CHEMISTRY III

8341. STEREOCHEMISTRY

8342. INTRODUCTION TO RESEARCH

8343. THEORETICAL ORGANIC CHEMISTRY

8344. THEORETICAL ORGANIC CHEMISTRY

8390. ORGANIC CHEMISTRY SEMINAR

8401. BIOORGANIC CHEMISTRY I

8402. BIOORGANIC CHEMISTRY II

8403. BIOORGANIC CHEMISTRY III

8500. GENERAL SURVEY OF PHYSICAL CHEMISTRY

8531-8532-8533. INTRODUCTORY QUANTUM MECHANICS AND SPECTROSCOPY

8534. GROUP THEORY

8535. VIBRATION-ROTATION SPECTRA

8536. ELECTRONIC STRUCTURE AND SPECTROSCOPY

8541-8542-8543. THERMODYNAMICS, STATISTICAL MECHANICS AND KINETICS

8544. COLLISION THEORY

8545. REACTION DYNAMICS

8560. SEMINAR: PHYSICAL CHEMISTRY OF BIOLOGICAL SYSTEMS

8565. SEMINAR: PHYSICAL CHEMISTRY OF POLYMERS

8570. SEMINAR: MOLECULAR SPECTROSCOPY

8571. ADVANCED QUANTUM MECHANICS

8572. INTERACTION OF RADIATION WITH MATTER

8575. SEMINAR: MAGNETOCHEMISTRY

8580. SEMINAR: PHOTOCHEMISTRY

8581. MAGNETIC RESONANCE

8585. SEMINAR: THEORETICAL CHEMISTRY

8590. SEMINAR: PHYSICAL CHEMISTRY

8601-8602-8603. MOLECULAR THEORY OF TRANSPORT PROCESSES

8610. POLYMER SCIENCE

8650. SEMINAR: SOLID STATE CHEMISTRY AND STRUCTURE

8700. GENERAL SURVEY OF INORGANIC CHEMISTRY

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

8994, 8995, 8996. 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.

3050. ENGINEERING INTERN WORK ASSIGNMENT. (4 cr; prereq regis in intern program; S-N only)
Requires submission of two formal written reports, one covering the work completed during the six-month professional assignment and the second involving an in-depth presentation of a related engineering problem.

3051. ENGINEERING INTERN WORK ASSIGNMENT. (4 cr; prereq regis in intern program; S-N only)
For description, see 3050.

5001. BUILDING AND CONSTRUCTION CONTRACTS AND SPECIFICATIONS. (4 cr; prereq 3rd yr or #)
Overview of the law of contracts, sales, agency, negotiable instruments, real property, personal property, partnerships, corporations, insurance contracts, worker's compensation, labor law, mechanics' liens, government construction contracts, and torts with applications to the performance of engineering and construction contracts.

5002. ENGINEERING ECONOMICS. (2 cr; prereq jr standing; 2 lect hrs per wk)
Time value of money; compound amount factors; present worth of uniform and single payments; cost-benefit analysis; net present worth analysis; internal rate of return.

5004. STRUCTURAL AND CONSTRUCTION CONSIDERATIONS FOR EARTH-SHELTERED BUILDINGS. (4 cr; prereq jr standing in civil engineering or architecture)
Application of structural and foundation design techniques to earth-sheltered buildings; construction techniques and problems. Topics include temporary retaining systems, soil pressures, drainage systems, waterproofing, site investigation, construction scheduling and construction materials. Housing, large scale buildings, and mines space.

5097, 5098, 5099. ADVANCED DESIGN, ANALYSIS, RESEARCH, OR TUTORIAL IN CIVIL ENGINEERING. (Cr ar; courses may be taken more than once; prereq approval of faculty adviser)
Special studies in the planning, design, or analysis of complex civil engineering systems. Individual laboratory research problems, literature studies, and reports supervised by staff members. Studies may be conducted in any discipline within civil engineering and hydraulics including, but not limited to, hydraulics and hydrology, land development, materials, sanitary engineering, soil mechanics, structures, and transportation.

Surveying and Mapping

3100. INTRODUCTION TO SURVEYING AND MAPPING. (4 cr; prereq Math 1211; 3 lect and 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-wk lab plus 3 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, 5102 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)
Size and shape of the earth; properties of ellipsoids; reference ellipsoids; Legendre 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.

5105. SURVEY ADJUSTMENTS. (4 cr; prereq 3100 and CSci 3101 or #; 3 lect and 3 lab hrs per wk)
Application of statistical theory to the adjustment of surveying and photogrammetric measurements. Includes the concepts of precision and accuracy, error propagation, observation and condition equations, weighting of observations, solution of systems of equations by method of least squares, and precision of adjusted quantities.

Transportation

320(. 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 emphasis of costs of transportation systems.

5200. GEOMETRIC DESIGN OF HIGHWAYS. (4 cr; prereq 5102, 3200 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; applications of signs, signals, and markings in traffic control.

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

5210. INTRODUCTION TO TRANSPORTATION SYSTEMS ANALYSIS. (4 cr; prereq #)
Techniques of analysis and planning for transportation services; demand-supply interactions; evaluating transportation alternatives; travel demand forecasting; integrated model systems; citizen participation in decision making; proposal writing.

5212. TRANSPORTATION PRODUCTIVITY AND ENERGY CONSERVATION. (4 cr; prereq #)
Measuring transportation productivity and energy consumption; application of control theory for improving transportation productivity; simulation of energy-conservation policies and effect of such policies on transportation ridership and economics through time; transportation use and energy consumption in relation to urban and rural structures; case studies.

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.

Geomechanics (Soil Mechanics and Rock Mechanics)

3300. ELEMENTS OF SOIL MECHANICS. (4 cr; prereq AEM 1015; 4 lect hrs per wk)
Physical properties of soils; soil classification. Stresses and strains. Laboratory experiments on dry soil and rock. Moisture, permeability and flow nets. One-dimensional consolidation, laboratory tests on wet soil.

3301. SOIL MECHANICS LABORATORY. (1 cr; prereq 3300; 4 lab hrs for 5 wks)
Index tests; consolidation; triaxial compression; unconfined compression; permeability and direct shear.

5300. THEORY OF GEOMECHANICS. (4 cr; prereq 3300; 3 lect and 2 rec hrs per wk)
Groundwater flow. Introduction to linear elasticity. Consolidation; settlement calculations. Limit analysis, bearing capacity.

5301. APPLIED SOIL MECHANICS. (4 cr; prereq 3300, 5300; 3 lect and 2 rec hrs per wk)
Design of footings and deep foundations. Soil slope stability. Retaining walls. Practice in the application of standard numerical techniques.

5302. APPLIED ROCK MECHANICS. (4 cr; prereq 5300; 3 lect and 2 rec hrs per wk)
Principles and techniques of site investigation in rock. Design of surface and underground excavations, including excavation and mine stability, and methods of ground control. Application of numerical models in design.

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 statics and dynamics for liquid and gases. Kinematics of fluid flow, viscous effects, and introduction to incompressible and compressible duct flow.

5401. WATER RESOURCES ENGINEERING. (4 cr; prereq 3400; 3 lect and 3 lab hrs per wk)
Introduction to water resources engineering including flow in conduits, pumps, open channels and culverts; introduction to flow measurements, hydraulic structures and systems approach to water resources engineering.

5402. HYDRAULIC ANALYSIS WITH COMPUTER APPLICATIONS. (4 cr; prereq 5401, CSci 3101 or #; 3 lect and 3 lab hrs per wk)
Computer applications in hydraulic engineering with emphasis on iteration techniques and finite increment methods applied to open channel flow profile analysis: analysis of flow through spillways, bridge waterways, culverts, and similar structures.

5405. HYDROLOGY AND HYDROLOGIC DESIGN. (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, application of hydrology to design of outlet works and flow control structures.

5410. OPEN CHANNEL HYDRAULICS. (4 cr; prereq 3400, 5401 or #; 3 lect and 2 rec 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)
U.S. and world water resources; human water use; economic, environmental, social, and political problems related to water.

5425. GROUNDWATER MECHANICS. (4 cr; prereq 3400 or #)
Basic equations. Horizontal confined, unconfined, and interface flow. Flow from rivers and lakes toward wells. Systems of interconnected aquifers. Leaky flow. Modeling of aquifers through use of boundary integral equation techniques. Nonsteady flow. Application of finite element methods. Explicit finite difference methods.

5435. INTERMEDIATE FLUID MECHANICS WITH APPLICATIONS. (4 cr; prereq 3400)
Basic laws and equations of fluid flows; exact and approximate solution; 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 PROBLEMS AND ANALYSIS. (4 cr; prereq Chem 1005)
Environmental problems and an interdisciplinary approach to problem solving. Water pollution, water pollution control technology, air pollution, air pollution control technology, noise, alternative energy resources, solid waste disposal, nuclear energy, radioactive wastes and the overall impact of technology on environmental quality.

5500. ANALYSIS AND DESIGN OF WATER SUPPLY SYSTEMS. (4 cr; prereq 3500 or #)
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 WASTEWATER SYSTEMS. (4 cr; prereq 3400, 3500 or #)
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 wastewaters, and storm water runoff. Environmental effects, cost, and political aspects of ultimate disposal.

5505. WATER QUALITY AND TREATMENT. (4 cr; prereq 3500)
Chemical and physical properties of natural waters, introduction to aquatic biology, and ecological considerations of element cycling of natural carbon, nitrogen, phosphorus, oxygen, and anthropogenic chemical species (pesticides, PCBs, heavy metals). Physical and chemical processes of water treatment.

5506. ENVIRONMENTAL WATER CHEMISTRY. (4 cr; prereq Chem 1006 or equiv or #; 3 lect and 1 recitation hrs per wk)
Composition of natural waters and wastewater; chemical processes affecting distribution of pollutants and waters; methods of evaluation to determine fate of organic pollutants.

5510. SOLID WASTE MANAGEMENT. (4 cr)
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 unit costs.

5511. HAZARDOUS WASTE ENGINEERING. (4 cr; prereq 5510 or #; 3 lect and 2 lab hrs per wk)
Analysis and design of facilities for disposal of hazardous wastes. Focuses on technologies for treatment and conversion of wastes into reusable or innocuous materials; technologies for isolation and permanent storage of hazardous residues.

Structural Engineering

3600-3601-3602. STRUCTURAL DESIGN FOR ARCHITECTS. (4 cr per qtr; prereq AEM 3092, 3093; 4 lect and 1 rec hrs per wk)
Behavior, analysis, design, and construction of structural systems and members in steel, reinforced concrete, timber, masonry, and plastics.

5600. LINEAR STRUCTURAL SYSTEMS. (4 cr; prereq AEM 1015, 3016)
Analysis of determinate and indeterminate linear structural systems; analysis of trusses and frames through virtual work, moment distribution, energy methods, and slope-deflection equations. Influence lines. Approximate methods of analysis. Design considerations.

5601. MATRIX ANALYSIS OF STRUCTURES. (4 cr; prereq 5600)
Analysis of linear structural systems through matrix methods; stiffness and flexibility methods of analysis. Introduction to computerized structural analysis of trusses and frames.

5610. DESIGN OF METAL STRUCTURES: INTRODUCTION. (4 cr; prereq 5600)
Loads on civil structures. Load factor and working stress philosophies of design. Design of tension, compression, and flexural members and their connections. Codes, properties of structural metals.

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, 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; plate girder bridges, industrial buildings, multistory structural frames.

5613. INTERMEDIATE REINFORCED CONCRETE DESIGN. (4 cr; prereq 5611; 4 lect hrs per wk)
In-depth treatment of 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 concretes. Design of pretensioned and posttensioned members. Posttensioning systems. Precast, prestressed building systems, floors, roofs, bridges. Continuity in precast, prestressed systems. Design of connections.

5617. DESIGN OF MASONRY STRUCTURES. (4 cr; prereq 5600 or #; 4 lect hrs per wk)
Masonry materials and their production, mortars and grouts, design of nonreinforced and reinforced masonry structural systems, walls, columns, lintels, arches. Codes and specifications, testing and inspection.

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 characteristics 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.

5703. CONSTRUCTION PROJECT MANAGEMENT. (4 cr; prereq sr or above)
A broad, practical examination of construction project management including project planning, budgeting, scheduling, staffing, task and cost control, and communicating with, motivating, and managing team members.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

8097-8098-8099. CIVIL ENGINEERING RESEARCH

8200. THEORY OF TRAFFIC FLOW

8201. URBAN TRAFFIC OPERATIONS

8202. FREEWAY TRAFFIC OPERATIONS

8210. MODELING CONSUMER CHOICES IN TRANSPORTATION

8211. TRAVEL DEMAND FORECASTING

8302. ADVANCED HIGHWAY LABORATORY

8303. SPECIAL STUDIES IN CONCRETE MATERIALS

8320. THREE-DIMENSIONAL CONSOLIDATION

8321. MECHANICS OF GRANULAR MEDIA

8400. HYDRAULIC TRANSIENTS

8406. SEMINAR: ADVANCED HYDROLOGY

8410. FLUID TURBULENCE

8412. MECHANICS OF SIMILITUDE AND DIMENSIONAL ANALYSIS

8413. MECHANICS OF SEDIMENT TRANSPORT

8415. HYDRO AND THERMAL POWER DEVELOPMENT

8416. HYDRAULIC MEASUREMENTS

8417. HYDRAULIC PUMPS AND TURBINES

8419. WATER RESOURCES SYSTEMS SIMULATION

8421. INCOMPRESSIBLE POTENTIAL FLOW

8422. INCOMPRESSIBLE BOUNDARY LAYER FLOW

8425. ADVANCED GROUNDWATER MECHANICS

8430. LAKE, RESERVOIR, AND OCEAN HYDRODYNAMICS

8432. HYDRODYNAMICS OF THE BOUNDARY LAYER

8435-8436-8437. TOPICS: HYDRODYNAMIC THEORY

8440. FLOW EFFECTS ON STRUCTURES

8497-8498-8499. ADVANCED HYDRAULIC LABORATORY

8500. PHYSICAL AND CHEMICAL PROCESSES FOR WATER AND WASTEWATER TREATMENT I

8501. BIOLOGICAL AND CHEMICAL PROCESSES FOR WASTEWATER TREATMENT

8502. TECHNIQUES OF WATER AND WASTEWATER ANALYSIS

8505, 8506. AQUATIC CHEMISTRY FOR ENVIRONMENTAL ENGINEERS

8507. PHYSICAL AND CHEMICAL PROCESSES FOR WATER AND WASTEWATER TREATMENT II

8510. INDUSTRIAL WASTEWATER TREATMENT AND DISPOSAL

8520. WATER TREATMENT PLANT DESIGN

8521. WASTEWATER TREATMENT PLANT DESIGN

8530. MODELING AND CONTROL OF WATER AND WASTEWATER TREATMENT PROCESSES

8550. ANALYSIS AND MODELING OF AQUATIC ENVIRONMENTS

8551. SEMINAR ON MODELS OF AQUATIC ENVIRONMENTS

8560. SEMINAR: SPECIAL TOPICS IN ENVIRONMENTAL ENGINEERING

8605. THE FINITE ELEMENT METHOD IN CIVIL ENGINEERING

8606. APPROXIMATE METHODS OF STRUCTURAL ANALYSIS

8608. ADVANCED THEORY OF STRUCTURES

8609. PRINCIPLES OF STRUCTURAL STABILITY

8610. SHELL STRUCTURES

8611. PLATE STRUCTURES

8612. PLASTIC DESIGN OF STEEL STRUCTURES

8616. NONLINEAR STRUCTURAL SYSTEMS

8620-8621. STRUCTURAL DYNAMICS I, II

8697-8698-8699. SEMINAR: STRUCTURES

Computer Science (CSci)

1100. INTRODUCTION TO FORTRAN PROGRAMMING I. (2 cr, §3103, §3131; informal lab)
Introduction to computer programming using FORTRAN; elementary-intermediate level applications. (See 3103 and 3131 for comparison.)

1101. INTRODUCTION TO FORTRAN PROGRAMMING II. (2 cr; 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, §1100, §1101)
FORTRAN computer language with extensions; applications; programming techniques. Designed to bring students to advanced-level competence in FORTRAN programming. Integral nonscheduled laboratory.

3103. INTRODUCTION TO PROGRAMMING LANGUAGES AND PROBLEM SOLVING. (3 cr; §3101, §3104; 3131 or 3134 is recommended to be taken concurrently)
Problem solving. Algorithms. Programming language concepts: sequencing, decision making, data description, operation, name assignment, iteration, subprogram units. Program development: style, structure, checkout, maintenance.

3104. INTRODUCTION TO PROGRAMMING AND PROBLEM SOLVING. (4 cr; informal lab; required introductory course for all computer science majors; offered through CEE or Summer Session only)
Problem-solving techniques, stepwise refinement, modularization. Algorithms, introduction to evaluation criteria, representation of algorithms, flowcharts, metalanguages. The PASCAL language. Elements of programming style, program checking. Design of test data. Documentation. Comparison of PASCAL and FORTRAN.

3105. FUNDAMENTALS OF ALGORITHMS AND LANGUAGES I. (4 cr; prereq 3104 or 3101, Math 1211 or #; informal lab)
Informal and formal approaches to algorithms, their properties, and their specification through an algorithmic language; problem solving and software engineering aspects of solution implementations; analysis of algorithms and techniques for algorithm development; errors—their causes and effects as studied in several numerical applications.

3106. FUNDAMENTALS OF ALGORITHMS AND LANGUAGES II. (4 cr; prereq 3105 or #; informal lab)
Nonnumeric applications of computer sicence; system processors and processes; basic information structures and their relation to algorithm complexities; nonnumeric programming languages—SNOBOL; text processing; recursion as an algorithm development technique and its implementation in a programming language; introduction to artificial intelligence.

3107. INTRODUCTION TO THE STRUCTURE AND PROGRAMMING OF COMPUTER SYSTEMS. (4 cr, §5101; prereq 3104 or 3101 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.

3131. FORTRAN LABORATORY. (2 cr, §1100, §1101, §3101; prereq 3103 or ¶3103)
The FORTRAN programming language; applications, techniques. Concepts from 3103 are studied in terms of FORTRAN. Designed to help students acquire competence in FORTRAN programming.

3134. PASCAL LABORATORY. (2 cr, §3104; prereq 3103 or ¶3103)
The PASCAL programming language; applications, techniques. Concepts from 3103 are studied in terms of PASCAL. Designed to help students acquire competence in PASCAL programming.

3400. DISCRETE STRUCTURES OF COMPUTER SCIENCE. (4 cr; prereq Math 1231 or 1331 or equiv or #)
Proof techniques. Propositional calculus. First-order logic. Sets and multisets. Combinatorics. Analysis of algorithms. Graphs.

5001. THEORY AND APPLICATION OF LINEAR PROGRAMMING ALGORITHMS. (4 cr; prereq 1101 or 3103...and 3131 or 3134...and Math 3142 or #; informal lab)
Basic solutions to linear systems; inequalities; convex polyhedral sets; linear programming formulation and optimal conditions; theoretical and computational aspects of simplex algorithm; postoptimal analysis; duality. Revised simplex and numerically stable methods, upper bounded problems; commercially available LP systems; methods for large, sparse systems.

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

5101. STRUCTURE AND PROGRAMMING OF SOFTWARE SYSTEMS I. (4 cr, §3107; intended for non-CSci majors...majors should take 3107; prereq 1101 or 3101 or 3104 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.

5102. STRUCTURE AND PROGRAMMING OF SOFTWARE SYSTEMS II. (4 cr; prereq 3107 or 5101 or #; informal lab)
Extension of basic machine architecture and principles of system programming; closed subroutines; parameter passing mechanisms; macros and conditional assembly; input-output; assembly linking and loading; dynamic resource allocation; introduction to operating systems, job control language, and processes.

5103. STRUCTURE AND PROGRAMMING OF SOFTWARE SYSTEMS III. (4 cr; prereq 5102 or #; informal lab)

5104. SYSTEM SIMULATION: LANGUAGES AND TECHNIQUES. (4 cr; prereq 3107 or 5101, Stat 3091 or #; informal lab)
Methodologies relevant to simulation including queuing theory, variable generation, design of experiments, data collection, statistical analysis of output. Simulation languages, both flow and event oriented, including GPSS, SIMULA, SIMSCRIPT. Application to job shops; operations research and modeling of computer and communications 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 values and sign arithmetic, scaling and floating point operations.

5106. STRUCTURE OF HIGHER LEVEL LANGUAGES. (4 cr; prereq 5102 and 5121 or #)
Formal definition of the syntax and semantics of programming languages; semantics both by means of interpreters and by using the axiomatic approach. Concepts underlying programming languages and their instantiations in a selected group of languages. Program description at compilation time and execution time.

5107. COMPUTER GRAPHICS I. (4 cr; prereq 3107 or 5101 or #)
Introduction. Definition of interactive computer graphics, its goals and its problems. A model system. Data structures for computer graphics, picture structure and transformations. Perspective views of three-dimensional objects. Structures of graphical programming languages. Interaction handling.

5117. COMPUTER GRAPHICS II. (4 cr; prereq 5107 or #)
Display processor architecture. Data base management and display file handling. Multilevel software systems for enhanced portability and protocol handling in graphical networks. Examples of graphical programming systems. Methodology of curve and surface interpolation and approximation. Programs for three-dimensional display, and curve and surface approximation.

5121. INTRODUCTION TO DATA STRUCTURES. (4 cr; prereq 3106 or #; informal lab)
Basic concepts of data and their representation. Sequential and linked representations. Arrays, stacks and queues. Chains, circular lists and doubly linked lists. Dynamic storage management. Garbage collection and storage compaction. Generalized lists. Strings. Binary trees and trees. Tree traversal. Graphs. Activity networks.

5122. ADVANCED DATA STRUCTURES. (4 cr; prereq 5121 or #; informal lab)
Internal and external sorting. Symbol tables. Optimal binary trees. AVL trees. Hashing. B-trees, tries. Files and indexes. ISAM, multilists, inverted files, cellular partitions, differential files.

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. PRINCIPLES OF CONTINUOUS SYSTEM SIMULATION. (4 cr; prereq 1101, Math 3221 or 3061 or #; 3 lect and 1 lab hrs per wk)
Analog computation. Digital simulation of continuous systems. Hybrid computation. Programming systems. Applications of hybrid computation.

5201. COMPUTER ARCHITECTURE. (4 cr; prereq 3400, 3107 or 5101 or #)
Elementary computer architecture, gates and digital logic, register transfers and micro operations, processor studies of existing systems.

5211. DATA COMMUNICATIONS AND COMPUTER NETWORKS. (4 cr; prereq 5102 or #; informal lab)
Network classification and services. Hardware components: multiplexors, concentrators, communications media. Network protocols and architectures. Research areas.

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; prereq Math 3142 or #...a knowledge of FORTRAN is assumed; informal lab)
Floating point arithmetic and rounding errors. Iterative methods. Numerical solution of nonlinear equations. Newton's method. Direct methods for linear systems of equations. Gaussian elimination. Factorization methods. Interpolation and approximation. Numerical integration and differentiation. Introduction to numerical solution of ordinary differential equations.

5302. NUMERICAL ANALYSIS. (4 cr; prereq 5301 or #; informal lab)
Norms, condition numbers and error analysis. Convergence rates for iterative methods. Numerical approximation methods. Least squares. Fast Fourier transorm. Gaussian quadrature. Spline interpolation. Computation of eigenvalues and eigenvectors. Stability and error analysis of methods for solution of ordinary differential equations.

5304. COMPUTATIONAL ASPECTS OF MATRIX THEORY. (4 cr; prereq 5302 or #; informal lab)
Direct and iterative solution of large linear systems. Decomposition methods. Computation of eigenvalues and eigenvectors. Singular value decomposition. Linpack and other software packages. Methods for sparse and large structured matrices.

5305. NUMERICAL METHODS FOR ORDINARY DIFFERENTIAL EQUATIONS. (4 cr; prereq 5302 or #; informal lab)
Initial value problem. Convergence and stability. Efficient implementation. Error estimation and step size control. Comparison of recent software packages. Two-point boundary value problems. Collocation and finite element methods.

5306. NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS. (4 cr; prereq 5304, 5305 or #; informal lab)
Finite difference methods for elliptic, parabolic, and hyperbolic problems. Convergence, stability and error analysis. Finite element methods. Galerkin and collocation methods. Efficient implementation.

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 3105 and 3400 or #)
Turing machines, computable functions, unsolvability of the halting problem, recursive functions. Finite state models; equivalence, minimization, properties, decision questions, characterizations, Regular expressions. 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. Pushdown 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. (4 cr; prereq 3106 and 5121 or #; informal lab)
Concept of a "mechanized" intelligence, operational definitions of intelligence. Heuristic search techniques: problem representation, world model representation, solution search. Application to game playing systems. Natural language processing and semantic information systems. Introduction to machine perception and integrated robots. The future of artificial intelligence.

5502. INTRODUCTION TO OPERATING SYSTEMS. (4 cr; prereq 5102 and 5121 or #; informal lab)
Definition and historical development of operating systems. Abstractions and implementations of features common to most systems. Concurrency and related control problems. Resource allocation. Storage allocation. Process manager and the kernel of an operating system. Sharing. Capability-based addressing. Protection. Performance measurement and analysis.

5503. INTRODUCTION TO COMPILERS. (4 cr; prereq 5106 and 5121 or #; informal lab)
A higher level language (PL/.5), machine language, loaders, linkage editors; mapping PL/.5 onto machine language, code generation techniques; derivation of an intermediate language and implementation of code generators for intermediate onto machine language. Students write the back end of a PL/.5 compiler.

5504. INTRODUCTION TO COMPILERS. (4 cr; prereq 5106 and 5121 or #; informal lab)
Lexical scanning together with preprocessing and macro expansion, symbol tables, parsing, intermediate text generation, error detection and correction. Students design and implement a front end for a PL/.5 compiler.

5521. PATTERN RECOGNITION. (4 cr; prereq Math 3142 or equiv and Stat 3091 or #; informal lab)
Definition pattern recognition, feature selection, measurement techniques, and similar problems. Classification methods: statistical decision theory, nonstatistical techniques. Automatic feature selection. Syntactic pattern recognition. The relationship between mathematical pattern recognition and artificial intelligence. Applications.

5702. THE PRINCIPLES OF DATA BASE SYSTEMS. (4 cr; prereq 5122 or #; informal lab)
Fundamental concepts. Conceptual data organization. Data models. Data manipulation languages. Data base design. Security and integrity. Performance evaluation. Query optimization. Distributed data base systems.

5703. DATA BASE SYSTEM DESIGN. (4 cr; prereq 5702 and #; informal lab)
Application of data base concepts to the design and development of data base systems and data base applications. Design of current commercial and research-oriented data base systems. Techniques of using data base systems for applications.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

8101. COMPUTER SYSTEM

8102. 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

8505. OPTIMIZATION IN COMPILERS

8511. ADVANCED CONCEPTS IN ARTIFICIAL INTELLIGENCE

8599. SEMINAR: NONNUMERIC COMPUTATION

8699. SEMINAR: CONTROL SCIENCE

8701. ADVANCED CONCEPTS IN ARTIFICIAL INTELLIGENCE

8799. SEMINAR: INFORMATION SCIENCE

Electrical Engineering (EE)

1000. INTRODUCTION TO ELECTRICAL ENGINEERING. (1 cr; S-N only; prereq IT lower division or △)
An introduction to electrical engineering presented by practicing engineers and members of the faculty.

1510. ELEMENTS OF ELECTRICAL ENGINEERING. (5 cr; prereq grades of at least C in Math 3211, 3221, Phys 1291 or ¶Phys 1291; 5 lect-rec-dem and 3 lab hrs per wk)
Physical principles underlying the modeling of circuit elements. Two- and three-terminal resistive elements. Kirchhoff laws. Simple resistive circuits. Linearity in circuits. Storage elements. First- and second-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 3010 or 3000 or ¶3000; 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; prereq grade of at least C in 1510)
3010: Modeling of lumped-parameter networks. 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 △)

3050-3051-3052. ELECTRONICS I-II-III. (4 cr per qtr; prereq 3010-3011-3012 or ¶3010-3011-3012)
Elementary semiconductor physics; physical description of pn junction diodes, bipolar junction transistors, and field effect transistors; large and small signal circuit models for transistors and diodes; applications in elementary analog and digital circuits; elementary amplifiers at high frequencies; feedback amplifiers; oscillators; differential and operational amplifiers.

3050H-3051H-3052H. HONORS COURSE: ELECTRONICS I-II-III. (4 cr per qtr; prereq △)

3100-3101. ELECTROMAGNETIC FIELDS I, II. (4 cr per qtr; prereq grades of at least C in Phys 1291, Math 3231 or ¶Math 3231 with #)
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 3010, 3050 or ¶3010, ¶3050 for 3400...3011, 3051 or ¶3011, ¶3051 for 3401...3012, 3052 or ¶3012, ¶3052 for 3402)
Experiments in circuits, electronics, and electromagnetic fields.

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. INDUSTRIAL ASSIGNMENT I, II. (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.

5002. DIGITAL SIGNAL PROCESSING. (4 cr; prereq 3012)
General concepts of signal processing; discrete-time systems and digital filters.

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.

5051. LOGIC DESIGN AND MICROPROCESSORS. (4 cr; prereq 3051 or #)
Switching algebra, design of combinational logic networks, Karnaugh maps. Flip-flops, counters, and shift registers. Microprocessor architecture, programming, and input-output devices.

5052. LOGIC DESIGN AND MICROPROCESSOR LABORATORY. (1 cr; prereq ¶5051)

5053. DESIGN OF DIGITAL CIRCUITS. (4 cr; prereq 3052, 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. INSTRUMENTATION AND CONTROL ELECTRONICS. (4 cr; prereq 3012 or ¶3012, 3052 or #)
Internal circuitry of modern integrated circuit operational amplifiers; linear and nonlinear applications of operational amplifiers; power amplifiers; semiconductor controlled rectifiers and their applications; linear voltage regulators; switching regulators.

5056. ELECTRONIC CIRCUITS LABORATORY. (1 cr; prereq 3401, ¶5055; 2 lab hrs per wk)

5062. COMMUNICATION CIRCUITS. (4 cr; 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)
Plane-wave propagation, transmission lines, antennas, and other topics.

5100H. HONORS COURSE: ELECTROMAGNETIC FIELDS III. (4 cr; prereq △)

5101. ELECTROMAGNETIC FIELDS LABORATORY. (1 cr; prereq 3401, 5100 or ¶5100)

5112. ELECTROMAGNETIC BOUNDARY VALUE PROBLEMS. (4 cr; 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; 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 #)
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; 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; 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. DIGITAL CONTROL SYSTEMS. (4 cr; prereq 5051, 5052, and 5002 or ¶5002 or #; 3 lect and 2 lab hrs per wk)
Time- and frequency-domain analysis of discrete-time and digital control systems. Data conversion and interfacing. Digital computers as control system components. Software and hardware considerations in digital control system design.

5253. LINEAR CONTROL SYSTEMS. (4 cr; 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 #)
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.

5310. ELECTRIC POWER SYSTEMS. (4 cr; prereq 5300 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; prereq 5300 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, 5333. ENERGY CONVERSION METHODS. (4 cr per qtr; prereq 3050, 3101, ME 3301, Phys 3501 or #)
Principles of energy conversion systems: thermodynamic considerations, various nonconventional energy conversion systems with emphasis on technical, environmental, and economic problems. Special topics of current interest.

5352. DESIGN OF DIGITAL SYSTEMS. (4 cr, §5851, §5852, §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.

5451-5452. ENGINEERING DESIGN. (3 cr per qtr [no cr for EE majors]; prereq #, permission of student's major dept)
Application of mathematical and computational techniques to design problems chosen from a wide range of engineering disciplines. Frequent use of interdisciplinary problems first encountered in industry. Topics include circuits, classical control theory, discrete time systems, state-space analysis, distributed systems, microprocessors, and mathematical and statistical techniques appropriate to these topics. Weekly written reports required.

5470. DIRECTED STUDY. (Cr ar [may be repeated for cr]; prereq △)
Studies of approved topics, theoretical or experimental in nature.

5478-5479†. INDUSTRIAL ASSIGNMENT III, IV. (2 cr per qtr; prereq 3477, 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.

5490H-5491H-5492H. HONORS PROJECT. (3 cr per qtr; prereq △)
Design project for students in electrical engineering honors program.

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.

5511-5512. DIGITAL FILTERS AND SIGNAL PROCESSING. (3 cr per qtr; prereq 5002 or #)
5511: Theory of discrete-time systems, Z-transform, sampling and interpolation. Discrete-Fourier transform. Several methods of designing finite-impulse-response (FIR) and infinite-impulse-response filters. 5512: Quantization effects. Theory of two-dimensional digital filters and image processing. Fast-Fourier transform and applications of digital signal processing. Adaptive and homomorphic filtering.

5550-5551-5552. SWITCHING AND DIGITAL CIRCUITS. (3 cr per qtr; prereq 3052 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 #)
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 #)
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.

5625. FOURIER OPTICS. (4 cr; prereq 5100 or Phys 3012 or #)
Fourier analysis of optical systems and images with applications to spatial filtering, optical information processing, and holography. Fresnel and Fraunhofer diffraction. Current topics such as speckle interferometry, hybrid (optical-digital) information processing systems, and computer-generated holograms.

5630. CONTEMPORARY OPTICS. (4 cr; prereq 5100 or Phys 3012 or #)
Current developments in optics. 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.

5650. DYNAMICAL METHODS IN ELECTRICAL ENGINEERING. (3 cr; prereq #)
Lagrange and Hamilton formulations of dynamics, with applications to electromagnetic systems. Lagrange equations; dissipative forces, normal coordinates and small oscillations; Hamilton equations; variational principles for discrete and continuous systems.

5651. THERMODYNAMIC METHODS IN ELECTRICAL ENGINEERING. (3 cr; prereq #)
Basic thermodynamic concepts and laws with 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 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 #)
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 theorem. Block codes for the binary channel.

5702. STOCHASTIC PROCESSES AND OPTIMUM FILTERING. (3 cr; prereq Stat 3091, grad standing or #)
Stochastic processes, linear system response to stochastic inputs. Gaussian process, Markov process. Linear filtering, maximum likelihood estimate, stochastic control.

5750. TOPICS IN SYSTEM ANALYSIS. (3 cr; prereq grad standing or #)
Linear system models, controllability, observability, stability. Structure of linear systems. Minimization on inner product spaces.

5751. OPTIMIZATION TECHNIQUES. (3 cr; prereq grad standing or #)
Finite dimensional optimization, infinite dimensional optimization. Controller synthesis for the linear, quadratic problem.

5752. NONLINEAR SYSTEM DESIGN. (3 cr; prereq grad standing or #)
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.

5808. DIRECT-CURRENT POWER CONVERSION AND TRANSMISSION. (3 cr; prereq #)
General aspects of DC power transmission and comparison with AC transmission. Theory of operation and control of solid state AC/DC power converters. Transients due to long DC transmission lines. System protection and harmonic filtering. Environmental impact. Current research topics.

5815. SEMICONDUCTOR POWER DEVICES AND APPLICATIONS. (3 cr; prereq 3052, 3402 or grad standing)
Terminal characteristics and qualitative physics of power semiconductor devices such as diodes, transistors, thyristors, power MOSFETs, and optoelectronics, used in power electronics applications. Application of these devices for AC and DC motor drive, regulated DC power supplies, PWM choppers, and cycloconverters. Design considerations and protection of devices.

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, CSci 3101 or CSci 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.

5951. M.E.E. PROJECT I. (3-9 cr [may be repeated for max 9 cr]; prereq △, enrollment in MEE program)
Completion of first half of the M.E.E. project: a sequence of small design projects.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

8000. ADVANCED TOPICS IN NETWORK THEORY

8051-8052-8053. LARGE-SCALE INTEGRATED CIRCUITS

8060. BIPOLAR TRANSISTOR THEORY

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

8203-8204. 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

Geo-Engineering (GeoE)

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.

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.

5216. GEO-ENGINEERING I. (3 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.

5218. TUNNEL TECHNOLOGY. (3 cr; prereq 5302 or #)
Tunneling systems, site problems. Analysis of stress and load. Design of minings and support. Materials handling. Planning. Special problems. Case histories.

5262. GEO-ENGINEERING ANALYSIS. (4 cr; prereq sr or #; 8 lab hrs per wk)
Comprehensive analysis of a geological engineering or rock mechanics problem chosen by the student and staff. Involves the integration of concepts of rock and soil mechanics, geology and geophysics, mineral engineering and economics. Preparation of a professional report.

5300. THEORY OF GEOMECHANICS. (4 cr; prereq CE 3300; 3 lect and 2 rec hrs per wk)
Groundwater flow. Introduction to linear elasticity. Consolidation; settlement calculations. Limit analysis, bearing capacity.

5302. APPLIED ROCK MECHANICS. (4 cr; prereq 5300)
Principles and techniques of site investigation in rock. Design of surface and underground excavations, including excavation and mine stability, and methods of ground control. Application of numerical models in design.

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.

5660-5661-5662. SPECIAL GEO-ENGINEERING PROBLEMS. (Cr and hrs ar; prereq sr or #)
Literature survey, research work, or design study in geo-engineering problems.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

8336. ANALYTICAL METHODS IN ROCK MECHANICS

8350-8352. ADVANCED ROCK MECHANICS I, II

8601-8602-8603. SEMINAR

8612-8613-8614. RESEARCH PROBLEMS

Geology and Geophysics (Geo)

1001f,w,s. PHYSICAL GEOLOGY. (5 cr; 4 lect hrs and one 2-hr lab per wk) Staff
Introduction to scientific method and nature of the earth; main features of the physical world and processes that have formed them.

1002w,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; the succession of physical and biological events of past 600 million years.

1005w. GEOLOGIC PERSPECTIVES ON ENERGY. (4 cr; 3 lect hrs per wk, 2 field trips) Alexander, Shaw
Introduction to the geologic aspects of energy resources, conventional and unconventional. History of energy use, distribution and amounts of known and potential reserves, environmental aspects and implications of U.S. consumption patterns.

1007s. ENVIRONMENTAL GEOLOGY. (4 cr, §1008; prereq 1001) Wright
Geological application in resource management, land use planning, technology, and conservation. Geological evolution of the biosphere and the impact of human activities on land, sea, and air resources. Geological hazards. The Twin Cities metropolitan area as a geological environment. Lectures, labs, and field trips.

1012f. EARTH AS A PLANET. (4 cr; 3 lect and 1 lab hrs per wk) Alexander
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-cell 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) Shaw
For prospective majors and others desiring a more intensive lecture and laboratory sequence than 1001.

1601w. OCEANOGRAPHY. (4 cr; 3 lect and 1 lab hrs per wk) Johnson
How various processes in the ocean interact; analogies between the oceans and Lake Superior and smaller lakes in Minnesota. Topics include marine biology, waves, tides, chemical oceanography, marine geology and human interaction with the sea. Lab work includes study of live marine invertebrates and manipulation of oceanographic data.

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.

3100f. SEDIMENTARY PETROLOGY. (5 cr, §5652; prereq 3102; 3 lect and 4 lab hrs per wk) Johnson
Interpretation of the origin and diagenetic history of sedimentary rocks, utilizing knowledge of present-day depositional environments and petrographic microscopy.

3101w. SURFICIAL GEOLOGIC PROCESSES. (5 cr; prereq 3102 and 3401 or #)
Geological processes acting at the surface of the earth.

3102s. PETROLOGY. (5 cr; prereq 3401 or #) Stout
Introduction to the lithologic character and genesis of igneous, metamorphic, and sedimentary 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.

3112f. EARTH HISTORY. (5 cr; prereq 1111 or #; 3 lect hrs, 1 rec hr, two 2-hr labs per wk) Sloan
For prospective majors and others desiring a more intensive course than 1002.

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
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 grad students in education; prereq 1001 or #, 1 term college chemistry, Math 1221; 3 lect and 6 lab hrs per wk) Zoltai, Stout
For description, see 3401.

5051su. PHYSICAL GEOLOGY FOR TEACHERS. (4 cr, §1001, §1111; prereq education degree, 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; prereq education degree, 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.

5099. SENIOR THESIS. (2 cr per qtr; prereq geology or geophysics major with 4th-yr standing, #)
Independent research under faculty supervision. Problems selected according to individual interests and through consultation with faculty committee. Involves thesis and oral defense.

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. STRATIGRAPHIC ANALYSIS. (4 cr; prereq 3112) Crews
Principles of correlation, facies models, and tectonics applied to the history of sedimentary basins.

5108w. ADVANCED ENVIRONMENTAL GEOLOGY. (4 cr; prereq geology core courses 1111 through 3103 or equiv or #) Pfannkuch
Human impact on the geological environment and the effect of geology/geologic processes on human life from the point of view of ecosystems and biogeochemical cycles. Geologic limits to resources and carrying capacity of the earth. Land use planning, environmental impact assessment, ecogeologic world models. Field project.

5110su. FIELD GEOLOGY. (9 cr; open only to geology, geophysics, and geo-engineering majors; prereq 3103, #)
Measurement of stratigraphic sections, fossils and igneous, sedimentary, and metamorphic rocks. Geological surveying on aerial photographs and topographic maps. Preparation of geologic maps and report writing.

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 EBB 5114) Sloan
Morphology, evolution, and stratigraphic distribution of fossil fish, amphibians, reptiles, and birds.

5155s. VERTEBRATE PALEONTOLOGY II. (5 cr; prereq 5154 or EBB 5114) Sloan
Morphology, evolution, and stratigraphic distribution of fossil mammals.

5156. ZOOARCHAEOLOGY. (5 cr; primarily for paleontology, anthropology or classics students; prereq 5155 or #; 3 lect and 2 lab hrs per wk; offered 1981 and alt yrs)
Identification and interpretation of animal remains in an archaeological context.

5202. TECTONIC STYLES. (3 cr; prereq 3101 or #; 3 lect hrs per wk; offered 1982 and alt yrs) Hudleston
The origin and nature of major types of disturbances affecting the continental crust, including analysis of the form and development of individual structural components.

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) Hooke
Detailed study of selected geomorphic processes. Emphasis on fluvial processes and arid region geomorphology.

5253. SEDIMENT TRANSPORT MECHANISMS. (3 cr; prereq 5251 or 5652 or CE 5410)
Properties of sediment, water bed interaction, types of transport (bed load, suspended load), suspension of sediment, sediment transport theories, consequences of sediment movement in alluvial channels.

5254. CARBONATE PETROLOGY. (5 cr; prereq 3102; 3 lect and 4 lab project hrs per wk) Crews
Factors controlling modern carbonate deposition, interpretation of carbonate facies through geologic time, and effects of diagenesis.

5255w.* GLACIOLOGY. (4 cr [5 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.

5261f.* GLACIAL GEOLOGY. (4 cr [5 cr with term paper or map lab] ; 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 nonglaciated areas. Field trips.

5301. GENERAL GEOCHEMISTRY. (3 cr; prereq 1 qtr chemistry, #) Seyfried, Alexander
Basic principles of geochemistry; stresses distribution and mobilization of elements in the earth's crust, stable isotope geochemistry, and geochemical reactions involved in the formation of igneous, metamorphic, and sedimentary rocks.

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 isotopic tracer techniques in crust-mantle evolution, igneous processes and the early history of the earth.

5303. AQUEOUS GEOCHEMISTRY. (3 cr; prereq Chem 5501 or Chem 5520, #)
Chemical processes in the oceans, mineral equilibria, and exchange with the atmosphere. Redox processes and controls of the chemistry of natural waters.

5351f.* ECONOMIC GEOLOGY: METAL SULFIDE DEPOSITS. (5 cr with lab, 4 cr without lab; prereq 3401 or 5404, 3103 or #) Sawkins
Nature and distribution of sulfide deposits, and analysis of the processes by which metals are concentrated in magmatic, hydrothermal and sedimentary environments.

5352. ECONOMIC GEOLOGY: FERROUS METAL AND NONMETALLIC DEPOSITS. (4 cr; prereq 3401, 3103 or #)
Environmental setting, mineralogy, and genesis of ferrous metal ore deposits and nonmetallic deposits.

5404. MINERAL SYSTEMS I. (4 cr, §3401, §5004; prereq 1 qtr chemistry) Zoltai
Crystallography: basic and compound symmetry operations, point and space groups, crystal forms and coordinate systems. Systematics of basic and derivative close-packed and coordination polyhedral structures of rock forming and ore minerals. Demonstrations of crystallographic and crystal structural concepts.

5405. MINERAL SYSTEMS II. (4 cr; prereq 3401 or 5404, 1 qtr physics) Shaw
Review of optical mineralogy. Bonding and relative size of atoms and ions. Chemical substitutions. Crystal growth and imperfections. X-ray powder diffraction. Thermal, electric, elastic, and magnetic properties of minerals. Absorption phenomena. Laboratory: optical mineralogy and crystal physics exercises.

5452s.* IGNEOUS AND METAMORPHIC PETROLOGY. (4 cr; prereq 3102, Chem 5520 or 5521, Math 3211 or #) Stout
Theoretically oriented treatment of 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.

5501w. GEOPHYSICAL METHODS IN GEOLOGY. (4 cr; prereq 3102, Phys 1291)
Introduction to geophysical properties of the earth and earth materials, internal structure and constitution, geophysical exploration, methods of geologic interpretation, radioactivity and thermal structure of the earth, physical basis for plate tectonics.

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 #) Shaw
Origin and chemical evolution of the earth through geologic time.

5507s. PHYSICS AND CHEMISTRY OF THE EARTH III. (4 cr; prereq 1111, Phys 1291; 5505 or 5506 *not* required) 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.

5531. HIGH PRESSURE MINERALOGY WITH GEOPHYSICAL APPLICATION. (3 cr; prereq 3401 or #) Shaw
Phase transformation in solids at high pressures and temperatures with emphasis on silicates and silicate analogs, likely mineralogic constitution of the mantle, and detailed structure of the mantle.

5541f.* GEOMAGNETISM. (3 cr; prereq 1 qtr each of geology, physics, mathematics) Banerjee
Historical introduction. Theory of the geodynamo. Magnetic properties of rocks and minerals. Polar wandering and continental drift.

5601f. LIMNOLOGY. (4 cr, §EBB 5601; prereq Chem 1005 or equiv) Shapiro
Description and analysis of events occurring in lakes, reservoirs, and ponds, from their origins through 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) Shapiro
Detailed analysis of specific studies on lakes, and problems of lakes throughout the world.

5611s. GROUNDWATER GEOLOGY. (4 cr; prereq 1001 or 1111, Math 1231, 1 qtr physics and chemistry or #) Pfannkuch
Origin, occurrence, and movement of groundwater viewed in the context of the hydrologic cycle. Characteristics of aquifer systems. Exploratory investigations. Hydrogeologic units and boundaries of regional systems. Analysis of surface water groundwater interaction, recharge. Quality and chemistry of groundwater supplies.

5642f. MARINE GEOLOGY. (4 cr; prereq geology core course sequence or #)
Physiography and structure of ocean basins and continental margins; their development as suggested by concepts of global tectonics. Emphasis on geologic processes in the marine environment. Review of marine geological and geophysical techniques.

5651. GEOLOGICAL LIMNOLOGY. (5 cr; prereq 5601 or EBB 5601) Johnson
Tectonic and climatic setting of lakes; physical, chemical, and biological processes of sedimentation in lakes.

5652. SEDIMENTARY PETROLOGY. (5 cr, §3100; prereq 3102; 3 lect and 4 lab hrs per wk) Johnson
Interpretation of the origin and diagenetic history of sedimentary rocks, utilizing knowledge of present-day depositional environments and petrographic microscopy. Term paper required.

5653. DEPOSITIONAL SYSTEMS. (5 cr; prereq 3102) Crews
Facies relations in modern and ancient sedimentary environments.

FOR GRADUATE STUDENTS ONLY OR FOR SENIORS WITH SPECIAL PERMISSION

(For course descriptions, see the *Graduate School Bulletin*)

General Geology

8098. SEMINAR: CURRENT TOPICS IN GEOLOGY AND GEOPHYSICS

8099. RESEARCH IN GEOLOGY AND GEOPHYSICS

8103. BIOSTRATIGRAPHY

8152. ADVANCED INVERTEBRATE PALEONTOLOGY

8156. MICROPALEONTOLOGY

8201. GEOTECTONICS

8202. ADVANCED STRUCTURAL GEOLOGY

8262. QUATERNARY PALEOECOLOGY AND CLIMATE

Mineralogy and Petrology

8351. ADVANCED MINERAL DEPOSITS I

8352. ADVANCED MINERAL DEPOSITS II

8402. X-RAY MINERALOGY

8404. X-RAY CRYSTALLOGRAPHY

8453. PHASE EQUILIBRIA IN MINERAL SYSTEMS

8454. IGNEOUS PETROLOGY

8455. METAMORPHIC PETROLOGY

Hydrogeology

8602. ADVANCED LIMNOLOGY

8603. METHODS FOR ANALYSIS OF NATURAL WATERS

8611. TRANSPORT PHENOMENA IN NATURAL POROUS MEDIA

8612. ANALYTICAL GEOHYDROLOGY

8651. CHEMICAL SEDIMENTOLOGY

8657. MARINE SEDIMENTS

Geophysics

8521. LINEAR DATA PROCESSING WITH GEOPHYSICAL APPLICATIONS

8531-8532. THEORY OF ELASTIC WAVE PROPAGATION I, II

8542. PRINCIPLES OF ROCK MAGNETISM I

8543. PRINCIPLES OF ROCK MAGNETISM II

8551. EQUATION OF STATE AND CONSTITUTION OF THE EARTH'S INTERIOR

8564. PROPERTIES OF THE EARTH'S MANTLE: RELATIONSHIP TO CRUSTAL MOTION

History of Science and Technology (HSci)

Courses may be taken to support existing majors as well as to broaden knowledge of the nature and development of science and technology. All courses satisfy group C distribution requirements.

1711, 1712, 1713. TECHNOLOGY AND WESTERN CIVILIZATION. (4 cr per qtr, §3711, §3712, §3713) Layton History and sociocultural relations of Western technology. 1711: The relations of technology to culture from the Bronze Age to the Middle Ages. 1712: Technology and science in the Renaissance; technology and the scientific revolution; emergence of industrialism. 1713: Diffusion of the industrial revolution; technological development and its impact on industry, government, and society.

1811, 1812, 1813. INTRODUCTION TO HISTORY OF SCIENCE. (4 cr per qtr, §3811, §3812, §3813) Shapiro 1811: Babylonian and Egyptian science; Greek natural philosophy, mathematics, astronomy, and biology; the Aristotelian world; decline and transmission of Greek science. 1812: Medieval background; the "experimental philosophy": dissecting and describing nature; anatomy, circulation, and respiration; Copernican revolution; physical world of Kepler, Galileo, Descartes, and Newton; science and the popular imagination. 1813: 19th and 20th centuries; Newtonian triumph, romantic reaction, and modern revolution; the aether, electrical and optical, to Einstein; history of the earth; evolution before and after Darwin; nuclear physics and nuclear weapons.

3201, 3202, 3203. HISTORY OF BIOLOGY. (4 cr per qtr, §5201, §5202, §5203) Kottler
3201: Antiquity to 1700. Biology, medicine, and natural history in antiquity: Hippocrates, Aristotle, Galen. Revival of biology in Renaissance and 17th century: Vesalius and anatomy, Harvey and circulation. 3202: Physiology and cell theory since 1700. Conceptual development of the various branches of modern biology: physiology, chemistry, and the experimental method; embryology, descriptive and experimental; cytology and microscopy. 3203: Evolution and genetics since 1700. Darwin and evolution; Mendel and genetics.

3711, 3712, 3713. TECHNOLOGY AND WESTERN CIVILIZATION. (4 cr per qtr, §1711, §1712, §1713)
For description, see 1711, 1712, 1713.

3811, 3812, 3813. INTRODUCTION TO HISTORY OF SCIENCE. (4 cr per qtr, §1811, §1812, §1813)
For description, see 1811, 1812, 1813.

3825. PHYSICS AND SOCIETY IN 20TH-CENTURY AMERICA. (4 cr, §3835, §5825) Stuewer
Nineteenth-century heritage; 20th-century discoveries and physical theories; growth of physics in America after World War I: the intellectual migration of the 1930s; nuclear physics, the Manhattan project, and the atomic bomb; McCarthyism and Oppenheimer; current and past contributions of Minnesota physicists.

3835. THE ATOMIC AGE. (4 cr, §3825, §5825) Stuewer
Development of nuclear energy in the 20th century; construction and use of the bomb; postwar military and political impact.

5011. THEORIES OF COLOR: NEWTON TO HELMHOLTZ. (4 cr) Shapiro
Physical and physiological investigations of color from the 17th to the mid-19th centuries, focusing on fundamental contributions of Newton, Young, Maxwell, and Helmholtz.

5111f. PHYSICAL SCIENCES IN ANTIQUITY. (4 cr) Shapiro
Mathematics and astronomy in Babylonia; Greek mathematics, Euclid and Archimedes; Aristotle's physics and cosmology; the emergence of mathematical and experimental natural science in Greece; Ptolemaic astronomy.

5201, 5202, 5203. HISTORY OF BIOLOGY. (4 cr per qtr, §3201, §3202, §3203)
For description, see 3201, 3202, 3203.

5242. EVOLUTION BEFORE AND AFTER DARWIN. (4 cr; prereq Biol 1011 or 1101 or #) Kottler
Philosophical conceptions of species; natural theology, design, and providential creation of species; Lamarck and evolution before Darwin; catastrophist and uniformitarian geology; Darwin and the background of the *Origin*; Darwin's early critics; evolutionary theory, 1882 to modern synthesis.

5311. TECHNOLOGY IN AMERICAN LIFE. (4 cr) Layton
Technology in America with emphasis on its impact on society and culture. Traces the growth of American technology in its cultural and intellectual context from colonial period to present.

5825. PHYSICS AND SOCIETY IN 20TH-CENTURY AMERICA. (4 cr, §3825, §3835) Stuewer
For description, see 3825.

5924. HISTORY OF 19TH-CENTURY PHYSICS. (4 cr, §Phys 5924; prereq general physics or #) Stuewer
Conceptual development in physics (Young, Fresnel, Oersted, Ampère, Faraday, MacCullagh, Maxwell, Hertz, Lorentz, Lavoisier, Rumford, Dalton, Mayer, Joule, Helmholtz, Carnot, Clausius, Kelvin, Boltzmann, Mach, others). Relationships of these developments to social, philosophical, and theological influences.

5925. HISTORY OF 20TH-CENTURY PHYSICS. (4 cr, §Phys 5925; prereq general physics or #) Stuewer
Conceptual developments in relativity (Michelson, Lorentz, Poincaré, Einstein, others), quantum mechanics (Planck, Einstein, Rutherford, Bohr, Sommerfeld, Ehrenfest, Pauli, Millikan, Compton, Heisenberg, de Broglie, Schrödinger, Born, others), and nuclear physics (Chadwick, Gamow, Fermi, others). Relationships of these developments to social, philosophical, and theological influences.

5970. DIRECTED STUDIES. (1-15 cr per qtr; prereq #)
Guided individual reading or study.

5990. DIRECTED RESEARCH. (1-15 cr per qtr; prereq #)

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, motivation 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.

5050. ENGINEERING ECONOMIC ANALYSIS. (4 cr; prereq 5000 or #; 3 lect and 1 rec hrs per wk)
Fundamental principles and techniques of economic analysis of engineering projects including economic measures of effectiveness, time value of money, cost estimation, depreciation, taxes, breakeven, replacement and investment analysis.

5070. INTRODUCTION TO HUMAN FACTORS ENGINEERING. (4 cr; prereq #; 3 lect and 1 rec-lab hrs per wk)
Analysis and design of operations, machines, equipment, work stations, and work environments relative to the capabilities, limitations, and needs of the human operator. Topics include human-machine systems, displays, controls, human-machine interface layout, work station design, anthropometry, work physiology and biomechanics, illumination, noise, toxicology, and climate.

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, Markov 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)
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.

5701. TECHNOLOGY ASSESSMENT. (4 cr; prereq upper division; 4 lect hrs per wk)
Unintended consequences of specific technologies on society. The history, institutional structures, and methodology of technology assessment; specific technology assessments. One or more class projects.

5710. TRANSIT SYSTEMS ANALYSIS AND DESIGN. (4 cr; prereq sr engineering status; 3 lect and 1 rec hrs per wk)
Introduction to transit systems: performance and energy relationships; kinematical design of curved guideways; lateral suspension dynamics; performance and cost effectiveness of shuttle, loop, line haul, and network systems operating in scheduled and demand modes; patronage analysis.

5711. TRANSIT SYSTEMS ANALYSIS AND DESIGN. (4 cr; prereq 5710; 3 lect and 1 rec hrs per wk)
Design of transit vehicles for safe operation; reliability allocation in transit systems for minimum life cycle cost; theory of control of automated guideway transit systems; cost-effective design of guideway structures; synthesis and basic design requirements of transit systems for maximum cost and energy effectiveness.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

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; perception and our relationship to our environment; and the social effects and psychological basis for design.

1025. BASIC VISUALIZATION I. (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.

1026. BASIC VISUALIZATION II. (4 cr; prereq 1025; 6 studio hrs per wk)
Students continue to refine their ability to execute acceptable line drawings developed in 1025 and to develop their own techniques. Continued emphasis on perspective sketching, color sense, psychology of graphic interpretation, mixed media, and printing reproduction processes.

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 3083, CE 3100 or AgEn 1400 or #; 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, §FR 5233; 4 lect hrs per wk)
For advanced students interested in 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 of study; 2 lect and 12 lab hrs per wk)
Advanced studies in area of student's option.

5117. PLANTING DESIGN SEMINAR: AESTHETIC PRINCIPLES. (2 cr; prereq 3081 and Hort 1021)
Lectures, presentations, field trips, and readings exploring aesthetic design principles and philosophies related to the use of plant materials in the landscape. Historic examples related to design principles, and philosophies or styles of expression.

5118. PLANTING DESIGN SEMINAR: PLANTS FOR FUNCTIONAL PURPOSES. (2 cr; prereq 3092)
Lectures, presentations, readings, and field trips focusing on development of planting designs and specifications; maintenance concerns.

5119. PLANTING DESIGN SEMINAR: ECOLOGICAL PRINCIPLES OF PLANTING DESIGN. (2 cr; prereq 3093)
Lectures, presentations, field trips, and readings related to the principles and practices of using plant materials in an ecologically sound and environmentally sensitive manner. Prairie, north woods, riverine, and wetland environments. Use of naturalized materials for such purposes as highway planting.

5131-5132-5133. SELECTED PROBLEMS IN LANDSCAPE ARCHITECTURE. (Cr ar; prereq #)

5224. CONTEMPORARY ISSUES IN LANDSCAPE ARCHITECTURE. (4 cr; prereq terminal yr of study; 4 discussion hrs per wk)
Analysis of design principles and design goals in modern society. Review of current site development projects. Investigation in depth into specific areas of land development.

5225. LANDSCAPE TECHNOLOGY: WORKING DRAWINGS AND SPECIFICATIONS. (4 cr; prereq 3072; 3 lect and 3 lab hrs per wk)
Lectures, exercises, and projects in working drawing and specification preparation.

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.

5261. HISTORY OF LANDSCAPE ARCHITECTURE: SEMINAR I. (2 cr; prereq 1st-yr LA student; 2 discussion hrs per wk)
History as a resource for the landscape architect; historic perspective on use of elements such as line, texture, form, water, stone/earth, and vegetation.

5263. HISTORY OF LANDSCAPE ARCHITECTURE: SEMINAR II. (2 cr; prereq 2nd yr-LA student; 2 discussion hrs per wk)
Historical perspective on functional use of space at the micro and macro scales; theories of space organization from medieval through modern periods; mood, place, intimacy, and security as design elements viewed in historic perspective.

5265. HISTORY OF LANDSCAPE ARCHITECTURE: SEMINAR III. (2 cr; prereq 3rd-yr LA student; 2 discussion hrs per wk)
Works of key landscape architects and concepts and theories that influenced their designs. Integration of design concepts into the design process.

Mathematics (Math)

0006. ELEMENTARY ALGEBRA (See *Extension Classes Bulletin*)

0007. PLANE GEOMETRY. (See *Extension Classes Bulletin*)

0008. SOLID GEOMETRY. (See *Extension Classes Bulletin*)

0009. PREPARATORY MATHEMATICS. (See *College of Liberal Arts Bulletin*)

1005-1006. FOUNDATIONS OF ARITHMETIC. (See *College of Liberal Arts Bulletin*)

1008. TRIGONOMETRY. (See *College of Liberal Arts Bulletin*)

1111. COLLEGE ALGEBRA AND ANALYTIC GEOMETRY. (See *College of Liberal Arts Bulletin*)

1131. FINITE MATHEMATICS. (See *College of Liberal Arts Bulletin*)

1142. SHORT CALCULUS. (See *College of Liberal Arts Bulletin*)

1201. PRE-CALCULUS. (5 cr, §1111; for students who need to review high school higher algebra and trigonometry before taking a calculus sequence; prereq 4 yrs high school math including trigonometry)
Inequalities, analytical geometry; complex numbers, binomial theorem; mathematical induction; functions and graphs; trigonometric, exponential, and logarithmic functions.

1211-1221-1231. CALCULUS I-II-III. (5 cr per qtr; prereq 4 yrs high school math including trigonometry...or grade of C or better in 1201...or grade of C or better in 1008 and 1111...or equiv...grade of C or better required to continue in sequence)
Analytical geometry and calculus of functions of one variable, applications. Infinite series and sequences.

1311-1321-1331. COMPUTER CALCULUS I-II-III. (5 cr per qtr; prereq 4 yrs high school math including trigonometry...or grade of C or better in 1201...or grade of C or better in 1008 and 1111...or equiv...grade of C or better required to continue in sequence)
Essentially the same as 1211-1221-1231 but topics presented from a computer viewpoint and in a different order.

1511H-1521H-1531H. HONORS CALCULUS I-II-III. (5 cr per qtr; prereq △)
Honors sequence for high ability students. Covers content of 1211-1221-1231 with emphasis on theory but computational aspects are not neglected.

1611-1621. ACCELERATED CALCULUS I-II. (5 cr per qtr; prereq △)
Accelerated sequence for high-ability students. Covers content of 1211-1221-1231 with emphasis on computational aspects.

3000. MATHEMATICS AS A HUMAN ENDEAVOR. (1 cr; prereq 1221 or equiv or #)
Mathematics as a career. Applications to science, engineering, and business. Views of mathematics as a science, a liberal art, and a human activity. Lectures by academic and industrial mathematicians and practitioners in related areas.

3057. ACTUARIAL SCIENCE PRINCIPLES—LIFE CONTINGENCIES I. (4 cr, §Ins 3230; prereq 1231 or 1131, 1221)
Calculation of net premiums, gross premiums, reserves, and nonforfeiture values for major life insurance contracts. Impact of assumed mortality, interest, and expense assumptions on these items.

3066. ELEMENTARY DIFFERENTIAL EQUATIONS. (4 cr, §3221; prereq grade of C or better in 1231 or equiv)
Elementary techniques of problem solving. First- and second-order equations, linear equations of higher order.

3142. INTRODUCTION TO LINEAR ALGEBRA. (4 cr, §3221, §3511; prereq 2 qtrs calculus)
Vectors, systems of linear equations, matrices, determinants, eigenvalues, applications. Techniques and some proofs of theorems.

3161. SYNTHETIC METRIC GEOMETRY. (4 cr; prereq 1211 or equiv)
Euclidean geometry: ruler and compass constructions and theorems on triangle and circle not studied in high school plane geometry.

3211. MULTIVARIABLE CALCULUS. (5 cr; prereq grade of C or better in 1231 or equiv)
Partial differentiation, chain rule, implicit functions, applications. Multiple integrals in two and three dimensions.

3221. INTRODUCTION TO LINEAR ALGEBRA AND LINEAR DIFFERENTIAL EQUATIONS. (5 cr, §3066, §3142, §3511; prereq grade of C or better in 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.

3231. 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.

3511-3521-3531. LINEAR ANALYSIS I-II-III. (5 cr per qtr, §3142, §3221 for 3511; primarily for high-ability math majors, engineers, scientists; prereq grade of B or better in 1231 or equiv)
3511: Ideas and computations of linear algebra including linear independence, linear transformations, matrices, and determinants. 3521-3531: Calculus of several variables relying heavily on linear algebra including differentiation and integration of functions of several variables, coordinate systems, Jacobian of a map, application of concepts and computations to vector analysis, basics of linear differential equations. Applications. The order of topics may vary from year to year.

3581. FOUNDATIONS OF ARITHMETIC. (4 cr; prereq 3211 or equiv)
Sets, relations, order. Real number system. Continuous functions.

3582. FOUNDATIONS OF ALGEBRA. (4 cr; prereq 3142 or equiv)
Groups, rings, fields. Applications to number theory and polynomials.

3583. FOUNDATIONS OF GEOMETRY. (4 cr; prereq 1231 or equiv)
Axiomatics. Non-Euclidean geometry. Theorems of Desargues and Pappus.

3611. MULTIVARIABLE CALCULUS. (5 cr; prereq 1621)
Vector functions, partial derivatives, gradient, chain rule, directional derivatives, higher partial derivatives, max-min problems, multiple integrals, cylindrical and spherical coordinate systems.

3621. LINEAR MATHEMATICS. (5 cr; prereq 3611)
First- and second-order differential equations, linear differential equations with constant coefficients. Undetermined coefficients, variation of parameters. Linear algebra: vectors in n-dimensions, linear systems of equations, Gaussian elimination, matrix algebra.

3631. LINEAR MATHEMATICS. (5 cr; prereq 3621)
Linear algebra: vector spaces, subspaces, linear independence, bases, rank, nullity, linear transformations, matrices, matrix inversion, characteristic polynomial eigenvalues. Review of multivariable calculus. Differentiation of vector valued functions in a linear algebra setting.

3675. INTRODUCTORY MATHEMATICS. (4 cr; prereq 1231 or equiv)
Designed to prepare sophomore mathematics majors for the theoretical courses they will encounter during the junior and senior years.

5070. TOPICS IN THE HISTORY OF MODERN MATHEMATICS. (4 cr [may be repeated for cr with △]; prereq one 5xxx mathematics sequence or equiv)
Mathematical developments within the last 200 years.

5151. ELEMENTARY SET THEORY. (4 cr; prereq 3211 or equiv or #)
Basic properties of operations on sets, cardinal numbers, simply ordered sets, well ordered sets, ordinal numbers, axiom of choice, axiomatics.

5152. ELEMENTARY MATHEMATICAL LOGIC. (4 cr, §5162; prereq 3211 or equiv or #)
Sets and relations; statement calculus; Boolean algebra; predicate calculus, models, validity and truth; first-order theories as illustrations of the axiomatic method; the completeness theorem, the incompleteness theorem, and metamathematics.

5162-5163-5164. MATHEMATICAL LOGIC. (4 cr per qtr; prereq 3211, 3142...or 3211, 3221...or equiv...or Phil 5202 or #)
Propositional and predicate calculi, models for systems of logic, recursive functions, decision and completeness problems.

5209. THEORY OF NUMBERS. (4 cr; prereq 3211 or equiv or #)
A rigorous introduction to the elementary theory of numbers up to the classical results concerning congruences to a prime modulus (e.g., Fermat's theorem). Usually covers one more advanced topic such as continued fractions, Gaussian integers, or quadratic reciprocity.

5232-5233. COMPUTER-ORIENTED LINEAR ALGEBRA. (4 cr per qtr, §5242-5243, §5262 or §5282 if content was linear algebra, §5264, §5284; prereq 3142 or 3221 or equiv or #)
Linear transformations on finite dimensional vector spaces. Linear dependence, matrix algebra, inner products, orthogonality, and matrix inversion presented from algorithmic viewpoint, with students constructing and running illustrative computer programs. Eigenvalues and eigenvectors, Jordan canonical form, polar representation of linear transformations, determinants.

5242-5243. LINEAR ALGEBRA WITH APPLICATIONS. (4 cr per qtr, §5232-5233, §5262 or §5282 if content was linear algebra, §5264, §5284; prereq 3142 or 3221 or equiv or #)
Systems of linear equations, finite dimensional linear spaces, bases, linear transformations, matrices, determinants, eigenvalues, reduction to canonical forms, quadratic and bilinear forms, applications.

5244. GROUP THEORY. (4 cr, §5262, §5282; prereq 3142 or 3221 or equiv or #)
Permutation groups; groups related to geometrical configuration; invariant subgroups, Jordan-Holder composition theorem, Sylow groups, Abelian groups, elementary divisors, applications.

5262-5263-5264. MODERN APPLIED ALGEBRA. (4 cr; prereq 3221 or 3142 or equiv)
Modern algebra developed in an application-oriented way. Sets, functions, binary relations graphs, and partially ordered sets with applications to finite state machines, matrix models, and trees. Groups, modular arithmetic, polynomial rings, finite fields, and linear algebra with applications to switching functions, cyclic codes, shift registers, fast adders, and enumeration.

5282-5283-5284. FUNDAMENTAL STRUCTURES OF ALGEBRA. (4 cr per qtr; prereq one soph sequence or #...some previous abstract mathematics recommended)
Theory course, principally for students planning mathematics graduate work. Group theory: normal subgroups, homomorphism, automorphism, the theorems of Lagrange, Cayley, and Sylow. Ring theory: rings, ideals, integral domains, Euclidean rings, polynomial rings, fields. Linear algegra: abstract approach to vector spaces, linear transformations; the theory of canonical forms, including the Jordan and rational.

5341-5342. INTRODUCTION TO TOPOLOGY. (4 cr per qtr; prereq one soph sequence or #...some previous abstract mathematics recommended)
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)
Classification of two-manifolds, fundamental group, homology theory.

5375. DIFFERENTIAL GEOMETRY. (4 cr; prereq 3211 or equiv or #)
Plane and space curves. Frenet formulas, elementary theory of surfaces.

5376-5377. DIFFERENTIAL GEOMETRY. (4 cr per qtr; prereq 5375 and 1 qtr linear algebra)
Differential forms. Advanced theory of surfaces, integral geometry, Riemannian geometry.

5404. VARIATIONAL PROBLEMS. (4 cr; prereq 3211, 3066...or 3211, 3221...or equiv or #)
Introduction to the calculus of variations and its applications. Topics may include fundamental theory, Euler-Lagrange equations, necessary and sufficient conditions, stability, isoperimetric problems, rudiments of the Mayer-Lagrange-Bolza problems, multiplier rule, direct methods, Rayleigh-Ritz method, eigenvalue problems, multiple integrals.

5427. APPLIED MATHEMATICS FOR THE LIFE SCIENCES. (4 cr; prereq 3066, 3142...or 3211, 3221...or equiv)
Mathematical tools useful in deterministic models arising in life sciences. Linear systems of difference and differential equations. Stability of nonlinear systems, including linearization techniques and Liapunov theory. Examples from demography, population ecology, and population genetics.

5428. MATHEMATICAL MODELS IN ECONOMICS AND THE SOCIAL AND MANAGEMENT SCIENCES. (4 cr; prereq 3211 with 3066, 3142...or 3211, 3221...or equiv or #)
Mathematical models and associated mathematical techniques for describing the behavior of and for optimizing various systems. How to find a model for a given situation.

5441. MATHEMATICAL THEORY OF FLUID FLOW. (4 cr; prereq 5568 or 5572 or equiv or #)
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.

5457-5458-5459. METHODS OF APPLIED MATHEMATICS. (4 cr per qtr; prereq 3211, 3066...or 3211, 3221...or equiv or #)
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.

5473-5474-5475. APPROXIMATION THEORY AND THEORY OF NUMERICAL ANALYSIS. (4 cr per qtr; prereq 3211, 3142...or 3211, 3221...or equiv...and CSci 1100; 3 lect per wk, informal lab)
5473: Finite differences. Interpolation. Linear systems. Numerical integration and differentiation. Successive approximations. Newton's method. Numerical analysis of raw data. 5474: Approximation theory. Polynomial and spline interpolation. Gaussian quadratures. Numerical solutions of ordinary differential equations. Runge-Kutta methods. Numerical stability. Error estimates. 5475: Topics selected from Padé approximations. Continued fraction expansions. Trigonometric approximations. Symbolic calculus. Dynamics of mappings including invariant manifolds and heteroclinic orbits. Advanced topics in the actuarial sciences.

5476. 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.

5512. DIFFERENTIAL EQUATIONS WITH APPLICATIONS I. (4 cr; prereq 3211, 3066...or 3211, 3221...or equiv or #)
Applications, review of special techniques, and numerical approximation for first-order equations. Euler and Runge-Kutta methods with error analysis. Applications and power series solutions for second-order equations.

5513. DIFFERENTIAL EQUATIONS WITH APPLICATIONS II. (4 cr; prereq 5512)
Applications and Laplace transforms for second-order linear equations. First-order linear systems with elementary linear algebra. Phase plane analysis with applications. Boundary value problems and an introduction to partial differential equations.

5514. INTEGRAL EQUATIONS. (4 cr; prereq 3211, 3066...or 3211, 3221...or equiv or #)
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.

5521-5522-5523. INTRODUCTION TO ORDINARY DIFFERENTIAL EQUATIONS. (4 cr per qtr; prereq one soph sequence or #)
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; Poincaré-Bendixson theory; linear and nonlinear oscillations; stability theory; asymptotic behavior of solutions; control theory. 5523: Power series solutions majorant method; regular and irregular singular points; error estimates perturbation methods.

5567. FOURIER SERIES AND BOUNDARY VALUE PROBLEMS. (4 cr, §5571; prereq 3211, 3066...or 3211, 3221...or equiv or #)
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.

5568. ELEMENTARY THEORY OF COMPLEX VARIABLES. (4 cr; prereq 3231 or 5602 or equiv course in vector analysis)
Derivative and integral of a function of a complex variable. Cauchy integral theorem and formula, residues. Application to evaluation of integrals, conformal mapping.

5569. OPERATIONAL MATHEMATICS. (4 cr; prereq 5568)
Laplace transforms, Fourier transforms, inversion theorems; applications to differential equations.

5571-5572-5573. ELEMENTARY PARTIAL DIFFERENTIAL EQUATIONS. (4 cr per qtr, §5567, §5568; prereq 5603 or 5613)
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 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.

5601-5602-5603. ADVANCED CALCULUS. (4 cr per qtr; prereq 3211 or equiv or #)
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.

5611. VECTOR FUNCTIONS. (4 cr; prereq 3631)
Vector analysis, line integrals, divergence and Gauss theorem, Stokes theorem. Applications of linear algebra to systems of differential equations.

5612-5613-5614. INTRODUCTION TO ANALYSIS. (4 cr per qtr; principally for students planning a grad major in mathematics, as preparation for grad courses in analysis; prereq one soph sequence or #)
Theory of real numbers; elements of point set theory; limits; differentiation; multivariable analysis.

5615. LEBESGUE INTEGRAL. (4 cr; prereq 5603 or 5612 or #)
Basic limit theorems. Comparison with Riemann integral. Lebesgue measure. Absolute continuity.

5679. PROBABILITY. (4 cr, §5681; prereq 3211 or equiv or #)
Elementary principles of probability, total and compound probability, expectation, repeated trials, and topics chosen from the following: Stirling formula, the probability integral, geometrical probability, probability of causes, Bayes theorem, errors of observation, principle of least squares.

5681-5682-5683. INTRODUCTION TO PROBABILITY. (4 cr per qtr; prereq 3531 or 3631 or two 5xxx math courses or Stat 5133 or #)
Logical development and various applications of probability. Probability spaces, random variables, central limit theorem; Markov chains.

5701. COMBINATORICS. (4 cr; prereq 3211 or equiv, 3rd-yr standing... soph-level linear algebra is helpful)
Basic concepts in combinatorics. Enumeration including binomial counting, permutations, generating functions, inclusion-exclusion principle, recurrence relations. Application. Matching theory and designs.

5702. INTRODUCTION TO GRAPH THEORY. (4 cr; prereq 3211 or equiv, 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.

5703. COMBINATORIAL ALGORITHMS AND OPTIMIZATION. (4 cr; prereq 3211 or equiv, knowledge of some programming language)
Basic algorithmic methods in combinatorics with emphasis on optimization.

5900. TUTORIAL COURSE IN ADVANCED MATHEMATICS. (Cr ar; prereq #)
Qualified students whose needs are not met by courses offered may make arrangements to study content of other graduate courses.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

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

8351-8352-8353. GLOBAL ANALYSIS

8360-8361-8362. TOPICS IN TOPOLOGY

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 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.

1025. ENGINEERING GRAPHICS. (4 cr; ¶Math 1211 or equiv recommended; 3 lect and 1 rec hrs per wk, open lab hrs)
Engineering representation in pictorial view and multiview; sketching techniques, size description, standard and simplified practices applied to graphical communication. Analysis of systems of projection; correlation of graphical, numerical, and computer solutions of space problems, intersections and development. Methods of computer-aided graphics.

3201. MECHANICAL ENGINEERING SYSTEMS ANALYSIS. (4 cr, §AEM 3401; prereq AEM 3036; 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 AEM 3016; 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 per qtr; prereq 3702 or equiv; 4-hr lect-lab combination per wk)
Systems measurement and evaluation involving various areas of study in mechanical engineering. Each quarter involves two five-week laboratory modules as selected by the student.

3740. INDUSTRIAL ASSIGNMENT. (2 cr [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 submission of approved dept! permission form)
Special investigations in various fields of mechanical engineering and related areas including an independent study project.

5203. ADVANCED ANALYSIS AND SYNTHESIS OF MECHANISM SYSTEMS. (3 or 4 cr; prereq 3203 or equiv... computer programming desirable; 3 lect hrs per wk)
Analytical methods of kinematic, dynamic, and kineto-elasto-dynamic analysis and synthesis of mechanisms. Computerized design for function, path and motion generation based on Burmester theory.

5205. CREATIVITY IN ENGINEERING DESIGN. (3 or 4 cr [1 cr term paper option] : completion of ME core courses or equiv desirable; 3 lect hrs per wk)
The role of creative action at various stages in 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 or 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.

5220. COMPUTER-AIDED DESIGN. (4 cr; prereq 3rd-yr ME courses and FORTRAN programming; 3 lect and 1 rec hrs per wk)
Application of computer-aided design techniques to engineering design. Engineering design projects/case studies utilizing selected computerized numerical techniques, design optimization, and computer graphical presentation of results.

5221. COMPUTER GRAPHICS IN DESIGN. (4 cr; prereq 5220 or #; 3 lect and 2 lab hrs per wk)
Introduction to software techniques and hardware for applications of computer graphics to mechanical engineering design. Modeling and analysis of systems using graphical techniques to enhance human-machine interaction.

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] ; prereq 5254; 1 lect and 2 lab sessions per wk)
Participation in solution of systems design problems that 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 hrs 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 hrs per wk)
Theory and application of joining techniques, welding, brazing, and adhesive bonding. Metal forming, rolling, swaging, drawing, and similar operations. 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 hrs 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 hrs 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, treatment, 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 2 lab hrs per wk)
Basic theory of linear feedback control systems. Transfer function representation of electromechanical, pneumatic, and hydraulic components. Industrial automatic controllers. Root-locus and frequency-response methods of analysis and design.

5284. CONTROL SYSTEMS. (4 cr; prereq 5283 or equiv; 4 lect hrs per wk)
State-space analysis of discrete-time and continuous-time control systems. Z-transform method. Liapunov stability analysis. Controllability and observability. Introduction to optimal control and adaptive control.

5288. MODELING AND SIMULATION OF DYNAMIC SYSTEMS. (4 cr; prereq 5283 or equiv; 3 lect and 1 lab hrs per wk)
Generalized approach to developing models for describing complex dynamic interactions between mechanical, electrical, fluid, and thermal systems. Analog and digital simulation. Applications to electromechanical devices, transducers, hydraulic power and thermofluid systems.

5342. HEAT TRANSFER. (4 cr; prereq 3301 and CE 3400 or AEM 3200; 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 AEM 3200; 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.

5402. ECOLOGY, TECHNOLOGY, AND SOCIETY. (4 cr; 4 lect hrs per wk)
Dilemmas produced as a result of conflicts between finite limits and population and industrial growth; underlying causes: current technology, values, economics, institutions, and political structures; and possible directions for resolution. Faculty members from various disciplines participate.

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.

5609. AIR POLLUTION. (4 cr; prereq 3303 or #; 4 lect hrs per wk)
Air pollution sources, atmospheric transport, transformations and fate. Air pollution meteorology, dispersion, and models. Basic chemistry of secondary pollutant formation, aerosol growth, air pollutant visibility relationships. Standards and regulations.

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.

5712. SOLAR ENERGY UTILIZATION. (4 cr; prereq 5342 or #; 4 lect hrs per wk)
History and potential of solar energy utilization; availability of solar radiation on clear and cloudy days; incident radiation on horizontal, vertical, and inclined surfaces; flat-plate and concentrating solar collectors; heating and cooling with solar energy; power generation; review of current research.

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

(For course descriptions, see the *Graduate School Bulletin*)

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

8351. COMPUTATION OF FLUID FLOW AND HEAT TRANSFER

8352. ADVANCED COMPUTATION OF FLUID FLOW AND HEAT TRANSFER

8353. COMPUTATION OF BOUNDARY LAYER FLOWS

8360-8361-8362. INTRODUCTION TO PLASMA TECHNOLOGY

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

8770-8771-8772. MECHANICAL ENGINEERING RESEARCH

8773-8774-8775. GRADUATE SEMINAR

Metallurgy/Materials Science (MatS)

3090, 3091, 3092. INDUSTRIAL EMPLOYMENT. (1-2 cr per qtr [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; 3 lect and 1 rec or 2 lab hrs per wk)
Introduction to the structure-property relationships of metals, alloys, and polymers. Crystal structure, diffusion, and the theoretical basis of elasticity and plasticity will be related to practical topics. Includes materials processing laboratory/recitation with emphasis on engineering alloys and heat treatment.

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.

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 per qtr; prereq 3rd-yr IT student)
Relationship between atomic structure and basic properties of metals, semiconductors, glasses, polymers, ceramics, and composites. 5011: Physical properties. 5012: Mechanical properties. 5013: Electrical and magnetic properties.

5101. THERMODYNAMICS AND MATERIALS STATES. (4 cr; prereq ChEn 5101, Chem 5534 or #; 3 lect and 2 rec hrs per wk)
(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 discussed in terms of dislocation behavior, creep, fatigue, fracture toughness. Control of mechanical properties through manipulation of microstructure in metal processing; drawing, forging, rolling, and forming processes.

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 per qtr; 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 physical chemistry or 5011 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 and crystalline state, rubber elasticity, flow and viscoelasticity, environmental degradation.

5620. POLYMER PROCESSING. (4 cr; prereq engineering transport phenomena or #; 3 lect and 1 open lab-rec hrs per wk)
Polymer processing principles and applications; rheology of long chain molecules, flow in simple geometries, die design, mixing, thermal properties, heat transfer and phase change; thermoplastic operations: extrusion, calendaring, forming and molding; thermoset operations.

5630. POLYMER PHYSICAL PROPERTIES. (4 cr; prereq 5011 or 3400 and 5610 or Chem 5610 or #; 3 lect and 1 open lab-rec hrs per wk)
Polymer structure-property relations: structure and morphology of the crystalline and amorphous state. Crystallization kinetics, vitrification and the glass transition, mechanical properties, failure, permeability, optical and electrical properties, polymer composites, effect of processing on properties.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin)*

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 ALLOYS AND ORIGINS OF 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

8521. TOPICS IN ELECTRON MICROSCOPY

8522. ADVANCED X-RAY DIFFRACTION OF METALS

Mineral Engineering (MinE)

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 5611; 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 PROPERTIES. (4 cr; prereq 5612 or Geo 1111 or #; 4 lect hrs per wk)
Reasons for examination; geological, technical, economic, and political factors; mineral laws; sampling methods; various methods to calculate reserves including geostatistics; elementary accounting; determination of direct costs, taxes, depreciation, depletion, profitability; present worth, rate-of-return and discounted cash flow; financing methods.

5619. ENGINEERING FIELD STUDY. (3 cr; prereq sr or grad student 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 5613 and Geo 1111 or #)
Unit operations of drilling, blasting, loading, hauling, and transportation of surface rocks and soils. Equipment productivity, selection, and cost estimation. Design of open pits and quarries. Economics, environment, and organization.

5640. INTRODUCTION TO ECONOMICS OF THE MINERAL INDUSTRIES. (4 cr; prereq 5613 or #)
Elementary principles of economics and applications to the mineral industries; developed areas versus underdeveloped areas; marginal ore production; markets and marketing of raw materials, and their peculiarities.

5642. THE MINERAL INDUSTRIES. (4 cr; prereq 5613 or #)
Minerals and the developing economies; minerals and modern industrial economics; minerals and international trade; gold and silver as monetary metals. Problems in the analysis of resources: mineral supply; secondary (scrap) supply; depletion, exhaustibility, and conservation. Quantitative economic analysis: interindustry; projecting and forecasting; computer applications; marketing; mineral financing.

5650. MINERAL ENGINEERING DESIGN I. (4 cr; prereq 5720, 5722 or #, grad student in mineral engineering; 10 design hrs per wk)
Systems approach to selected aspects of a mining project: exploration, mining, mineral processing, metals extraction. Bound final report of an in-depth engineering feasibility study required.

5652. MINERAL ENGINEERING DESIGN II. (4 cr; prereq 5650 or #)
For description, see 5650.

5660. SPECIAL MINERAL ENGINEERING PROBLEMS. (Cr and hrs ar)
Literature survey or research work on mining problems.

5700. SYSTEMS ANALYSIS FOR MINERAL ENGINEERS. (4 cr; prereq #; 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 and 3 lab hrs per wk)
Basic engineering principles in design and selection of mine plant equipment such as hoists, conveyors, and railroad systems. Calculations 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 5800 or #; 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; to recovery of metals. Integration of operations and processes on a plant basis.

5820. PRINCIPLES OF METALS EXTRACTION I. (4 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 Geo 3401 or #)
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 that control beneficiation processes.

5910. METALLURGICAL UNIT PROCESSES. (5 cr; prereq 5825 or #)
Unit processes of chemical metallurgy; roasting, agglomeration, smelting, converting, refining, vaporization, and electrolytic methods.

5920. METALLURGICAL PROCESSES. (2 cr; prereq 5820 or #; 4 lect and 4 lab hrs per wk)
Examination of the unit processes of extractive metallurgy to illustrate the known technologies for producing metal from ore. Both ferrous and nonferrous applications and recent innovations in the field stressed.

5940. SPECIAL PROBLEMS IN EXTRACTIVE METALLURGICAL ENGINEERING. (Cr and hrs ar; prereq sr)
Laboratory investigation of problems in extractive metallurgy.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

8470-8471-8472. MINING RESEARCH PROBLEMS I, II, III

8601-8602-8603. SEMINAR: MINERAL ENGINEERING

8620. ADVANCED ENGINEERING DESIGN

8640. ADVANCED MINERAL ECONOMICS

8641. SELECTED MINERALS IN NATIONAL AND WORLD AFFAIRS

8830. ELECTRIC AND MAGNETIC SEPARATION OF MINERALS

8838-8839. OPTIMIZATION AND CONTROL TECHNIQUES IN MINERAL PROCESSING I, II

8842. SURFACE CHEMISTRY OF MINERAL SUSPENSIONS

8921-8922-8923. RESEARCH IN EXTRACTIVE METALLURGICAL ENGINEERING

8930-8932-8934. PHYSICAL CHEMISTRY OF HIGH TEMPERATURE METALLURGICAL REACTIONS I, II, III

Physics (Phys)

1004. PHYSICAL WORLD, PHYSICS. (4 cr, §any other physics courses; prereq 1 yr high school algebra; 3 lect and 1 problem hrs per wk)
Topics illustrate the methods of science and acquaint students with the physical universe.

1005. PHYSICS LABORATORY. (1 cr; S-N only; prereq 1004 or ¶1004; 2 lab hrs per wk)
Laboratory offered in conjunction with 1004.

1031-1032. INTRODUCTORY PHYSICS: MEASUREMENT AND APPLICATIONS. (4 cr per qtr, §other introductory physics courses; prereq high school algebra and plane geometry; 4 class hrs per wk)
Lectures and problem sessions. Application of physics emphasized. Primarily for students interested in topics useful in technical areas. 1031: Electricity and magnetism, electric circuits, feedback and control, waves, light, optical instruments. 1032: Mechanics, fluids and gases, heat, random processes, atoms and spectra, nuclei, radioactivity.

1035-1036. INTRODUCTORY PHYSICS LABORATORY. (1 cr per qtr; S-N only; prereq 1031 or ¶1031 for 1035...1032 or ¶1032 for 1036; 2 lab hrs per wk)
Laboratory experiments offered in conjunction with 1031-1032.

1061. PHYSICS OF HUMAN MOTION. (4 cr; prereq 1 yr high school algebra, ¶1065; 3 lect-discussion hrs per wk)
Basic concepts of classical mechanics applied to motion of human bodies in various forms of work, athletics, and dance. Physics of muscles. Eight labs, some in gym.

1065. HUMAN MOTION LABORATORY. (1 cr; S-N only; prereq ¶1061; 2 lab hrs per wk)
Human motion experiments to accompany 1061.

1071. INTRODUCTORY METEOROLOGY. (4 cr; prereq high school algebra; 4 lect hrs per wk)
Physics of atmospheric processes. Clouds, fronts, and cyclones. Weather forecasting. Human influence on the atmosphere.

1075. INTRODUCTORY METEOROLOGY LABORATORY. (1 cr; S-N only; prereq 1071 or ¶1071; 2 lab hrs per wk)
Field experiments offered in conjunction with 1071.

1104-1105-1106. GENERAL PHYSICS. (4 cr per qtr; prereq Math 1142 and high school trigonometry or Math 1008 for 1104; 4 lect and 1 quiz hrs per wk)
Primarily for premedical and biological science students. 1104: Mechanics. 1105: Heat and electricity. 1106: Magnetism, sound, light, modern physics.

1107-1108-1109. GENERAL PHYSICS LABORATORY. (1 cr per qtr; S-N only; prereq 1104-1105-1106 or ¶1104-1105-1106; 2 lab hrs per wk)
Laboratory exercises offered in conjunction with 1104-1105-1106.

1121-1122. PHYSICS FOR ARCHITECTS. (4 cr per qtr; prereq Math 1211 or ¶Math 1211; 4 lect hrs per wk)
General principles of physics useful to prearchitecture students. Mechanics, heat, electric circuits, gases, light, sound, properties of materials.

1123-1124. PHYSICS FOR ARCHITECTS LABORATORY. (1 cr per qtr; S-N only; prereq 1121-1122 or ¶1121-1122; 2 lab hrs per wk)
Laboratory exercises offered in conjunction with 1121-1122.

1271-1281-1291. GENERAL PHYSICS. (4 cr per qtr; prereq completion of or concurrent regis in Math 1221 or 1321 or 1621 or equiv for 1271...completion of 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; 4 lect, and 1 quiz hrs 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 ¶1271-1281-1291; 2 lab hrs per wk)
Laboratory exercises offered in conjunction with 1271-1281-1291.

3011. OSCILLATIONS. (4 cr; prereq 1291, Math 3221 or equiv; 3 lect and 1 prob hrs per wk)
Physical and mathematical study of the harmonic oscillator. Transient behavior; resonance; impedance; mechanical and electrical examples; coupled systems; traveling and standing waves; Fourier series, interference.

3015. LABORATORY IN OSCILLATIONS AND WAVES. (1 cr; prereq 3011 or ¶3011; 3 lab hrs per wk)
Laboratory exercises in oscillations and waves.

3201. THERMODYNAMICS. (4 cr; prereq 1281 or #; 3 lect and 1 prob session per wk)
The laws of thermodynamics, entropy, and probability; applications to simple systems, phase equilibrium, chemical potential.

3501. MODERN PHYSICS. (4 cr, §3511-3512-3513; prereq 1291 or 1106; 3 lect and 1 prob hrs per wk)
Descriptive course in modern physics; quantum mechanics, hydrogen atom, multielectron atoms, molecular structure, quantum statistics, thermal radiation, solid state physics, nuclear physics.

3511-3512-3513. MODERN PHYSICS. (4 cr per qtr; prereq 1291 or 1106 or ¶1291 or ¶1106, Math 1231 for 3511...Math 3221 or 3066 or ¶Math 3221 or ¶3066 or equiv for 3512; 3 lect and 1 prob hrs per wk)
Introduction to special relativity, statistical physics, quantum mechanics, and surveys of selected topics in atomic, molecular, solid state, nuclear and particle physics phenomena.

3515. PHYSICS LABORATORY. (1 cr; prereq 3501 or ¶3501 or 3512 or ¶3512; 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. 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.

5021-5022.* INTRODUCTION TO ANALYTIC MECHANICS. (4 cr per qtr; prereq 3011, Math 3231 or equiv; 3 lect and 1 prob hrs per wk)
Analytical course in Newtonian mechanics. Vectors and vector operators; central force problem; systems of particles; tensors; rigid bodies; moving coordinate systems; continuous media; Lagrange equations. Mathematics beyond the prerequisites developed as required.

5023-5024.* INTRODUCTION TO ELECTRIC AND MAGNETIC FIELDS. (4 cr per qtr; prereq 3011, Math 3231 or equiv; 3 lect and 1 prob hrs per wk)
Classical theory of electric and magnetic fields making free use of vector algebra and vector calculus. Maxwell equations for free space and material media. Wave solutions.

5025.* SPECIAL TOPICS IN ELECTRIC AND MAGNETIC FIELDS. (4 cr; prereq 5024; 3 lect and 1 prob hrs per wk)
Special topics selected by instructor.

5031-5032-5033.* TOPICS IN MATHEMATICAL PHYSICS. (4 cr per qtr; prereq two 5000-level math courses; 3 lect and 1 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 5022 and 5024, advanced calculus or #; 3 lect and 1 prob hrs per wk)
Classical mechanics, special relativity, and classical electrodynamics. Applications of advanced mathematical techniques.

5090. PHYSICS OF MUSICAL INSTRUMENTS. (3 cr [may be repeated for cr with #; 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 instructor; 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 hrs per wk)
Mathematical techniques of quantum mechanics. Wave packets; Schrödinger equation, angular momentum; radial equation; spin; perturbation theory; collision theory.

5121. METHODS OF EXPERIMENTAL PHYSICS: I. (5 cr; prereq 3513 or #...knowledge of FORTRAN programming desirable; 3 lect and 4 lab hrs per wk)
Contemporary techniques. Includes probability and errors, introduction to analog and digital electronics, experimental strategy, and introduction to computer-based data acquisition and experimental control.

5122. METHODS OF EXPERIMENTAL PHYSICS: II. (4 cr; prereq 5121 or #; 2 lect and 6 lab hrs per wk)
Contemporary techniques. Includes applications of Fourier transforms, signal averaging and phase-lock detectors, high vacuum techniques, magnet and charged particle beam design. Laboratory: problems involving the use of microcomputers for data acquisition and experimental control.

5123. METHODS OF EXPERIMENTAL PHYSICS: III. (4 cr; prereq 5122 or #; 8 lab hrs per wk)
Contemporary techniques. Laboratory: choice of experimental projects in low temperature, solid state, nuclear, elementary particle, and cosmic ray physics.

5124. EXPERIMENTAL PROJECT. (Cr ar; prereq 5123 and #)
Research project in some aspect of contemporary physics. Project must be approved by faculty coordinator prior to registration.

5151-5152-5153.* QUANTUM MECHANICS. (4 cr per qtr; prereq 5102 or equiv, advanced calculus or #; 3 lect and 1 prob hrs per wk)
Development from first principles. Schrödinger 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 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.

5202-5203.* STATISTICAL MECHANICS, TRANSPORT THEORY, AND IRREVERSIBLE PROCESSES. (4 cr per qtr; prereq 3201 or #; 3 lect and 1 prob hrs per wk)
5202: Equilibrium ensembles, quantum statistics, applications of statistical mechanics to interacting and noninteracting systems. 5203: Boltzmann equation and its applications, fluctuations and Brownian motion, irreversible processes.

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)
Crystal structure and binding; diffraction; phonons; thermal and dielectric properties of insulators; free-electron model; band structure; semiconductors; diamagnetism; paramagnetism; ferromagnetism and antiferromagnetism; optical phenomena, lasers; superconductivity; surface properties; ferroelectricity.

5301.* INTRODUCTION TO NUCLEAR PHYSICS. (4 cr; prereq 5102 or equiv; 3 lect and 1 prob hrs 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 equiv; 3 lect and 1 prob hrs per wk)
Relativistic kinematics; mass, spin, isospin, and strangeness of elementary particles; SU3 classification and the quark model; 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 METEOROLOGY 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.

5461.* PHYSICS AND CHEMISTRY OF THE EARTH'S UPPER ATMOSPHERE. (4 cr; prereq general physics and calculus)
Survey of atmosphere above 15 km; physics and chemistry of the stratosphere, mesosphere, and thermosphere; temperature and density profiles; major and minor constituents and their distributions; aspects of pollutants; reactions and rates; global variation of constituents; the energy budget of the atmosphere.

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, 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 general physics and calculus)
Atoms (dispersion, absorption, spectra, polarized light). X-rays (production, absorption, dosimetry). Nuclei (nuclear size, mass, decay).

5801.* MODERN OPTICS. (4 cr; prereq 5024 or #; 4 lect hrs per wk)
Modern theoretical and experimental optics, broadly defined to include, for example, radio astronomy. Matrix methods in geometrical optics including charged particle optics; optical detectors and noise; phenomena in intense coherent radiation including nonlinear effects.

5805.* CONTEMPORARY OPTICS. (4 cr; prereq #; 3 lect and 1 prob hrs 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.

5924.* HISTORY OF 19TH-CENTURY PHYSICS. (4 cr, §HSci 5924; prereq general physics or #)
Conceptual developments in physics in 19th century (Young, Fresnel, Oersted, Ampère, Faraday, MacCullagh, Maxwell, Hertz, Lorentz, Lavoisier, Rumford, Dalton, Mayer, Joule, Helmholtz, Carnot, Clausius, Kelvin, Boltzmann, Mach, others). Relationships of these developments to social, philosophical, and theological influences.

5925.* HISTORY OF 20TH-CENTURY PHYSICS. (4 cr, §HSci 5925; prereq general physics or #)
Conceptual developments in relativity (Michelson, Lorentz, Poincaré, Einstein, others), quantum mechanics (Planck, Einstein, Rutherford, Bohr, Sommerfeld, Ehrenfest, Pauli, Millikan, Compton, Heisenberg, de Broglie, Schrödinger, Born, others), and nuclear physics (Chadwick, Gamow, Fermi, others). Relationships of these developments to social, philosophical, and theological influences.

5950. SEMINAR. (Cr ar; primarily for sr physics majors, △)

5970. DIRECTED STUDIES. (1-5 cr; prereq #, △)
Independent, directed study in physics in areas arranged by the student and a faculty member.

5990. DIRECTED RESEARCH. (Cr ar; prereq 3rd yr, △)
Problems, experimental or theoretical, of special interest to students. Written reports.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin)*

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

8420.* SEMINAR: MAGNETOSPHERIC PHYSICS

8421-8422.* SOLAR MAGNETOSPHERIC PHYSICS

8440.* SEMINAR: ATMOSPHERIC PHYSICS

8445.* ADVANCED TOPICS IN ATMOSPHERIC PHYSICS

8484.* ORIGIN AND EVOLUTION OF THE SOLAR SYSTEM

8500. PLAN B PROJECT

8950.* SEMINAR: PROBLEMS OF PHYSICS TEACHING AND HIGHER EDUCATION

8990.* RESEARCH IN PHYSICS

Statistics (Stat)

1051f,w,s. INTRODUCTION TO IDEAS OF STATISTICS. (4 cr; prereq high school higher algebra)
Presentation and analysis of data. Probabilistic models for inference. Inference and decision procedures. Emphasis on concepts rather than computation.

3091f,w,s. *INTRODUCTION TO PROBABILITY AND STATISTICS.* (4 cr, §5121, §5131; *prereq differential and integral* calculus; one section designated primarily for IT majors)
Elementary probability and probability distributions, sampling and elements of statistical inference. Treatment more mathematical than that in 1051.

5021f,w. STATISTICAL ANALYSIS I. (5 cr; prereq college algebra or #)
Frequency distributions; descriptive statistics; elementary probability; binomial, Poisson, and normal distribution; estimation and testing; analysis of variance; multiple comparisons; linear regression.

5022w,s. STATISTICAL ANALYSIS II. (5 cr; prereq 5021 or #)
(Continuation of 5021) Multiple regression and correlation; multiway analysis of variance, variance components, covariance; elementary principles of design; basic nonparametric methods.

5071. STATISTICAL APPLICATION OF MATRIX ALGEBRA. (3 cr; prereq 5021, ¶Math 3142 or #)
Specific matrix operations with vector realizations, presuming no prior knowledge. Uses in analysis of variance and multivariate methods. Correlation structures, characteristic vectors, quadratic forms.

5101s. INTRODUCTION TO DECISION THEORY. (4 cr, §5133; prereq Econ 5111 or Math 1142 or 1211 or #)
Elements of probability; basic concepts in statistical decision theory; relationship to game theory and other types of decision problems; prediction and inference.

5121f-5122w. THEORY OF STATISTICS. (4 cr per qtr, §5131-5132-5133; prereq Math 1231 or 1331 or 1621)
Univariate and multivariate distributions, law of large numbers, sampling, likelihood methods, estimation and hypothesis testing, regression and analysis of variance and covariance, confidence intervals, distribution-free methods.

5131f-5132w-5133s. THEORY OF STATISTICS. (4 cr per qtr, §5121-5122; prereq Math 3411 or 3211)
5131: Probability models, univariate and bivariate distributions, independence, basic limit theorems. 5132-5133: Statistical decision theory, sampling, estimation, testing hypotheses, parametric and nonparametric procedures for one-sample and two-sample problems, regression, analysis of variance. Treatment more mathematical than that in 5121-5122.

5201w. SAMPLING METHODOLOGY IN FINITE POPULATIONS. (4 cr; prereq 5021 or 5121 or 3091 or #)
Simple random, systematic, stratified, and unequal probability sampling. Ratio and regression estimation. Multistage and cluster sampling.

5211. THEORY OF SAMPLE SURVEYS. (4 cr; prereq 5122 or 5133)
Mathematical treatment of survey sampling including stratified and multistage sampling, models for nonsampling errors.

5271-5272. BAYESIAN DECISION MAKING. (4 cr per qtr. §Econ 5271-5272; prereq ¶5122 or ¶5132 for 5271...5122 or 5132, Econ 1002 for 5272...5271 recommended for 5272)
5271: Axioms for personal probability and utility. Elements of statistical decision theory. Bayesian analysis of linear models. 5272: Expected utility models for economic decisions made under conditions of uncertainty. Applications to portfolio selection, forward and future trading, betting, contingency markets, business planning.

5301f,s. DESIGNING EXPERIMENTS. (4 cr; prereq 5022 or 5122 or 5133 or #)
Control of variation, construction, and analysis of complete and incomplete block, split plot, factorial, and other groups of similar experiments. Confounding, crossover, and optimum seeking designs.

5302f,s. APPLIED REGRESSION ANALYSIS. (4 cr; prereq 5022 or 5122 or 5133 or #)
Simple, multiple, and polynomial regression. Estimation, testing, and prediction. Stepwise and other numerical methods; residuals; weighted least squares; nonlinear models; response surface. Experimental research and economic applications.

5401s. INTRODUCTION TO MULTIVARIATE METHODS. (4 cr; prereq 5071 or 5022 or 5122 or #)
Bivariate and multivariate distributions. Inference based on multivariate normal distributions. Discrimination and classification. Multivariate analysis of variance. Partial, canonical correlation and independence. Principal component analysis, factor analysis, analysis of repeated measurements, cluster analysis, profile analysis.

5421. ANALYSIS OF CATEGORICAL DATA. (4 cr; prereq 5022 or 5122 or 5133 or #)
Varieties of categorical data, cross-classifications and contingency tables, tests for independence. Multidimensional tables and log linear models, maximum likelihood estimation, and tests of goodness of fit. Analysis of incomplete tables. Marginal homogeneity and symmetry in square tables. Analysis of Markov chain data. Smoothing counts.

5601w. NONPARAMETRIC METHODS. (4 cr; prereq 5022 or 5122 or #)
Necessary discrete and continuous probability distributions. Goodness of fit, sign tests, order statistics, rank tests for location and for scale, two-sample and k-sample comparisons, association. Methods and applications.

5900. TUTORIAL COURSE. (Cr ar; prereq #)
Directed study in areas not covered by regular offerings.

5911, 5912, 5913. TOPICS IN STATISTICS. (3 cr per qtr [may be repeated for cr with △]; prereq 5122 or 5133, #)
Topics vary.

FOR GRADUATE STUDENTS ONLY

(For course descriptions, see the *Graduate School Bulletin*)

8151-8152-8153. MATHEMATICAL STATISTICS

8161-8162-8163. APPLIED STATISTICAL METHODS

8171-8172-8173. THEORY OF INFERENCE

8191-8192. LARGE-SAMPLE THEORY

8311-8312. LINEAR MODELS AND EXPERIMENTAL DESIGN

8411-8412. MULTIVARIATE ANALYSIS

8501-8502. INTRODUCTION TO STOCHASTIC PROCESSES WITH APPLICATIONS

8511-8512. TIME SERIES ANALYSIS

8611-8612. NONPARAMETRIC INFERENCE

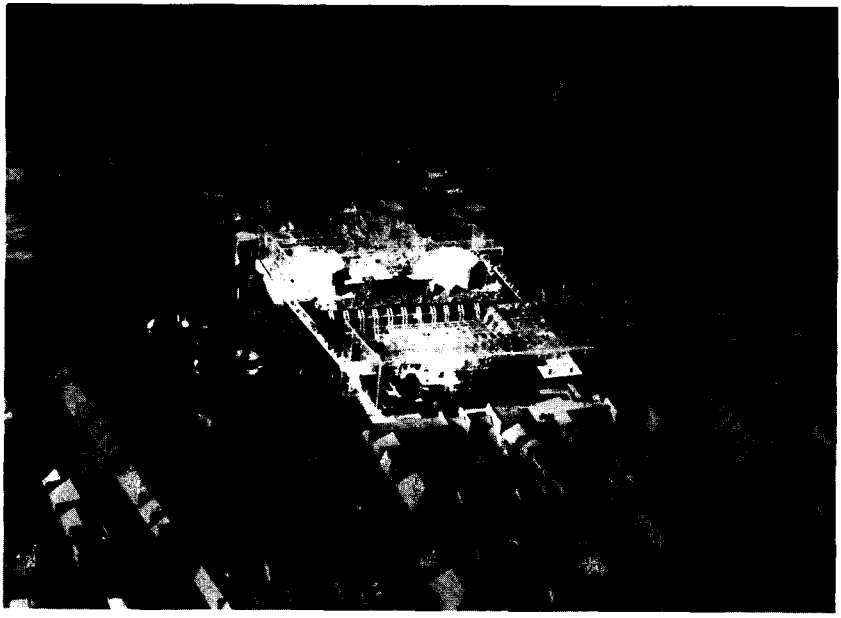
8731-8732. STATISTICAL DECISION THEORY

8751-8752. SEQUENTIAL ANALYSIS

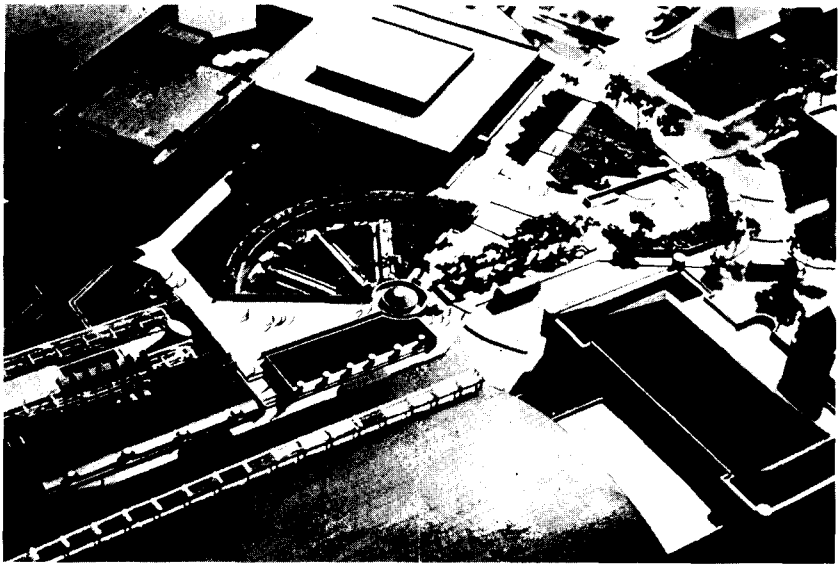
8801. STATISTICAL CONSULTING

8900. SEMINAR IN STATISTICAL LITERATURE

8931-8932-8933. ADVANCED TOPICS IN STATISTICS



In 1980, this model of a world information center, created by a team of five architecture students as a class project, tied for first place in an international competition to redesign the Les Halles market quarter in Paris.



The new Civil and Mineral Engineering Building, which will be 95 percent earth sheltered, was designed as an energy efficient demonstration project. The building is currently under construction.

V. FACULTY

In the faculty listing that follows, P.E. designates licensure as a professional engineer, R.A. designates licensure as a registered architect, and R.L.A. designates licensure as a registered landscape architect.

AEROSPACE ENGINEERING AND MECHANICS

Professor

Patarasp R. Sethna, *head*
Gordon S. Beavers, *associate head*
Abraham S. Berman
Roger L. Fosdick
Philip G. Hodge, Jr.
Chih Chun Hsiao
Daniel D. Joseph
Thomas S. Lundgren
Robert Plunkett, P.E.
William H. Warner
Theodore A. Wilson

Associate Professor

William L. Garrard, Jr.
John P. Moran
Eugene Stolarik

AGRICULTURAL ENGINEERING

Professor

Arnold M. Flikke, *head*
Evan R. Allred
Donald W. Bates
Frederick G. Bergsrud
Harold A. Cloud
Kenneth A. Jordan
Curtis L. Larson
Roger E. Machmeier
Jesse Pomroy
Cletus E. Schertz
John Strait
John A. True

Associate Professor

James J. Boedicker
Philip R. Goodrich
Robert J. Gustafson
R. Vance Morey
Ronald T. Schuler
Donald C. Slack
David R. Thompson

Assistant Professor

Kevin A. Janni
Leslie K. Lindor
Charles A. Onstad
Robert A. Young

Instructor

Charles J. Clanton
Larry D. Jacobson
Hal D. Werner
Jerry A. Wright

Research Fellow

David P. Thimsen

ARCHITECTURE AND LANDSCAPE ARCHITECTURE

Professor

Ralph Rapson, R.A. *head*
Roger D. Clemence, R.L.A.
Carl Graffunder, R.A.
Dennis Grebner, R.A.
Thomas H. Hodne, R.A.
Roger B. Martin, R.L.A.
Valerius Michelson, R.A.
John S. Myers, R.A.
Leonard S. Parker, R.A.
John G. Rauma, R.A.
James E. Stageberg, R.A.
Milo H. Thompson, R.A.
George C. Winterowd, R.A.

Associate Professor

David J. Bennett, R.A.
Joseph Blair, R.A.
Robert E. Diedrich, P.E., R.A.
Gunter A. Dittmar
Kay M. Lockhart, R.A.
Richard B. Morrill, R.A.
Peter Odegard
Duane Thorbeck, R.A.

Assistant Professor

John W. Cuningham, R.A.
Foster W. Dunwiddie, R.A.
Stanley Fishman, R.A.
Alfred W. French, R.A.
Samuel D. Heins, J.D.
Gerald S. Johnson, R.A.
Edward Kodet, R.A.
Lance LaVine, R.A.
Dale Mulfinger, R.A.
Julia Robinson
Garth Rockcastle, R.A.
David Showalter, R.A.
Lee Tollefson, R.A.
J. Stephen Weeks, R.A.

ASTRONOMY

Regents' Professor

Edward P. Ney

Professor

W. Butler Burton, *chairman*
Wayne A. Stein

Associate Professor

Kris Davidson
Roberta M. Humphreys
Thomas W. Jones

Assistant Professor

Robert C. Kennicutt, Jr.
Lawrence Rudnick
Gary D. Schmidt
J. M. van der Hulst

CHEMICAL ENGINEERING AND MATERIALS SCIENCE

Regents' Professor

Rutherford Aris

Professor

H. Ted Davis, *head*
Robert W. Carr, Jr.
E. L. Cussler
John S. Dahler
D. F. Evans
Arnold G. Fredrickson
William W. Gerberich
Herbert S. Isbin
K. H. Keller
C. W. Macosko
Morris E. Nicholson, P.E.
R. A. Oriani
William E. Ranz
Lanny D. Schmidt
L. E. Scriven
Louis E. Toth
Henry M. Tsuchiya

Associate Professor

John M. Sivertsen
George Stephanopoulos

Assistant Professor

G. L. Griffen
Craig L. Jensen
K. Jensen
Matthew V. Tirrell
John P. Wallace
Stephen T. Wellinghoff

CHEMISTRY

Professor

Victor A. Bloomfield
Robert C. Brasted
Doyle Britton
Robert G. Bryant
Bryce Crawford, Jr.
John S. Dahler
H. Ted Davis
Raymond M. Dodson
Stuart W. Fenton
Paul G. Gassman
W. Ronald Gentry
Robert M. Hexter
Maurice M. Kreevoy
Edward Leete
Sanford Lipsky
Rufus W. Lumry
C. Alden Mead
Edward J. Meehan
Larry L. Miller
Wilmer G. Miller
Albert J. Moscowitz
Wayland E. Noland
John Overend
Stephen Prager
Warren L. Reynolds
Harold S. Swofford, Jr.
Donald G. Truhlar
John E. Wertz
Archie S. Wilson

Associate Professor

Richard F. Borch
Lawrence E. Conroy
Jack Z. Gougoutas
Gary R. Gray
Louis H. Pignolet

Assistant Professor

George Barany
Paul Barbara
David Dixon
John E. Ellis
John F. Evans
William E. Farneth
Jed F. Fisher
William Fristad
Wayne Gladfelter
Thomas R. Hoye
Tom Livinghouse
Kent Mann
Marion Stankovich

CIVIL AND MINERAL ENGINEERING

Professor

Charles Fairhurst, *head*
Jesse E. Fant, P.E., L.S., *associate head,director of undergraduate studies*
Roger E. A. Arndt, *director of SAFHL*
Kenneth J. Reid, *director of MRRC*
Heinz G. Stefan, *associate director of SAFHL*
Gust Bitsianes, P.E.
C. Edward Bowers, P.E.
Lawrence E. Goodman, P.E., *James L. Record Professor of Civil Engineering*
Iwao Iwasaki
Walter J. Maier
Edward Silberman, P.E.
Charles C. S. Song
Anthony M. Starfield
Donald H. Yardley, P.E.

Associate Professor

Ladislav Cerny, *director of CE internship program*
Steven J. Eisenreich, *director of graduate studies*
Dimitrios E. Beskos, P.E.
Barry H. G. Brady
Steven L. Crouch
Adrian C. Dorenfeld, P.E.
Cesar Farell
Matthew J. Huber, P.E.
Thomas M. Lillesand
Panos G. Michalopoulos
John J. Moore
Gary Parker
Michael J. Semmens
Otto D. L. Strack

Assistant Professor

Roger D. Hart
Gerald W. Johnson
Eugene L. Skok, Jr., P.E.
Karl Smith
Yorgos J. Stephanedes
Raymond L. Sterling, P.E.
Ioannis Vardoulakis

Instructor

Hendrik M. Haitjema

Research Associate

Mark Christianson
John F. Gulliver
John M. Killen
Brian K. Martus
George D. Meixel
Kootalai Natarajan
Roger A. Plum
Norman F. Schulz
George F. Weaton

Research Fellow

Joseph M. Wetzel, *assistant director of SAFHL*
Charles A. Lane
Abelardo S. Malicsi
Tatiana Sabelin

COMPUTER SCIENCE

Professor

William D. Munro, *associate head*
Oscar H. Ibarra
J. Ben Rosen
Marvin L. Stein

Associate Professor

Kurt J. Maly, *acting head*
K.S. Frankowski
William R. Franta
Sartaj Sahni

Assistant Professor

Valdis Berzins
Steven C. Bruell
Tat-hung Chan
Alan R. Hevner
G. Michael Schneider
William Thompson

EARTH SCIENCES

Regents' Professor

Herbert E. Wright, Jr.

Professor

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Harold M. Mooney, *associate head, director of graduate studies*
Frederick J. Sawkins, *director of undergraduate studies*
Subir Banerjee
Roger L. Hooke
Joseph Shapiro
Robert E. Sloan
Matt Walton
Paul W. Weiblen
Tibor Zoltai

Associate Professor

E. Calvin Alexander
Clement G. Chase
Peter J. Hudleston
Thomas C. Johnson
Hans-Olaf Pfannkuch
George H. Shaw
James H. Stout

Assistant Professor

Anita L. Crews
William Seyfried

ELECTRICAL ENGINEERING

Professor

E. Bruce Lee, P.E., *head*
Vernon D. Albertson, P.E.
LeRoy T. Anderson (emeritus)
William F. Brown, Jr. (emeritus)
J. Alex Carruthers
Paul A. Cartwright, P.E. (emeritus)
Keith S. Champlin
Lorne M. Chanin
Robert J. Collins, P.E.
Jack H. Judy
Richard Y. Kain
K. S. P. Kumar
Robert F. Lambert, P.E.
Rolf K. Mueller
Allen Nussbaum
Hendrik J. Oskam
William T. Peria
Mahmoud Riaz
Gary Y. Robinson
Otto H. Schmitt
Belle A. Shenoi
W. G. Shepherd, P.E. (emeritus)
Aldert van der Ziel (emeritus)
Raymond M. Warner, Jr.
Gottfried K. Wehner (emeritus)

Associate Professor

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Richard P. Halverson
James E. Holte, P.E.
Mostafa Kaveh
Larry L. Kinney
David R. Lamb (adjunct)
Sidney C. Larson, P.E. (emeritus)
Thomas S. Lee
Ralph D. Masiello (adjunct)
Narendra Mohan
William P. Robbins
Rolf Schaumann
Michael Shur
Alfons Tuszynski
Frederick M. Waltz, P.E. (adjunct)
Harry M. Wechsler

Assistant Professor

Steven K. Case
Philip I. Cohen
Malur K. Sundareshan

MATHEMATICS

Regents' Professor

Lawrence Markus
James B. Serrin, Jr.

Professor

Willard Miller, Jr., *head*
Harvey B. Keynes, *associate head*
David A. Storvick, *associate dean*
Eugene B. Fabes, *director of graduate studies*
Alfred Aeppli

Donald G. Aronson
Thomas Berger
Luis Caffarelli
John A. Eagon
Robert Ellis
Steven A. Gaal
J. Gil de Lamadrid
Jay R. Goldman
Leon W. Green
Morton Harris
Dennis Hejhal
Naresh C. Jain
Troels Jorgensen
David Kinderleher
Walter Littman
Warren S. Loud
Albert Marden
Charles A. McCarthy
Richard McGehee
Norman G. Meyers
Johannes C. C. Nitsche
Steven Orey
Daniel Pedoe
William F. Pohl
Marian B. Pour-El
Karel Prikry
William E. Pruitt
Edgar Reich
Peter Rejto
J. Ian Richards
Joel Roberts
David H. Sattinger
George R. Sell
Yasutaka Sibuya
Leon Simon
Hans Weinberger

Associate Professor

James T. Joichi, *director of undergraduate studies*
Edwin F. Stueben, *associate dean for undergraduate studies*
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Chester L. Miracle
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Charlotte Striebel
James E. Thompson
Sidney Webster
Dennis White

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Maury Bramson
Andrew Chermak
Mark Feshbach
Richard Foote
Lawrence Gray
Laurence R. Harper
Carlos Kenig
Stephan List
Peter Olver
Mary Rees
Dennis Stanton
John Wierman

MECHANICAL ENGINEERING

Regents' Professor

Ernst R. G. Eckert (emeritus)

Professor

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J. Edward Anderson, P.E.
Sant Ram Arora
Perry L. Blackshear, Jr.
Arthur G. Erdman
Edward A. Fletcher
Darrell A. Frohrib
Warren E. Ibele, P.E.
Richard C. Jordan, P.E. (emeritus)
David B. Kittelson
Edwin T. Layton
Benjamin Y. H. Liu
Thomas E. Murphy, P.E.
Katsuhiko Ogata
Suhas V. Patankar
Emil Pfender
Frank A. Raley
Ephraim M. Sparrow
Kenneth T. Whitby
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Tarald O. Kvalseth
Virgil A. Marple
Charles J. Scott
Richard D. Springer, P.E.
Patrick J. Starr

Assistant Professor

Max Donath
Peter H. McMurry
James W. Ramsey
Donald R. Riley
Terrence W. Simon
Kevin Y. Teichman

PHYSICS

Regents' Professor

Alfred O. C. Nier (emeritus)

Professor

Walter V. Weyhmann, *head*
Morton Hamermesh, *director of graduate studies*
Robert O. Pepin, *director of undergraduate studies*
Benjamin Bayman
J. Morris Blair
John H. Broadhurst
Laurence J. Cahill, Jr.

Hans W. J. Courant
Dietrich Dehnhard
George D. Freier
Phyllis S. Freier
Stephen Gasiorowicz
Donald A. Geffen
Clayton F. Giese
Allen M. Goldman
George W. Greenlees
J. Woods Halley
Norton Hintz
Russell K. Hobbie
Walter H. Johnson
Paul J. Kellogg
Homer T. Mantis
Jonathan L. Rosner
Keith Ruddick
Roger H. Stuewer
Hiroshi Suura
Yau Chien Tang
Cecil J. Waddington
John R. Winckler
William Zimmermann, Jr.

Associate Professor

Charles Campbell
Paul Ellis
Kenneth Erickson (adjunct)
Roger S. Jones
Erwin Marquit
Marvin Marshak
Konrad Mauersberger
Earl A. Peterson
Peter Roll
Alan Shapiro

Assistant Professor

E. Dan Dahlberg
Kenneth Heller
Cheng-Cher Huang
Oriol T. Valls

STATISTICS

Professor

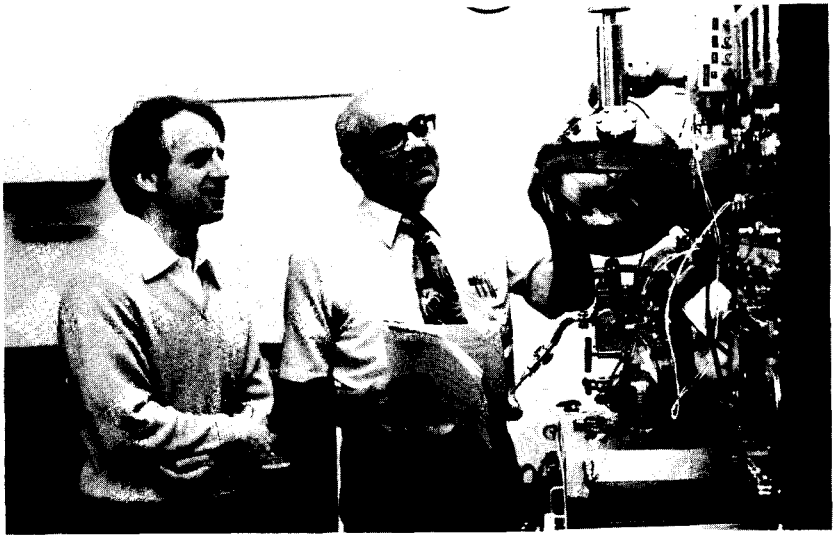
Seymour Geisser, *director*
Christopher Bingham
Robert J. Buehler
Raymond O. Collier
Somesh Das Gupta
Morris L. Eaton
Clifford Hildreth
David V. Hinkley
Bernard W. Lindgren
William D. Sudderth

Associate Professor

Donald A. Berry
R. Dennis Cook
David A. Lane
Kinley Larntz
Frank Martin
Sanford Weisberg

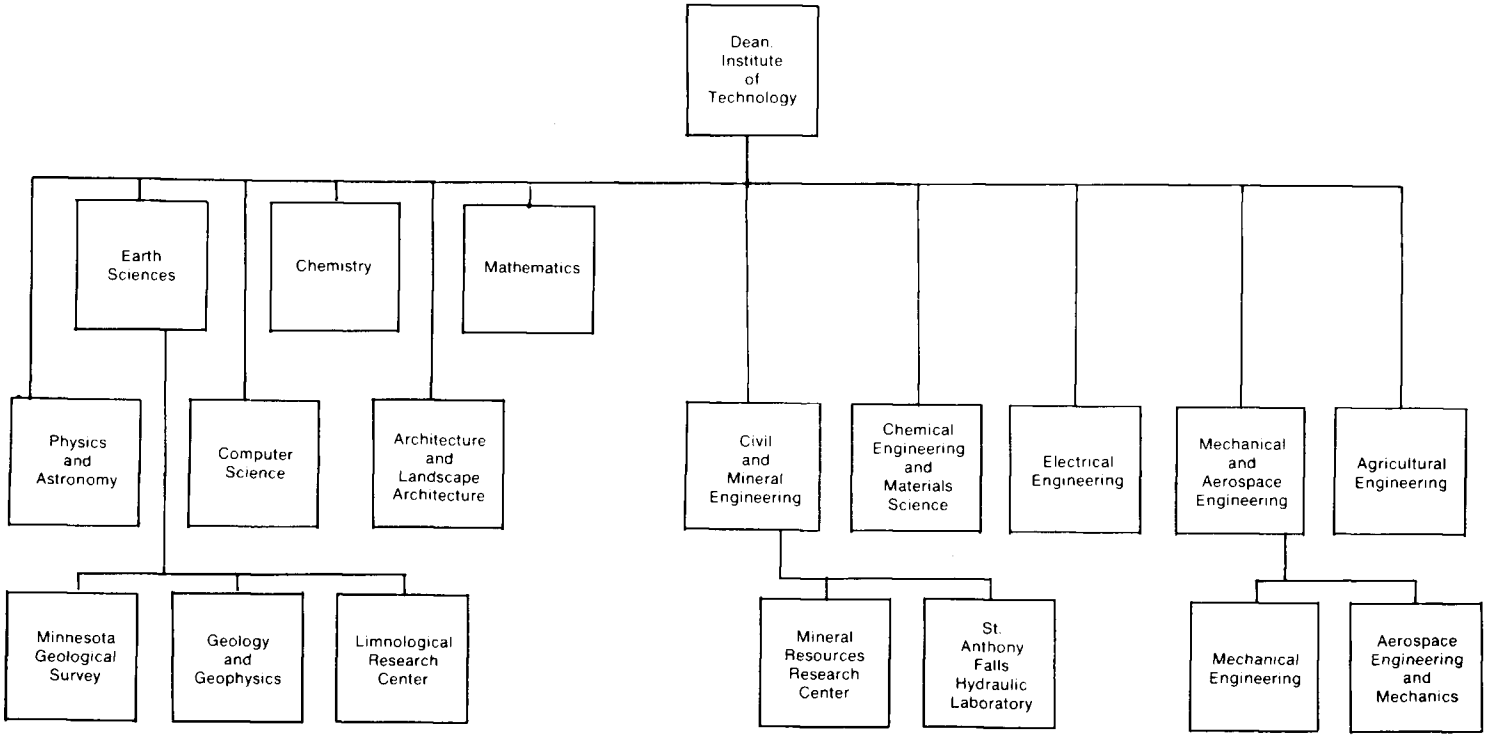
Assistant Professor

Stanley S. Wasserman



Associate Professor Konrad Mauersberger and Regents' Professor Emeritus Alfred O. C. Nier calibrate a mass spectrometer, which is used to study the composition of the earth's upper atmosphere.

ORGANIZATIONAL CHART
OF THE
INSTITUTE OF TECHNOLOGY



Participants give their all as the E Day bed race begins.

E Day wheelbarrow racers recover after crossing the finish line.

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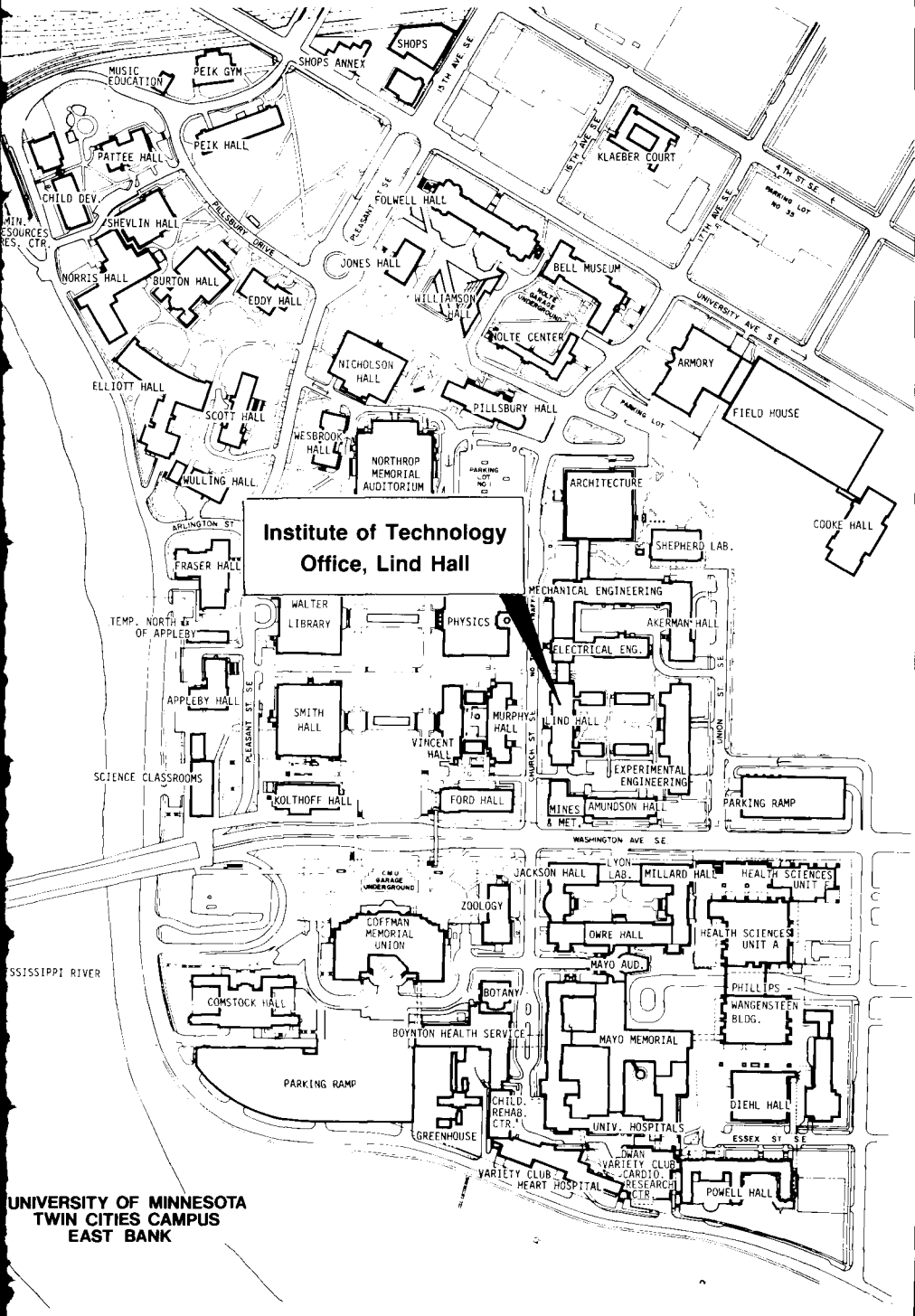

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