This is the **College of Science and Engineering** section of the 2007–2009 University of Minnesota Duluth Catalog

Contents

College of Science and Engineering (CSE)..... 218

Admission..... 218

Academic Standing..... 219

Student Affairs Office..... 219

Baccalaureate Degrees 219

College of Science and Engineering Departments 221

Collegiate Graduate Program..... 223

Pre-Professional Programs..... 224

Degree Programs..... 228

College of Science and Engineering

The College of Science and Engineering is committed to providing opportunities to learn through participation in research, honors programs, individual study, and special seminars.

College of Science and Engineering (CSE)

Dean: James Riehl,
140 Engineering Building, 218-726-6397

Associate Dean: Timothy B. Holst,
140 Engineering Building, 218-726-7585

The College of Science and Engineering has a fourfold mission: to help each student develop a foundation for a career by learning the substance and methods of an academic discipline; to participate fully in the liberal education mission of the campus; to foster significant scholarly research; and to serve the well-being of the community, state, and region. The college offers students a broad range of curricula covering the natural sciences, mathematical sciences, engineering, and technology.

Each student is provided the opportunity to develop competence in a special field of knowledge by learning its principles and perspectives, mastering its methods, and acquiring much of its accumulated knowledge.

In addition to offering formal coursework, the college is committed to providing students with opportunities to learn through participation in research, honors programs, individual study, and special seminars. Such programs, which emphasize undergraduate education, are enhanced and complemented by high quality graduate programs. These graduate programs form an integral component of our commitment to scholarship.

Several departments also offer master's degrees through the Graduate School.

Admission

The college has no specific secondary school preparation requirements for admission beyond the preparation standards of the University of Minnesota. However, secondary school students contemplating a baccalaureate degree in a physical or biological science, mathematics, computer science, or engineering are strongly urged to complete a college preparatory program that includes four years (grades 9–12) each of English, mathematics, and science.

The engineering programs have specific college-level course requirements and minimum GPAs that must be satisfied before students can be admitted into the upper division (junior and senior level) program.

For general admission information, see the Policies and Procedures section of this catalog.

Dean's List of Academic Excellence

Each semester, CSE students are recognized for high academic achievement by being placed on the CSE Dean's List of Academic Excellence. This honor is awarded to students who rank in the top 15% of the college based on their semester GPA. To be eligible, students must have completed at least 12 graded credits and have received no final grades of F, N, or I during that semester.

College Honors

At UMD a maximum of 15 percent of the graduating class can graduate with college honors. In CSE the top 3 percent of the graduating class is designated *summa cum laude*, the next 5 percent *magna cum laude*, and the next 7 percent *cum laude*.

At the beginning of each year, the GPAs necessary to achieve these honors are posted in the Student Affairs Office, 140 Engineering Building. These GPAs are based on those of the previous spring semester's graduating class. In addition, students receiving honors must have a coefficient of course completion of at least 90 percent. To be eligible for honors, students must earn at least 30 credits at UMD. For more information, contact the Office of the Associate Dean, 140 Engineering Building.

Honors Programs

The objective of the CSE honors programs is to offer highly motivated students of superior ability a greater challenge than is available through the traditional curriculum. Honors opportunities provide for closer student-faculty relationships, emphasize writing and speaking skills, and offer active learning in the disciplinary and interdisciplinary components.

In the lower division, honors opportunities include seminars and special sections of lecture and lab courses. Students may participate in these by invitation or by consent of the instructor.

Honors opportunities in the upper division are available for students in all departments. Department honors candidates are selected on the basis of coursework completed and potential for independent work. A research project is required.

More information about department honors is available through the departments.

Academic Standing

Good Academic Standing

CSE requires that its students maintain a minimum cumulative GPA to be in good academic standing. For students who have attempted 20 or more credits the minimum cumulative GPA is 2.00. Because some students have difficulty adjusting to the standards of a university education, students who have attempted fewer than 20 credits (at UMD or elsewhere) must maintain a minimum cumulative GPA of 1.80 to remain in good academic standing.

Probation

Students with a cumulative GPA lower than that required for good academic standing are placed on academic probation. If at the end of a semester on probation, the cumulative GPA is at or above 2.00, the student will be returned to good academic standing. Students also will be placed on probation if their semester GPA is less than 2.00 for two consecutive semesters, even if the cumulative GPA is above 2.00. To regain good standing, these students must achieve both a subsequent semester GPA of 2.00 and a cumulative GPA of 2.00.

Dismissal

If, after a semester of probation, a student fails to attain the required minimum GPA for good academic standing, the student is subject to dismissal. Dismissal decisions are made in the college office following fall and spring semester final exams. Dismissed students are notified immediately and their registration as a CSE student for the next semester is canceled. Students who fail to attain the minimum GPA, yet who are making academic progress, may be granted an additional semester of probation at the discretion of the college.

Readmission

Students who have been academically dismissed from CSE must present evidence of improved academic capability to the college to justify readmission. Petition forms for readmission and information concerning academic standing are available in the CSE Student Affairs Office, 140 Engineering Building.

Student Affairs Office

Information on academic matters, including academic standing; admission; advising; academic programs; change of major, college, or adviser; grievance and appeals procedures; honors programs; undergraduate research; student clubs; and tutoring is available in the CSE Student Affairs Office, 140 Engineering Building.

Baccalaureate Degrees

CSE offers the bachelor of science (B.S.), bachelor of science in chemical engineering (B.S.Ch.E.), bachelor of science in electrical and computer engineering (B.S.E.C.E.), bachelor of science in industrial engineering (B.S.I.E.), and bachelor of science in mechanical engineering (B.S.M.E.) degrees.

B.S. Majors

Biochemistry and molecular biology
Biology
Cell and molecular biology
Chemistry
Computer information systems
Computer science
Environmental science
Geological sciences
Mathematics
Physics
Applied physics
Statistics and actuarial science

Minors

Aerospace studies (*minor only*)
Astronomy (*minor only*)
Biochemical engineering (*minor only*)
Biology
Chemistry
Computer information systems
Computer science
Computer science, applied (*minor only*)
Electrical and computer engineering
Environmental science
Environmental engineering (*minor only*)
Geological sciences
Mathematics
Physics

For other minors available to students pursuing a bachelor of science degree, see the Labovitz School of Business and Economics, School of Fine Arts, College of Education and Human Service Professions, and College of Liberal Arts sections of this catalog.

General Requirements

- Completion of at least 30 degree credits at UMD.
- Completion at UMD of at least 20 of the last 30 degree credits immediately before graduation.
- Compliance with general regulations governing granting of degrees.

B.S. Requirements

- Completion of at least 120 degree credits.
- Completion of a major for the bachelor of science degree and a minor or second major in a different program, with a 2.00 minimum GPA in the major, including supporting courses, and a 2.00 minimum GPA in the minor, including supporting courses.
- Completion of UMD liberal education requirements. See Liberal Education Program
- A 2.00 minimum GPA in all work attempted at UMD; a 2.00 minimum GPA in all work, including transfer credits; and successful completion of 75 percent of all work attempted.
- If there are multiple majors and/or minors, this requirement holds for each major and minor, calculated separately.

For students completing two or more majors:

- A minor is not required.
- If the majors are for different degrees (e.g., a B.S. and a B.A.), the majors must be in different programs (e.g., a student may not receive a B.S. in chemistry and a B.A. in chemistry) and students must complete requirements for both degrees.

B.S.Ch.E. Requirements

- Completion of at least 130 degree credits.
- A 2.00 minimum GPA in all work attempted at UMD; a 2.00 minimum GPA in all work, including transfer credits; and successful completion of 75 percent of all work attempted.
- Completion of UMD liberal education requirements. See the Liberal Education Program section of this catalog.
- Completion of the chemical engineering major. Admission to the upper division program of the chemical engineering major is competitive and granted on a space-available basis. Application for admission to upper division must be filed with the department upon completion of lower division requirements.
- A 2.00 minimum GPA in all courses taken in the chemical engineering major, including required courses in related fields. This GPA requirement applies to all courses in the major taken at UMD calculated separately and also to all courses in the major when transfer credits are included.

B.S.E.C.E. Requirements

- Completion of at least 128 degree credits.
- Completion of the electrical and computer engineering major. Admission to the upper division program is competitive and granted on a space available basis. A minimum GPA of 2.00 in all work attempted at UMD, successful completion (with grades of A through D, or S) of 75 percent of all work attempted, and a minimum GPA of 2.00 (C) overall (including transfer credits) are required for admission to the electrical and computer engineering (ECE) upper division program.
- Completion of UMD and ECE liberal education requirements.
- A minimum GPA of 2.00 for all courses taken in the major, including required supporting courses. This average applies to all courses in the major taken at UMD and calculated separately and also to all courses in the major when transfer credits are included.

B.S.I.E. Requirements

- Completion of at least 128 degree credits.
- Grades of C- or better are required in all program courses. Transfer grades must be a C or better.
- A 2.00 minimum GPA (C) in all work attempted at UMD; a 2.00 minimum GPA in all work, including transfer credits; and successful completion of 75 percent of all work attempted.
- Completion of UMD liberal education requirements. See the Liberal Education Program section of this catalog. Courses for Categories 9 and 10 must have different designators.
- Completion of the industrial engineering major. Admission to the upper division program of the industrial engineering major is competitive and granted on a space-available basis. Application for admission to the upper division must be filed with the department upon completion of lower division requirements.
- A 2.00 minimum GPA in all courses taken in the industrial engineering major, including required courses in related fields. This GPA requirement applies to all courses in the major taken at UMD calculated separately and also to all courses in the major when transfer credits are included.

B.S.M.E. Requirements

- Completion of at least 128 degree credits.
- Grades of C- or better is required in all program courses. Transfer grades must be a C or better.
- A 2.00 minimum GPA (C) in all work attempted at UMD; a 2.00 minimum GPA in all work, including transfer credits; and successful completion of 75 percent of all work attempted.
- Completion of UMD liberal education requirements. See the Liberal Education Program section of this catalog. Courses for Categories 9 and 10 courses must have different designators.
- Completion of the mechanical engineering major. Admission to the upper division program of the mechanical engineering major is competitive and granted on a space-available basis. Application for admission to upper division must be filed with the department upon completion of lower division requirements.
- A 2.00 minimum GPA in all courses taken in the mechanical engineering major, including required courses in related fields. This GPA requirement applies to all courses in the major taken at UMD calculated separately and also to all courses in the major when transfer credits are included.

College of Science and Engineering Departments

Aerospace Studies

E-mail: air@d.umn.edu
Web site: www.d.umn.edu/air/

Professor: Lieutenant Colonel Al Chromy; *Assistant Professors:* Major Tim Allen, Captain Eric Fraser

The Aerospace Studies Department offers a curriculum to all students looking for insight into the mission, organization, and operation of the United States Air Force. Students study Air Force history, leadership, management, and professionalism as well as U.S. foreign and defense policy. The Department offers most of the courses required for an aerospace studies minor. Students have the opportunity to participate in the Air Force Reserve Officer Training Corps (AFROTC) and prepare for an Air Force commission as soon as they earn their academic degrees. Real-world application of organizational leadership and management skills is the backbone of their professional development. Scholarships covering the cost of education and a monthly stipend are available on a merit basis.

Biology

E-mail: biol@d.umn.edu
Web site: www.d.umn.edu/biology/

Professors: Matthew T. Andrews, Stephen A. Bortone, Stephen C. Hedman, Randall E. Hicks, M. Reza-Ul Karaim, Gerald J. Niemi, John J. Pastor; *Associate Professors:* Donn K. Branstrator, Timothy P. Craig,Thomas R. Hrabik, Allen F. Mensinger, David J. Schimpf; *Assistant Professors:* Clay J. Carter, Julie R. Etterson, Tim L. Kroft, Tali D. Lee, Amanda M. Little; *Instructors:* Colleen M. Belk, Lyle J. Shannon

Biology is one of the largest programs at UMD, with more than 600 undergraduate majors, more than 30 active graduate students, and 20 full-time faculty. We offer bachelor of science degrees in biology and cell and molecular biology and master of science degrees with concentrations in botany, zoology, environmental biology, cellular and physiological biology. In addition we provide pre-professional preparation for students interested in dentistry, fishery and wildlife management, medicine, optometry, pharmacy, and veterinary medicine. We also serve students seeking bachelor of arts degrees in biology through the College of Liberal Arts (CLA) and those seeking bachelor of applied science (B.A.Sc.) degrees in life science teaching through the College of Education and Human Service Professions. The faculty are actively involved in research supported by more than $8 million in external grants. This funding allows the department to offer all qualified undergraduate students the opportunity to participate in faculty research.

Chemical Engineering

E-mail: che@d.umn.edu
Web site: www.d.umn.edu/che

Professors: Richard A. Davis, A. Rashid Hasan (*department head*); *Associate Professors:* Keith Lodge, Steven Sternberg; *Assistant Professors:* Michael Rother, Gregory Rutkowski; *Instructor:* Carol Horabik

The Department of Chemical Engineering offers students a high quality educational experience that includes engineering theory, application, experimentation, and design. It is dedicated to achieving recognition for excellence in engineering education by continually improving its program, contributing to the body of knowledge through research, providing an environment for professional development, and serving the profession.

Chemistry and Biochemistry

E-mail: chem@d.umn.edu
Web site: www.d.umn.edu/chem/

Professors: Robert M. Carlson, Lester R. Drewes (MED), John F. Evans, John E. Fulkrod, Vincent Magnuson, Donald P. Poe, Joseph R. Prohaska (MED), James P. Riehl, Bilin P. Tsai, Kendall B. Wallace (MED), Viktor V. Zhdankin; *Associate Professors:* Benjamin L. Clarke (MED), Thomas E. Huntley (MED), Paul Kiprof, Paul D. Siders; *Assistant Professors:* Steven Berry, Robert Cormier (MED), Joseph L. Johnson, Sangeeta Mereddy, Venkatram Mereddy, Elizabeth Minor, Victor Nemykin, Edward L. Perkins (MED), Jon N. Rumbley, Josef Werne; *Instructor:* Patricia R. Splan

The Department of Chemistry and Biochemistry provides classroom and laboratory learning opportunities and research experiences across the discipline to meet the needs of students in engineering, liberal arts, and pre-professional programs, as well as those of students who wish to pursue careers or graduate studies in chemistry or related disciplines.

Computer Science

E-mail: cs@d.umn.edu
Web site: www.d.umn.edu/cs/

Professors: Donald B. Crouch, Carolyn J. Crouch, Douglas J. Dunham, Richard Maclin (*department head*); *Associate Professors:* Timothy R. Colburn, Linda L. Deneen, Theodore D. Pedersen, Christopher Prince, Gary M. Shute, C. Hudson Turner; *Assistant Professors:* James Allert, Peter Willemsen; *Instructor:* Steven Holtz

The Department of Computer Science provides instruction and research experiences for undergraduate and graduate students in preparation for careers in industry or for continuing on in graduate school. The department also provides instruction in computer literacy and software design for non-major students as part of a liberal education.

Electrical and Computer Engineering

E-mail: ece@d.umn.edu
Web site: www.d.umn.edu/ece

Professors: Stanley Burns (*department head*), Taek Mu Kwon, Marian Stachowicz, Jiann-Shiou Yang: *Associate Professors:* Christopher Carroll, Mohammed Hasan, Imran Hayee; *Assistant Professors:* Hua Tang, G. Lee Zimmerman; *Instructor:* Scott Norr

The goals of the Department of Electrical and Computer Engineering are to provide high quality educational opportunities in electrical and computer engineering for students of the region by delivering a program with a strong hands-on laboratory and design component in conjunction with a thorough foundation in theory; and to provide students with the tools and skills to be major life-long contributors to their professions and society as a whole.

Geological Sciences

E-mail: geol@d.umn.edu
Web site: www.d.umn.edu/geology

Professors: Erik T. Brown, Steven M. Colman, John W. Goodge, Vicki L. Hansen, Timothy B. Holst, Thomas C. Johnson, Howard D. Mooers (*department head*), Ronald L. Morton; *Associate Professors:* Christina Gallup, Penelope Morton, John B. Swenson, Nigel J. Wattrus

The Department of Geological Sciences offers three undergraduate programs: a bachelor of science program providing training for a career as a professional geologist, which usually requires graduate study; a liberal arts bachelor of arts program through the College of Liberal Arts; and a program for those interested in teaching earth sciences through the College of Education and Human Service Professions.

Mathematics and Statistics

E-mail: math@d.umn.edu
Web site: www.d.umn.edu/math

Professors: Joseph A. Gallian, Richard F. Green, Barry R. James (*department head*), Kang L. James, Zhuangyi Liu, Ronald R. Regal, Harlan W. Stech; *Associate Professors:* Guihua Fei, Dalibor Froncek, John R. Greene, Carmen Latterell, Kathryn E. Lenz, Robert L. McFarland, Bruce B. Peckman, Steven A. Trogdon; *Assistant Professors:* Marshall Hampton, Yongcheng Qi; *Instructors:* Anna C. Jacobson, Karl K. Kruppstadt, Chad Pierson, Deanna L. Riley, Angela M. Sharp

The Department of Mathematics and Statistics offers undergraduate degree programs in mathematics and statistics/actuarial science. These programs prepare students for careers in business, industry, government, and teaching, as well as for graduate studies in mathematics, statistics, and biostatistics.

Mechanical and Industrial Engineering

E-mail: mie@d.umn.edu
Web site: www.d.umn.edu/mie

Professors: Mark A. Fugelso, Richard R. Lindeke, David A. Wyrick (*department head*); *Associate Professor:* Ryan G. Rosandick; *Assistant Professors:* Seraphin C. Abou, Emmanuel U. Enemuoh, Robert Feyen, Bachel Han, William E. Pedersen, Daniel N. Pope, John C. Voss, Xun Yu; *Instructors:* Hongyi Chen, David Keranen, Hossain Khoroosi

The Department of Mechanical and Industrial Engineering (MIE) will be internationally recognized as the premier engineering department in the Great Lakes Region for its high quality undergraduate education, applied master's level programs in environmental health and safety and engineering management, and integrated outreach activities in regional economic development,

international partnerships, and applied research, thus enabling the growth of our students, faculty, alumni, industry, and economy.

Physics

E-mail: phys@d.umn.edu
Web site: www.d.umn.edu/physics

Professors: John R. Hiller (*department head*), Michael Sydor; *Associate Professors:* Alec T. Habig; *Assistant Professors:* Jay A. Austin, Richard W. Gran, Jonathan Maps; *Instructor:* Darrin E. Johnson

The Department of Physics offers two bachelor of science degrees that provide professional preparation in pure and applied physics as well as a liberal arts degree (B.A.). Students participate in research focused primarily on theoretical physics, instrumentation, experimental solid state and high energy physics, and physical oceanography. The department also offers courses required for such professional and pre-professional programs as engineering and medicine.

Collegiate Graduate Program

Master of Environmental Health and Safety

Professor: David A. Wyrick; *Assistant Professors:* Seraphin C. Abou, Robert Feyen, Bachel Han, Daniel N. Pope

The M.E.H.S. program prepares graduates for professional careers in environmental health and safety, which include occupational safety, industrial hygiene, ergonomics, risk management, and environmental health. The coursework includes analysis of occupational safety and health problems; accompanying problem-solving and decision-making techniques; and the application of established principles and practices of accident prevention, control, and reduction in occupational settings.

Admission Requirements

Applicants must have a baccalaureate degree from an accredited college or university, preferably with a major in science, engineering, or another appropriate field. Baccalaureate degree holders with different majors who have relevant backgrounds or qualifications are also considered. If deficiencies exist, candidates may be accepted into the program contingent upon successful completion of courses designed to correct them. All applicants must take the Graduate Record Examination (GRE) General Test and have an official report of the results sent to the mechanical and industrial engineering graduate programs office as part of their application for admission; minimum scores of 1,000 on the verbal and quantitative sections and 4.0 on the analytical writing are preferred. Because this test is given at limited times and places during the year, applicants are advised to register early for the examination. Applicants must furnish official transcripts showing that they have completed their baccalaureate degree before they will be admitted or allowed to enroll in any M.E.H.S. courses. Students may apply for admission during their last semester of undergraduate work, but they will not be formally admitted or allowed to begin M.E.H.S. coursework until the baccalaureate degree is completed.

Application Procedure

A completed admission application should be submitted prior to the year of anticipated enrollment. Information and applications are available from the M.E.H.S. program office, 229 Voss-Kovach Hall. The admission decision is based on an evaluation by the applicant screening committee of the undergraduate scholastic record, past work experience, GRE results, and letters of recommendation. International students must present a TOEFL score of 550 or above. Applicants are responsible for obtaining information on all admission deadlines and requirements and for submitting all required admission materials before the first day of classes or they will be denied admission and must reapply to the program.

Degree Requirements

Requirements for the M.E.H.S. include:

- 36 course credits in the M.E.H.S. program and maintenance of an overall minimum GPA of 3.00;
- a minimum of two semesters for the residence requirement;
- an additional 3-credit industrial internship with a Plan B type project, which must be fulfilled within six months following completion of coursework, unless a formal extension is requested and granted.

Required Courses

Core (29 credits)

SAFE 6002—Regulatory Standards and Hazard Control (3 cr)
SAFE 6011—System Safety and Loss Control Techniques (3 cr)
SAFE 6012—Risk Management and Workers' Compensation (2 cr)
SAFE 6051—Construction Safety Management (3 cr)
SAFE 6101—Principles of Industrial Hygiene (3 cr)
SAFE 6111—Industrial Noise and Ventilation Control (3 cr)

SAFE 6301—Occupational Biomechanics and Work Physiology (2 cr)
SAFE 6302—Occupational Ergonomics and Injury Management (3 cr)
SAFE 6401—Environmental Safety and Legal Implications (2 cr)
SAFE 6802—Leadership, Teamwork, Behavior in EHS (3 cr)
SAFE 6821—Organization and Administration of Safety Programs (2 cr)

Electives (7 credits)

EMGT 5995—Special Topics (1–3 cr)
EMGT 8993—Engineering Management Seminar (1 cr)
IE 5325—Advanced Engineering Economics (3 cr)
SAFE 6102—Advanced Industrial Hygiene and Health Physics (2 cr)
SAFE 6121—Epidemiology and Industrial Toxicology (2 cr)
SAFE 6201—Fire Prevention and Emergency Preparedness (2 cr)
SAFE 6211—Transportation Safety (2 cr)
SAFE 6291—Independent Study in Industrial Safety (1–3 cr)
SAFE 6295—Special Topics (1–3)
SAFE 6402—Environmental Control Operations and Design (2 cr)

Final Project (3 credits)

Upon completing program coursework on campus, students are required to complete a cooperative internship in an industrial, governmental, or other organization that has an established safety program or is implementing one. Students are required to complete SAFE 6997 a Plan B type project for the firm.

Grading System

The M.E.H.S. program uses two grading systems, mandatory A-B-C-D-F and S-N. The course syllabus identifies the grading system used for each course. The temporary grade I (incomplete) is assigned only when a student has made an agreement with the instructor to complete the requirements for a course before the instructor submits final grades for a semester. The I remains in effect for nine weeks after the beginning of the next semester during which the student is in attendance, unless a different time period has been arranged between the student and instructor. At the end of this period, the I is changed to an N or F unless the instructor has submitted a change of grade or has agreed to an extension of the incomplete. If an extension is permitted, it is the responsibility of the student to get an Extension of Incomplete form, the instructor's signature, and submit the form to the program office before the deadline.

A student with an excessive number of incompletes may be denied further registration until some of them have been removed.

The program discourages retaking courses to improve grades. Permission from the course instructor and the major adviser is required to retake courses. If a course is retaken, all registrations for it remain on the student's record.

Pre-Professional Programs

The college offers programs and special advising services for students who plan to enter professional schools. These programs offer preparation in pre-professional coursework as well as a broad background in mathematics, biological and physical sciences, humanities, and social science.

Some professional requirements can be fulfilled in two or three years; others take four years with the completion of a baccalaureate degree. In any case, students are encouraged to avoid narrow specialization during their undergraduate years.

The basic programs are described below. Variations in a curriculum may be arranged upon agreement among the student, pre-professional adviser, and admissions office of the pertinent professional school. Students are encouraged to seek admissions details from the professional school of their choice, see their advisers regularly, learn of visits by representatives of various professional schools, and receive help with course planning. UMD also offers preparatory courses for other health sciences professions.

Pre-Dentistry

The University of Minnesota's School of Dentistry requires at least three years of college, including:

BIOL 1011*—General Biology I (5 cr)
BIOL 1012—General Biology II (5 cr)
CHEM 1151*—General Chemistry I (5 cr)
CHEM 1152—General Chemistry II (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4–5 cr)
CHEM 3322—Biochemistry (3 cr)
COMP 1120*—College Writing (3 cr)
COMP 3xxx—Advanced Writing (3 cr)
MATH 1250*—Precalculus Analysis (4 cr)
PHYS 1001*—Introduction to Physics I (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
PSY 1003*—General Psychology (4 cr)

Electives especially recommended are art, cell biology, human anatomy, microbiology, and physiology. Additional electives can be selected from courses in business, biology, chemistry, social sciences, and the humanities.

It is also strongly recommended that students complete additional credits to achieve as broad and liberal an education as possible. About 80 percent of successful dental school candidates have a baccalaureate degree. Applicants to dental school must apply before December 1 for entry the following fall. The American Dental Association Admissions Test (DAT) is required and the official DAT score report must also be submitted by December 1 of the year before matriculation. The computerized DAT can be taken at any time, but students must first apply through the Dental Admission Testing Program.

** Courses that may be used to fulfill UMD liberal education program requirements.*

Pre-Medicine

Students admitted to medical school must complete four-year degrees before they begin medical studies. There is no prescribed pre-medical major—any recognized college major is acceptable. Admission requirements vary, however, and students should plan their academic programs with the assistance of a pre-medicine adviser. Students also should read and complete the specific admission requirements of the medical schools in which they are interested. The following courses are prerequisites for admission to many medical schools.

BIOL 1011*—General Biology I (5 cr)
BIOL 1012—General Biology II (5 cr)
CHEM 1151*—General Chemistry I (5 cr)
CHEM 1152—General Chemistry II (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4–5 cr)
CHEM 3322—Biochemistry (3 cr)
COMP 1120*—College Writing (3 cr)
COMP 3150—Advanced Writing: Science (3 cr)
MATH 1296*—Calculus I (5 cr)
PHYS 1001*—Introduction to Physics I (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
or PHYS 2011*—General Physics I (4 cr)
and PHYS 2012—General Physics II (4 cr)
PSY 1003*—General Psychology (4 cr)

Additional required or recommended courses may include cell biology, genetics, humanities, literature, microbiology, quantitative analysis, and social sciences.

** Courses that may be used to fulfill UMD liberal education program requirements.*

The Medical College Admission Test (MCAT) should be taken in the spring of the junior year or, at the latest, in the summer before the senior year. Students are advised to apply to medical school as early as possible after June 15 of the year preceding anticipated fall entrance. Most application deadlines are between October 1 and November 15.

Current information about admission requirements for all American medical schools can be found in *Medical School Admission Requirements*. Information on admission requirements for the three Minnesota medical schools is in the *Handbook on Pre-Medical Studies*, available from any pre-medicine adviser or the college's Student Affairs Office, 140 Engineering Building.

Pre-Optometry

Admission requirements for optometry colleges vary considerably. The following program satisfies pre-optometry requirements for most of these colleges. It is suggested that students begin application procedures during their third year of college study. Applicants are selected on a competitive basis and academic work is weighed heavily. In addition to GPA, admission is based on Optometry College Admission Test (OCAT) scores, letters of recommendation, volunteer or work experience in optometry, interview evaluations, and other supporting documents.

BIOL 1011*—General Biology I (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 2101—Cell Biology (3 cr)
CHEM 1151*—General Chemistry I (5 cr)
CHEM 1152—General Chemistry II (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)
COMP 1120*—College Writing (3 cr)
COMP 3xxx—Advanced Writing (3 cr)
MATH 1296*—Calculus I (5 cr)
PHYS 1001*—Introduction to Physics I (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
PSY 1003*—General Psychology (4 cr)
STAT 1411*—Introduction to Statistics (3 cr)

Additional required or recommended courses may include anatomy, biochemistry, communications, computer science, genetics, humanities, microbiology, physiology, and social sciences. Students should read and complete the specific admission requirements of the optometry school in which they are interested.

** Courses that may be used to fulfill UMD liberal education program requirements.*

Pre-Pharmacy

Students wishing to enter the four-year doctor of pharmacy (Pharm.D.) program in the College of Pharmacy on the Duluth or Minneapolis campus may complete their prerequisites with the coursework listed below. The Pharmacy College Admission Test (PCAT) is also required.

BIOL 1011*—General Biology I (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 1761—Human Anatomy (4 cr)

BIOL 2101—Cell Biology (3 cr)
BIOL 4501—General Microbiology (4 cr)
CHEM 1151*—General Chemistry I (5 cr)
CHEM 1152—General Chemistry II (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (5 cr)
COMM 1112*—Public Speaking (3 cr)
COMP 1120*—College Writing (3 cr)
COMP 3150—Advanced Writing: Science (3 cr)
ECON 1023*—Principles of Economics: Micro (3 cr)
or ECON 1022—Principles of Economics: Macro (3 cr)
MATH 1296*—Calculus I (5 cr)
PHYS 1001*—Introduction to Physics I (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
Two courses dealing with human behavior in society (psychology or sociology courses)

** Courses that may be used to fulfill UMD liberal education program requirements.*

In addition to the pre-pharmacy course requirements, students must complete at least 30 credits of general education (nonscience, nonmathematics, nonprofessional) courses. Pre-pharmacy credits earned in behavioral sciences, English composition, economics, and public speaking apply toward this general education requirement.

Although admission to pharmacy is possible after three years of undergraduate study, it is recommended that students pursue a baccalaureate degree while preparing for admission to the College of Pharmacy.

Pre-Veterinary Medicine

The pre-veterinary program at UMD is part of the preparation for entry into the College of Veterinary Medicine on the St. Paul campus. Students may apply for entry after their third year at UMD. Required courses must be completed A-F.

Students should apply for admission to the veterinary college no later than November 1 for entry the following fall. The Graduate Record Examination (GRE) is also required for admission.

A recommended pre-veterinary program appears below for those who wish to enter veterinary college after their third year.

BIOL 1011*—General Biology I (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 2101—Cell Biology (3 cr)
BIOL 2201—Genetics (3 cr)
BIOL 4501—General Microbiology (4 cr)
CHEM 1151*—General Chemistry I (5 cr)
CHEM 1152—General Chemistry II (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4–5 cr)
CHEM 3322—Biochemistry (3 cr)
COMP 1120*—College Writing (3 cr)
COMP 3xxx—Advanced Writing (3 cr)
MATH 1250*—Precalculus Analysis (4 cr)
PHYS 1001*—Introduction to Physics I (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
Arts and humanities electives
History and social sciences electives
Additional recommended electives include courses in business management, communications, economics, public speaking, and statistics.

** Courses that may be used to fulfill UMD liberal education program requirements.*

Note: *Students who choose to complete a degree at UMD before transferring to a veterinary college may do so within the usual four-year enrollment if they carefully select electives to fulfill pre-veterinary requirements and the requirements of their chosen major. Additional biology, chemistry, or mathematics coursework, for example, can lead to majors in these areas.*

Pre-Engineering

Students who are undecided on the specific engineering program they would like to pursue may be declared pre-engineering students. During their freshman year they should select a specific program from UMD's chemical, electrical and computer, industrial, or mechanical engineering programs, or from UMD's pre-aerospace engineering or pre-civil engineering programs. Students selecting one of the pre-programs may transfer to the Institute of Technology (IT) on the Minneapolis campus or other baccalaureate degree-granting institutions at the end of their sophomore year to complete their studies in those engineering fields.

Students are encouraged to select their engineering program as early as possible because programs commonly share only mathematics, physics, and college writing courses in the first year. Other required courses, such as chemistry, computer programming, economics, and engineering graphics differ between engineering programs even in the first year. After selecting a specified field, students are assigned advisers with the appropriate background who can advise them to take the proper courses. Students should choose a field of engineering before the beginning of their sophomore year.

Recommended Lower Division Courses for Students Who Wish to Transfer to IT or Another University

The course recommendations below have been designed to closely match the lower division programs (i.e., the first two years) at the University's Institute of Technology (IT). Students who wish to transfer to another engineering school can, with the aid of their engineering adviser, plan a program fulfilling the basic requirements for the

first two years. Programs in engineering specialties at other schools normally do not differ markedly from those listed below; they usually concentrate on mathematics and the basic sciences.

Pre-Aerospace Engineering

CHEM 1151*—General Chemistry I (5 cr)
COMP 1120*—College Writing (3 cr)
CS 1131*—Introduction to Programming in FORTRAN (3 cr)
or CS 1511*—Computer Science I (5 cr)
ENGR 2015—Statics (3 cr)
ENGR 2016—Mechanics of Materials (3 cr)
ENGR 2026—Dynamics (3 cr)
MATH 1296*—Calculus I (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations With Linear Algebra (4 cr)
MATH 3298—Calculus III (4 cr)
ME 2105—Introduction to Material Science for Engineers (3 cr)
PHYS 2011*—General Physics I (4 cr)
PHYS 2012—General Physics II (4 cr)
PHYS 2021—Relativity and Quantum Physics (4 cr)
Liberal education courses that complete Minnesota Transfer Curriculum or meet requirements of transfer institution

Pre-Civil Engineering

CHEM 1151*—General Chemistry I (5 cr)
CHEM 1152—General Chemistry II (5 cr)
COMP 1120*—College Writing (3 cr)
ENGR 2015—Statics (3 cr)
ENGR 2016—Mechanics of Materials (3 cr)
ENGR 2026—Dynamics (3 cr)
MATH 1296*—Calculus I (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations With Linear Algebra (4 cr)
MATH 3298—Calculus III (4 cr)
PHYS 2011*—General Physics I (4 cr)
PHYS 2012—General Physics II (4 cr)
STAT 3611—Introduction to Probability and Statistics (4 cr)
Liberal education courses that complete Minnesota Transfer Curriculum or meet requirements of transfer institution

** Courses that may be used to fulfill UMD liberal education program requirements.*

Other Engineering Specialties

Consult the CSE Student Affairs Office, 140 Engineering Building.

Upper Division

Upon completion of lower division requirements, students must apply for admission to the upper division of the engineering program in which they are interested. A minimum cumulative GPA, determined by the department, is required in the lower division courses. Students from other colleges wishing to transfer into UMD engineering programs should have completed the equivalent lower division courses with the required cumulative GPA. The completed application is evaluated on the basis of GPA, curriculum completed, and space availability. Students transferring from Minnesota state community colleges should refer to the list of equivalent lower division courses for their college. This list is available from CSE or the community college engineering adviser. Courses in which a D has been earned at an institution other than the University cannot be used to meet the specified course requirements of the engineering degrees except when the D is earned in a sequence course and a C or better is earned in the following course.

Pre-Fisheries and Wildlife Management

This curriculum provides two years of study that fulfill many of the basic requirements for professional study in fisheries and wildlife management. UMD courses below are required for the fisheries and wildlife management degree and have equivalents in the Department of Fisheries, Wildlife, and Conservation Biology in the College of Food, Agricultural and Natural Resource Sciences (CFANS) on the St. Paul campus.

BIOL 1011*—General Biology I (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 2201—Genetics (3 cr)
BIOL 2801—General Ecology (3 cr)
CHEM 1151*—General Chemistry I (5 cr)
CHEM 1152—General Chemistry II (5 cr)
COMM 1112*—Public Speaking (3 cr)
COMP 1120*—College Writing (3 cr)
MATH 1296*—Calculus I (5 cr)
and MATH 1297—Calculus II (5 cr)
or MATH 1160*—Finite Mathematics and Introduction to Calculus (5 cr)
PHYS 1001*—Introduction to Physics I (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
STAT 2411—Statistical Methods (3 cr)
Liberal education courses that complete the Minnesota Transfer Curriculum or meet requirement of transfer institution.

** Courses that may be used to fulfill UMD liberal education program requirements.*

Degree Programs

Aerospace Studies Minor

Aerospace Studies

Required credits in this minor: 32 to 33

The Air Force Reserve Officer Training Corps (AFROTC) is a college-level educational program that gives students the opportunity to become Air Force officers while completing their degrees. Any student may enroll in aerospace studies courses. AFROTC offers post-collegiate opportunities in more than 100 career specialties. Air Force officers are challenged with organizational responsibilities and experiences not often available to new college graduates. This program is for students who want to challenge themselves as Air Force leaders and managers while serving their country in a professional, high-tech environment.

Active-duty Air Force officers provide a curriculum that gives students insight into the mission, organization, and operation of the U.S. Air Force. Students study Air Force history, leadership, management, professionalism, and U.S. foreign policy and its relationship to defense policy. Scholarships are available on a competitive basis. High school seniors and college students can compete for five-, four-, three-, two (and sometimes one-) year scholarships that cover tuition, fees, and book expenses. Participants may qualify to receive a tax-free allowance for each month in school.

The aerospace studies minor provides preparation in areas studied by most officers early in their service careers. The minor increases future officers' performance potential in two areas in which all officers must eventually develop competence: communication skills and international affairs.

Minor Requirements

Lower Division (10 cr)

AIR 100—AFROTC GMC Leadership Laboratory (0 cr)
AIR 1101—Foundations of the U.S. Air Force (1 cr)
AIR 1102—Foundations of the U.S. Air Force (1 cr)
AIR 2101—The Evolution of the U.S. Air Force Air and Space Power (1 cr)
AIR 2102—The Evolution of the U.S. Air Force Air and Space Power (1 cr)
COMM 1112—Public Speaking, LE CAT3 (3 cr)
or COMM 1222—Interpersonal Communication, LECD CAT3 (3 cr)
Course requiring mathematical reasoning

Upper Division (22-23 cr)

AIR 3000 - Leadership Lab (1 cr) must be taken four times.
AIR 3101—Air Force Leadership Studies (3 cr)
AIR 3102—Air Force Leadership Studies (3 cr)
AIR 4101—National Security Affairs, Preparation for Active Duty (3 cr)
AIR 4102—National Security Affairs, Preparation for Active Duty (3 cr)
Advanced or technical writing course
AIR 3000—AFROTC POC Leadership Laboratory (1 cr)

Electives

One of the following or an approved substitute:
Take 1 or more course(s) from the following:
GEOG 4393—Political Geography (4 cr)
POL 3xxx
HIST 2xxx
or HIST 3xxx

Astronomy Minor

Geological Sciences

Physics

Required credits in this minor: 34

The astronomy minor enhances students' understanding of the formation, structure, and evolution of the Universe while providing a sound foundation for professional programs in the sciences. The minor program covers a wide range of topics in general astronomy, comparative planetology, stellar dynamics, astrophysics, cosmology, and techniques of astronomical observation and analysis.

Minor Requirements

Astronomy Required Courses

AST 1040—Introductory Astronomy, LE CAT5 (3 cr)
AST 4110—Observational Astronomy (3 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
PHYS 2021—Relativity and Quantum Physics (4 cr)
PHYS 3561—Astrophysics (3 cr)
GEOL 2120—The Earth's Dynamic Interior (3 cr)
or AST 2040—The Solar System (3 cr)

Required Courses From Other Programs

MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)

Biochemistry and Molecular Biology B.S.

Chemistry and Biochemistry

Required credits to graduate with this degree: 120

Required credits within the major: 83

Biochemistry and molecular biology is the study of life at the molecular level. This field is both a life science and a chemical science, exploring the chemistry of living organisms and the molecular basis for the processes that occur in living cells. The Department of Chemistry and Biochemistry provides classroom and laboratory learning opportunities and research experiences across the discipline to meet the needs of students in engineering, liberal arts and preprofessional programs as well as those of students who wish to pursue careers or graduate studies in chemistry or related disciplines.

Honors Requirements: The Department of Chemistry and Biochemistry honors program helps outstanding biochemistry and molecular biology majors become competent, independent research workers, encourages student interest in the discipline, and aids in the transition from student to working scientist. Qualified majors may apply after the first semester of their sophomore year. Participants choose a research adviser and complete two semesters on a jointly developed project. Written reports and an oral presentation of the research are also required.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in biochemistry and molecular biology include:

- Liberal education requirements
- Advanced writing requirement: COMP 3xxx
- A minor from another area of study is required

Students who earn a B.S. in biochemistry and molecular biology (BMB) will have met the requirements for the B.A. in chemistry and for the chemistry minor. However, neither the BMB major/B.A. chemistry major combination nor the BMB major/chemistry minor combination satisfies the college degree requirement for a second major or minor. The B.S. BMB major/B.S. chemistry major combination does satisfy the college degree requirement.

Students earning a B.S. degree who wish to have their program certified by the American Chemical Society must take advanced courses that include additional hours of laboratory work

Year One

BIOL 1011—General Biology I, LE CAT4 (5 cr)

BIOL 1012—General Biology II (5 cr)

MATH 1296—Calculus I, LE CAT2 (5 cr)

MATH 1297—Calculus II (5 cr)

CHEM 1151—General Chemistry I, LE CAT4 (5 cr)

or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)

CHEM 1152—General Chemistry II (5 cr)

or CHEM 1162—Honors: General Chemistry II, H (5 cr)

Year Two

CHEM 2242—Analytical Chemistry Applied to Environmental Problems in Eastern Europe (4 cr) may be substituted for CHEM 2222—Quantitative Analysis (3 cr) and CHEM 2223—Quantitative Analysis Lab (1 cr)

BIOL 2101—Cell Biology (3 cr)

CHEM 2222—Quantitative Analysis (3 cr)

CHEM 2223—Quantitative Analysis Laboratory (1 cr)

CHEM 2521—Organic Chemistry I (4 cr)

CHEM 2522—Organic Chemistry II (4 cr)

PHYS 2011—General Physics I, LE CAT4 (4 cr)

PHYS 2012—General Physics II (4 cr)

Year Three

BIOL 2201—Genetics (3 cr)

BIOL 4231—Molecular Biology (3 cr)

BIOL 5232—Molecular Biology Laboratory (2 cr)

CHEM 4363—Biochemistry Laboratory (2 cr)

CHEM 4632—Physical Chemistry (4 cr)

CHEM 4633—Physical Chemistry Laboratory (1 cr)

CHEM 4351—Biochemistry I (3 cr)

CHEM 4352—Biochemistry II (3 cr)

Year Four

CHEM 4184—Undergraduate Seminar I (1 cr)

CHEM 4185—Undergraduate Seminar II (1 cr)

CHEM 4242—Instrumental Analysis (3 cr)

CHEM 4434—Inorganic Chemistry (4 cr)

Biology B.A.

Biology

Required credits to graduate with this degree: 120

Required credits within the major: 59 to 70

Biology has long been recognized as basic to environment, agriculture, and medicine. Because the topics studied by biologists range from subcellular particles to global environmental concerns, and because of the variety of living organisms and the various ways of studying them, many specialties have developed. The B.A. program is committed to the advancement of knowledge through scholarly research and other creative activities.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

Program Requirements

Requirements for the B.A. in biology include:

- Liberal education requirements
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3 cr)
- Major requirements (59–70 cr): 24 core biology credits, which include coursework in general biology, genetics, cell biology, ecology, evolution, and seminar; 17–28 credits of supporting courses in mathematics, statistics, and chemistry; 18 credits of biology electives at 2xxx or above to provide flexibility in pursuing personal interests or career preparation
- A minor or a second major from another area of study

Biology Core Courses

BIOL 1011—General Biology I, LE CAT4 (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 2101—Cell Biology (3 cr)
BIOL 2201—Genetics (3 cr)
BIOL 2801—General Ecology (3 cr)
BIOL 2802—Ecology Laboratory (2 cr)
BIOL 3997—Seminar I (0.5 cr)
BIOL 3998—Seminar II (0.5 cr)
BIOL 4801—Evolution (2 cr)

Chemistry

CHEM 1113—Introduction to General, Organic, and Biological Chemistry I, LE CAT4 (5 cr)
CHEM 1114—Introduction to General, Organic, and Biological Chemistry II (5 cr)
or take the following four courses:
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
CHEM 1152—General Chemistry II (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)
or take the following four courses:
CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1162—Honors: General Chemistry II, H (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)

Math—Option A or Option B

Choose math from Option A or B

Option A

MATH 1250—Precalculus Analysis, LE CAT2 (4 cr)
STAT 1411—Introduction to Statistics, LE CAT2 (3 cr)
or STAT 2411—Statistical Methods, LE CAT2 (3 cr)

or Option B

MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)
or MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
or STAT 1411—Introduction to Statistics, LE CAT2 (3 cr)
or STAT 2411—Statistical Methods, LE CAT2 (3 cr)
or STAT 3611—Introduction to Probability and Statistics (4 cr)

Biology Electives (18 cr) 2xxx–5xxx

These courses must include a minimum of two lab courses or courses with a lab component. Two of the following may be used: MICB 5545, PHSL 5601, PHSL 5602.

Biology B.S.

Biology

Required credits to graduate with this degree: 120

Required credits within the major: 76 to 81

The B.S. in biology offers preparation for graduate school and a sound basis for professional training in the biological and health sciences. Biology is an unusually broad field, and students can tailor their programs to fit their own needs and interests. To provide flexibility in pursuing personal interests or career preparation, the student chooses 18 credits of upper division biology electives.

The Department of Biology encourages students to develop as active scholars and to participate in undergraduate research. The B.S. degree is detailed and specific with a concentration in science related coursework.

Admission Requirements

For information about UMD admission requirements, visit the UMD Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal

Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in biology include:

- Liberal education requirements
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3 cr)
- A minor or second major from another area of study; the cell biology major may not be used to meet this requirement
- Exit interview

Biology Core Courses

BIOL 1011—General Biology I, LE CAT4 (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 2101—Cell Biology (3 cr)
BIOL 2201—Genetics (3 cr)
BIOL 2801—General Ecology (3 cr)
BIOL 2802—Ecology Laboratory (2 cr)
BIOL 3997—Seminar I (0.5 cr)
BIOL 3998—Seminar II (0.5 cr)
BIOL 4801—Evolution (2 cr)

Courses From Other Programs

CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1162—Honors: General Chemistry II, H (5 cr)
MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)
or MATH 1296—Calculus I, LE CAT2 (5 cr)
STAT 2411—Statistical Methods, LE CAT2 (3 cr)
or STAT 3611—Introduction to Probability and Statistics (4 cr)
or MATH 1297—Calculus II (5 cr)

Take one of the following course pairs:

PHYS 1001—Introduction to Physics I, LE CAT4 (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
or PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)

Biology Electives (18 cr) 2xxx–5xxx

These courses must include a minimum of two lab courses or courses with a lab component. At least one of the following ***must*** be taken: BIOL 3601, BIOL 3701, or BIOL 4501. Two credits of SSP may be applied as upper division elective. Two of the following may be used: MDBC 5501, MICB 5545, MICB 5555, PHSL 5601, PHSL 5602.

Biology Minor

Biology

Required credits in this minor: 44 to 55

Biology has long been recognized as basic to such important areas as environment, agriculture, and medicine.

Minor Requirements

Biology Minor Courses

BIOL 1011—General Biology I, LE CAT4 (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 2101—Cell Biology (3 cr)
BIOL 2201—Genetics (3 cr)
BIOL 2801—General Ecology (3 cr)
BIOL 4801—Evolution (2 cr)
May include two of the following: MICB 5545, MICB 5555, PHSL 5601, PHSL 5602
Take 6 or more credit(s) from the following:
BIOL 2xxx
BIOL 3xxx
BIOL 4xxx
BIOL 5xxx

Chemistry

CHEM 1113—Introduction to General, Organic, and Biological Chemistry I, LE CAT4 (5 cr)
CHEM 1114—Introduction to General, Organic, and Biological Chemistry II (5 cr)
or take the following four courses:
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
CHEM 1152—General Chemistry II (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)
or take the following four courses:
CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1162—Honors: General Chemistry II, H (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)

MATH—Take Option A or Option B

Option A

MATH 1250—Precalculus Analysis, LE CAT2 (4 cr)
STAT 1411—Introduction to Statistics, LE CAT2 (3 cr)
or STAT 2411—Statistical Methods, LE CAT2 (3 cr)

or Option B

MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)
or MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
or STAT 1411—Introduction to Statistics, LE CAT2 (3 cr)
or STAT 2411—Statistical Methods, LE CAT2 (3 cr)
or STAT 3611—Introduction to Probability and Statistics (4 cr)

Biochemical Engineering Minor

Chemical Engineering

Required credits in this minor: 46 to 48

Significant advances in the biological sciences and engineering have had a dramatic effect on the environmental, chemical, and healthcare industries. Chemical engineering programs have become more diversified to include curriculum in biochemical engineering. The biochemical engineering minor provides students with additional training in this growing field beyond their traditional coursework. Students will gain the basic knowledge of the biological sciences and design as applied to bioreactor engineering and downstream processing.

The influence of the biological sciences in all academic disciplines within the sciences and engineering continues to expand. Any student may pursue a minor in biochemical engineering.

Minor Requirements

Biochemical Engineering Courses

BIOL 1011—General Biology I, LE CAT4 (5 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)
CHE 2111—Material and Energy Balances (3 cr)
CHE 4601—Biochemical Engineering (3 cr)
CHE 4602—Bioseparations (3 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1162—Honors: General Chemistry II, H (5 cr)
CHEM 3322—Biochemistry (3 cr)
or CHEM 4341 {Inactive}
CHEM 3324—Biochemistry Laboratory (1 cr)
or CHEM 4363—Biochemistry Laboratory (2 cr)

Cell and Molecular Biology B.S.

Biology

Required credits to graduate with this degree: 120

Required credits within the major: 80 to 86

Cell and molecular biology are two of the most rapidly growing areas of modern biology. This major prepares students for graduate school and careers in cell biology, genetics, developmental biology, physiology, immunology, biotechnology, molecular biology and microbiology. The major is also appropriate for students considering professional schools of medicine, dentistry, pharmacy, and veterinary medicine.

The program is administered by the Department of Biology and involves faculty in both the College of Science and Engineering and the Medical School Duluth.

Honors Requirement: In the lower division, honors opportunities include seminars and special sections of lecture and lab courses. Students may participate in these by invitation or by consent of the instructor. Honors opportunities in the upper division are available for students in all departments. Department honors candidates are selected on the basis of coursework completed and potential for independent work. A research project is required.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in cell biology include:

- Liberal education requirements
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3 cr)
- A minor or second major from another area of study; biology may not be used to satisfy this requirement
- Exit interview

Biology Core Courses

BIOL 1011—General Biology I, LE CAT4 (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 2101—Cell Biology (3 cr)
BIOL 2102—Cell Biology Laboratory (2 cr)
BIOL 2201—Genetics (3 cr)
BIOL 3703—Animal Physiology (3 cr)
BIOL 3997—Seminar I (0.5 cr)
BIOL 3998—Seminar II (0.5 cr)
BIOL 4231—Molecular Biology (3 cr)
BIOL 5232—Molecular Biology Laboratory (2 cr)
BIOL 4361—Developmental Biology (3 cr)
BIOL 4501—General Microbiology (4 cr)
BIOL 4801—Evolution (2 cr)

Courses From Other Programs

CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)

CHEM 3322—Biochemistry (3 cr)
CHEM 3324—Biochemistry Laboratory (1 cr)
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1162—Honors: General Chemistry II, H (5 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
or MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)
STAT 2411—Statistical Methods, LE CAT2 (3 cr)
or STAT 3611—Introduction to Probability and Statistics (4 cr)
Take one of the following course pairs:
PHYS 1001—Introduction to Physics I, LE CAT4 (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
or PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)

Electives

SSP 3002-max 2 cr may be applied to major (only for TA in genetics or cell biology).
Take 5 or more credit(s) from the following:
BIOL 2202—Genetics Laboratory (2 cr)
BIOL 2801—General Ecology (3 cr)
BIOL 3990—Special Topics: (Various Titles to be Assigned) (1–5 cr)
BIOL 3994—Undergraduate Research (1–3 cr)
BIOL 4199—Frontiers in Cell Biology (2 cr)
BIOL 4603—Plant Physiology (3 cr)
BIOL 5233—Genomics (3 cr)
BIOL 5235—Biotechnology (4 cr)
BIOL 5240—Ecological Genetics (3 cr)
BIOL 5365—Developmental Physiology (2 cr)
BIOL 5511—Virology (3 cr)
BIOL 5513—Experimental Immunology (4 cr)
BIOL 5603—Plant Physiology Laboratory (2 cr)
BIOL 5760—The Physiology of Fishes (3 cr)
BIOL 5772—Mechanisms of Neural Behavior (3 cr)
BIOL 5801—Microbial Ecology (2 cr)
BIOL 5802—Microbial Ecology Laboratory (2 cr)
BIOL 5868—Ecotoxicology (3 cr)
BIOL 5990—Special Topics: (Various Titles to be Assigned) (1–5 cr)
MATH 5233—Mathematical Foundations of Bioinformatics (3 cr)
MDBC 5501—Neurobiochemistry (2 cr)
MICB 5545—Immunobiology (3 cr)
MICB 5555—Molecular Pathogenesis: Current Concepts (3 cr)
PHSL 5601—Physiology of Organ Systems I (4 cr)
PHSL 5602—Physiology of Organ Systems II (2 cr)
SSP 3002—SSP Teaching Assistantship Practicum (1–3 cr)

Chemical Engineering B.S.Ch.E.

Chemical Engineering

Required credits to graduate with this degree: 130

Required credits within the major: 105

The mission of the Department of Chemical Engineering at the University of Minnesota Duluth is to offer students a high quality educational experience that includes engineering theory, application, experimentation, and design. The department is dedicated to achieving recognition for excellence in engineering education through continuously improving its program, adding to the body of knowledge through research, providing an environment for professional development, and serving the profession.

Program Educational Objectives are statements that describe the expected accomplishments of graduates during the first few years after graduation. The Chemical Engineering program's educational objectives are to produce graduates who

1. are able to apply theoretical and practical knowledge of engineering in the workplace,
2. possess the ability to communicate effectively with technical and non-technical users of technology,
3. are prepared to engage in advanced or additional education in their chosen field of endeavor or interest, and
4. recognize that the broader aspects of engineering practices include economic, environmental, social, political and professional constraints.

This four-year baccalaureate (B.S.Ch.E.) degree program emphasizes the development of the student's ability to analyze and design chemical processing systems. By the end of the program, the student must demonstrate the ability to solve engineering problems, a sensitivity to the social and environmental impacts of the engineering profession, and the ability to maintain a high level of competency.

Chemical engineering graduates are qualified for employment in diverse industries, ranging from those that manufacture inorganic chemicals, petrochemicals, plastics, synthetic fibers, paper and pulp, and pharmaceuticals to those that process hazardous and nuclear wastes. Graduates are qualified for assignments that include plant operations, process development, process control, project engineering, or sales, and frequently pursue engineering management later in their careers. They are also well qualified to continue with professional or graduate education.

The chemical engineering curriculum is based on fundamental sciences such as physics, chemistry, and mathematics; engineering sciences such as

statics and deformable body mechanics of materials; traditional chemical engineering sciences such as material and energy balance, transport phenomena, and thermodynamics; and chemical engineering design courses, with a capstone plant design course during the senior year. Students have a unique opportunity to become involved in research, through either the Undergraduate Research Opportunities Program or the department honors program.

Honors Requirement: To graduate with department honors, students must have a minimum 3.50 GPA and be nominated by the chemical engineering faculty.

Admission Requirements

Students may declare a chemical engineering major as freshmen or sophomores.

Students must complete the program's lower division before applying to upper division (junior and senior years).

Admission is competitive and applicants are admitted on a space-available basis, determined by the cumulative GPA in composition, physics, mathematics, engineering statics, and chemistry through CHEM 2521.

Transfer students should refer to the pre-engineering junior-level admission (upper division) requirements in the pre-professional programs. Students must complete the upper division courses to complete the degree. See the CSE section of the UMD online catalog.

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S.Ch.E include:

- Liberal education requirements: 1 from each category 6-10 except where an option is provided for category 10, another course from category 9 may be taken
- Successful completion of ChE 2111 (with a grade of C+ or better) required for admission to upper division
- Advanced writing requirement: COMP 31xx or COMP 5220 or COMP 5230 (3 cr)
- Completion at UMD of at least 20 of the last 30 degree credits immediately before graduation
- A 2.00 minimum GPA in all work attempted at UMD; a 2.00 minimum GPA in all work, including transfer credits; and successful completion of 75 percent of all work attempted
- A 2.00 minimum GPA in all courses taken in the chemical engineering major, including required courses in related fields. This GPA requirement applies to all courses in the major taken at UMD calculated separately and also to all courses in the major when transfer credits are included.

Year One

First math course is determined by math placement exam. This schedule presupposes placement into MATH 1296.
CHE 3xxx elective subject to department approval.
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
CHE 1011—Introduction to Chemical Engineering., LE CAT5 (3 cr)
or CHE 2001—Introduction to Environmental Engineering, LE CAT4 (3 cr)
or CHE 3xxx
or CHE 4xxx
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1162—Honors: General Chemistry II, H (5 cr)
Take 1 or more course(s) totaling 2 or more credit(s) from the following:
CS 1121—Introduction to Programming in Visual BASIC. NET, LE CAT3 (3 cr)
CS 1131—Introduction to Programming in FORTRAN, LE CAT3 (3 cr)
CS 1135—Introduction to Programming in FORTRAN 90, LE CAT3 (2 cr)
CS 1511—Computer Science I, LE CAT3 (5 cr)
CS 2121—Introduction to Programming in Java, LE CAT3 (3 cr)

Year Two

CHE 2011—Design of Engineering Experiments (3 cr)
CHE 2111—Material and Energy Balances (3 cr)
CHE 2121—Chemical Engineering Thermodynamics (3 cr)
CHEM 2521—Organic Chemistry I (4 cr)
ENGR 2015—Statics (3 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
PHYS 2012—General Physics II (4 cr)
Take all of the following in the same term:
CHEM 2222—Quantitative Analysis (3 cr)
CHEM 2223—Quantitative Analysis Laboratory (1 cr)

Year Three

CHE 3031—Computational Methods in Chemical Engineering (3 cr)

CHE 3112—Heat and Mass Transfer (3 cr)

CHE 3211—Chemical Engineering Laboratory I (3 cr)

CHE 3231—Properties of Engineering Materials (3 cr)

CHE 3241—Principles of Particle Technology (3 cr)

COMP 31xx or COMP 5220 or COMP 5230

CHE 3111—Fluid Mechanics (3 cr)

or ME 3111—Fluid Mechanics (3 cr)

CHE 4xxx–5xxx—Upper Division Requirements

Take 3 or more credit(s) from the following:

CHE 4xxx

CHE 5xxx

CHEM 252x–5xxx—Upper Division Requirements

Electives 252x or above; may not be satisfied with CHEM 3184 or CHEM 4632.

Take 8 or more credit(s) from the following:

CHEM 2xxx

CHEM 3xxx

CHEM 4xxx

CHEM 5xxx

SCI-ENGR 3xxx—Upper Division Requirements (3 cr)

Advanced science or engineering elective: 3xxx or higher course in the College of Science and Engineering.

Year Four

CHE 4111—Separations (3 cr)

CHE 4211—Chemical Engineering Laboratory II (3 cr)

CHE 4301—Chemical Reaction Engineering (3 cr)

CHE 4402—Process Dynamics and Control (3 cr)

CHE 4501—Chemical Engineering Design I (4 cr)

CHE 4502—Chemical Engineering Design II (4 cr)

Chemistry B.A.

Chemistry and Biochemistry

Required credits to graduate with this degree: 120

Required credits within the major: 53 to 55

Chemistry is the study of matter and the physical changes that matter undergoes. Chemical reactions occur every day and in every aspect of life: respiration, metabolism and growth in living systems, combustion in cars and heating plants, pharmaceutical and polymer production, and the conversion of raw materials to usable products.

Chemistry is an important subject for students who are interested in health sciences such as medicine, pharmacy, dentistry, and related fields need to take several semesters of chemistry. Students who like scientific and technical subjects, and who have a solid math and science background from high school are best prepared to major in chemistry.

Students completing the B.A. in chemistry generally plan to use chemistry as a study field that complements areas such as law, library science, technical writing, public relations, or sales. B.A. students are encouraged to participate in undergraduate research.

Honors Requirement: Qualified majors may apply after the first semester of their sophomore year. Participants choose a research adviser and complete two semesters of effort on a jointly developed project. Written reports and an oral presentation of the research are also required.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.A. in chemistry include:

- Liberal education requirements
- Advanced writing requirement: COMP 31xx
- Minor or second major from another area of study

First Year

First math course is determined by math placement exam; this list presupposed placement in MATH 1296 as the first course.

MATH 1296—Calculus I, LE CAT2 (5 cr)

MATH 1297—Calculus II (5 cr)

CHEM 1151—General Chemistry I, LE CAT4 (5 cr)

or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)

CHEM 1152—General Chemistry II (5 cr)

or CHEM 1162—Honors: General Chemistry II, H (5 cr)

Second Year

CHEM 2242—Analytical Chemistry Applied to Environmental Problems in Eastern Europe (4 cr) may be substituted for Chem 2222—Quantitative Analysis (3 cr) and Chem 2223—Quantitative Analysis (1 cr)

CHEM 2222—Quantitative Analysis (3 cr)

CHEM 2223—Quantitative Analysis Laboratory (1 cr)

CHEM 2521—Organic Chemistry I (4 cr)

CHEM 2522—Organic Chemistry II (4 cr)

Take one of the following course pairs (PHYS 2011 and 2012 are strongly encouraged):
PHYS 1001—Introduction to Physics I, LE CAT4 (5 cr)
PHYS 1002—Introduction to Physics II (5 cr)
or PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)

Third Year
CHEM 3322—Biochemistry (3 cr)
CHEM 3324—Biochemistry Laboratory (1 cr)
CHEM 4632—Physical Chemistry (4 cr)
CHEM 4633—Physical Chemistry Laboratory (1 cr)

Fourth Year
CHEM 4434—Inorganic Chemistry (4 cr)

Chemistry B.S.

Chemistry and Biochemistry

Required credits to graduate with this degree: 120

Required credits within the major: 69

Chemistry is a body of knowledge that helps explain the physical world and its processes. Chemists study substances—their composition, structures, properties, and reactions.

The Department of Chemistry and Biochemistry provides classroom and laboratory learning opportunities and research experiences across the discipline designed to meet the needs of students in liberal arts and preprofessional programs as well as those who wish to pursue careers in the field.

Honors Requirement: The Department of Chemistry and Biochemistry honors program helps outstanding chemistry majors develop into competent, independent research workers, encourages student interest in the discipline, and aids in the transition from student to working scientist. Qualified majors may apply after the first semester of their sophomore year. Participants choose a research adviser and complete two semesters on a jointly developed project. Written reports and an oral presentation of the research are also required.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in chemistry include:

- Liberal education requirement
- Advanced writing requirement: COMP 3xxx
- A minor from another area of study

The B.S. Chemistry major/B.S. BMB major combination satisfies the college degree requirement for a second major or minor

Students earning a B.S. degree who wish to have their program certified by the American Chemical Society must take advanced courses that include additional hours of laboratory work

Year One
High school algebra and high school chemistry are required for CHEM 1151 and CHEM 1161. First math course is determined by math placement exam. This schedule presupposed placement into MATH 1296.
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1162—Honors: General Chemistry II, H (5 cr)

Year Two
CHEM 2242—Analytical Chemistry Applied to Environmental Problems in Eastern Europe (4 cr) may be used as a substitution for CHEM 2222—Quantitative Analysis (3 cr) and CHEM 2223—Quantitative Analysis Lab (1 cr)
CHEM 2222—Quantitative Analysis (3 cr)
CHEM 2223—Quantitative Analysis Laboratory (1 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2532—Organic Chemistry II for B.S. Chemistry Majors (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)

Year Three
CHEM 3322—Biochemistry (3 cr)
CHEM 3324—Biochemistry Laboratory (1 cr)
CHEM 4641—Physical Chemistry I (3 cr)
CHEM 4642—Physical Chemistry II (3 cr)
CHEM 4643—Physical Chemistry Laboratory I (1 cr)
CHEM 4644—Physical Chemistry Laboratory II (1 cr)

Year Four
CHEM 4184—Undergraduate Seminar I (1 cr)
CHEM 4185—Undergraduate Seminar II (1 cr)
CHEM 4242—Instrumental Analysis (3 cr)
CHEM 4243—Instrumental Chemistry Laboratory (2 cr)
CHEM 4434—Inorganic Chemistry (4 cr)
CHEM 4435—Inorganic Chemistry Laboratory (1 cr)

Chemistry Minor

Chemistry and Biochemistry

Required credits in this minor: 29 to 31

Chemistry is a body of knowledge that helps explain the physical world and its processes.

Minor Requirements

Chemistry Minor Courses

CHEM 2242—Analytic Chemistry Applied to Environmental Problems in Eastern Europe (4 cr) may be used as a substitute for CHEM 2222—Quantitative Analysis (3 cr) and CHEM 2223—Quantitative Analysis Lab (1 cr).

CHEM 2521—Organic Chemistry I (4 cr)

CHEM 2522—Organic Chemistry II (4 cr)

CHEM 1151—General Chemistry I, LE CAT4 (5 cr)

or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)

CHEM 1152—General Chemistry II (5 cr)

or CHEM 1162—Honors: General Chemistry II, H (5 cr)

Take the following course or course pair:

CHEM 2212—Environmental Chemistry (4 cr)

or CHEM 2222—Quantitative Analysis (3 cr)

CHEM 2223—Quantitative Analysis Laboratory (1 cr)

Take exactly 1 course(s) from the following:

CHEM 3322—Biochemistry (3 cr)

CHEM 4632—Physical Chemistry (4 cr)

CHEM 4641—Physical Chemistry I (3 cr)

Take exactly 1 course(s) from the following:

MATH 1250—Precalculus Analysis, LE CAT2 (4 cr)

MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)

MATH 1296—Calculus I, LE CAT2 (5 cr)

Computer Information Systems B.S.

Computer Science

Required credits to graduate with this degree: 120

Required credits within the major: 78

Professionals in the field of information systems work with information technology and must have sound technical knowledge of computers, software, and communications. Since they operate within an organizational framework, they must also understand business and business functions. The B.S. in computer information systems is a four-year program that includes formal courses in information technology (including system architecture, operating systems, interactive multimedia computing, and networking), management information systems, project organization and management, and business organizational functions. The program also includes supporting courses in communications, mathematics and statistics, and the economic, social, and ethical implications of computing. Goals of the learning process include the development of good software development and communication skills and the ability to work effectively in team environments. This program provides both the necessary foundational studies for students seeking entry-level positions in information systems and a strong basis for continued career growth.

This program is appropriate for students seeking a professional career in the computer information systems field. It is a multidisciplinary program that emphasizes the study of systems development methodology and technology for our rapidly changing information society.

Graduates are prepared for positions in the design and development of information systems as project managers, information systems center specialists, network administrators, and database administrators. This major is also appropriate preparation for information systems graduate programs or MBA professional programs.

Admission Requirements

For information about UMD admission requirements, visit the UMD Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in computer information systems include:

- Liberal education requirements
- Advanced writing requirement: COMP 3121—Advanced Writing: Business and Organization or COMP 3130—Advanced Writing: Engineering or COMP 3150—Advanced Writing: Science (3)
- Minor in business administration
- Exit interview before graduation

Computer Information Systems Core Courses

CS 1521—Computer Science II (5 cr)

CS 2511—Software Analysis and Design (4 cr)

CS 3011—Information Technology Hardware and Software (4 cr)

FMIS 2201—Information Technology in Business (3 cr)

CS 1511—Computer Science I, LE CAT3 (5 cr)

or CS 1581—Honors: Computer Science I, LE CAT3, H (5 cr)

Advanced Courses

CS 3111—Computer Ethics (4 cr)

CS 3121—Interactive Multimedia Technology (4 cr)

CS 3211—Database System Concepts (4 cr)

CS 3221—Operating Systems Practicum (4 cr)

CS 4411—Data Communications and Network Technology (4 cr)

CS 4531—Software Engineering (4 cr)

Additional Requirements

Additional requirements also include completing a business administration minor for non-LSBE students.

COMM 1112—Public Speaking, LE CAT3 (3 cr)

MATH 1296—Calculus I, LE CAT2 (5 cr)

STAT 3611—Introduction to Probability and Statistics (4 cr)

21 credits of electives in the humanities, social sciences, and the arts

Exit interview before graduation

Computer Information Systems Minor

Computer Science

Required credits in this minor: 29

The computer information systems minor is not available to computer science majors.

Minor Requirements

Core Courses

CS 1511—Computer Science I, LE CAT3 (5 cr)

CS 1521—Computer Science II (5 cr)

CS 2511—Software Analysis and Design (4 cr)

CS 3011—Information Technology Hardware and Software (4 cr)

LSBE 1101—The Business Environment, LE CAT8 (3 cr)

or FMIS 2201—Information Technology in Business (3 cr)

Electives

Take 2 or more course(s) totaling no more than 8 credit(s) from the following:

CS 3121—Interactive Multimedia Technology (4 cr)

CS 3211—Database System Concepts (4 cr)

CS 3221—Operating Systems Practicum (4 cr)

CS 4411—Data Communications and Network Technology (4 cr)

CS 4531—Software Engineering (4 cr)

Computer Science B.S.

Computer Science

Required credits to graduate with this degree: 120

Required credits within the major: 105 to 108

Computer science is a discipline that requires understanding the design of computers and computational processes. The B.S. in computer science is an accredited, four-year program that provides a solid foundation in mathematics and statistics, computational problem solving, software design and analysis, programming languages, algorithms, data structures, and computer organization and architecture. The program also requires that students acquire significant knowledge in several subdisciplines of computer science, thus enabling them to apply and situate their knowledge of computer science fundamentals. Goals of the learning process include highly developed programming skills, an understanding of the context in which computing activities occur, and an ability to communicate effectively. The program provides the necessary foundational studies for students preparing for graduate school as well as those seeking careers in industry.

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

Honors Requirement: Program candidates submit an application to the department honors committee. Participants must maintain a 3.00 cumulative GPA and a 3.30 GPA in the major and complete an honors research project supervised by a faculty member; credit for the project can be earned in CS 4994—Honors Project.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in computer science include:

- Liberal education requirements
- Advanced writing requirement: COMP 3130 or 3150

- Senior survey, contact the computer science office for details.
- A minor or a second major from another department

Computer science majors *may not* minor in mathematics

Core Courses

CS 1521—Computer Science II (5 cr)
CS 2511—Software Analysis and Design (4 cr)
CS 2521—Computer Organization and Architecture (4 cr)
ECE 1315—Digital System Design (4 cr)
CS 1511—Computer Science I, LE CAT3 (5 cr)
or CS 1581—Honors: Computer Science I, H (5 cr)

Advanced Courses

CS 3111—Computer Ethics (4 cr)
CS 3512—Computer Science Theory (4 cr)
CS 5631—Operating Systems (4 cr)
CS 5621—Computer Architecture (4 cr)
or CS 5651—Computer Networks (4 cr)

Advanced Course Electives (Breadth)

Three additional advanced course electives, including at least one breadth course: CS 5621 or CS 5651 must be taken for this major. If both courses are taken, the second course fulfills the requirement of one additional breadth course.

Take 1 or more course(s) from the following:

CS 4511—Computability and Complexity (4 cr)
CS 4521—Algorithms and Data Structures (4 cr)
CS 4531—Software Engineering (4 cr)
CS 4611—Database Management Systems (4 cr)
CS 5541—Artificial Intelligence (4 cr)
CS 5551—User Interface Design (4 cr)
CS 5621—Computer Architecture (4 cr)
CS 5641—Compiler Design (4 cr)
CS 5651—Computer Networks (4 cr)

Advanced Course Electives (Other)

Take 0 - 2 course(s) from the following:

CS 4821—Computer Security (4 cr)
CS 5721—Computer Graphics (4 cr)
CS 5741—Object-Oriented Design (4 cr)
CS 5751—Introduction to Machine Learning (4 cr)
CS 5761—Introduction to Natural Language Processing (4 cr)
CS 5831—Information and Text Processing (4 cr)

Courses From Other Programs

COMM 1112—Public Speaking, LE CAT3 (3 cr)
COMP 1120—College Writing, LE CAT1 (3 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 2326—Introduction to Linear Algebra and Mathematical Reasoning (3 cr)
STAT 3611—Introduction to Probability and Statistics (4 cr)
COMP 3130—Advanced Writing: Engineering (3 cr)
or COMP 3150—Advanced Writing: Science (3 cr)

Lab Science Sequences

Complete one of the following lab science sequences:

BIOL 1011—General Biology I, LE CAT4 (5 cr)
BIOL 1012—General Biology II (5 cr)
or CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1162—Honors: General Chemistry II, H (5 cr)
or GEOL 1110—Geology and Earth Systems, LE CAT4 (4 cr)
GEOL 2311—Mineralogy (4 cr)
GEOL 2312—Petrology (4 cr)
or PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)

Electives From Other Programs (25 cr)

Additional approved courses from physics, chemistry, biology, astronomy and geology (4 cr). The total number of credits for the additional science course and the science sequence must be at least 12 credits.

Additional science course that is either in category 4 of the liberal education program or has a category 4 prerequisite.

21 credits of electives in the humanities, social sciences, and arts.

Computer Science Minor

Computer Science

Required credits in this minor: 30

Computer science is a discipline that requires understanding the design of computers and computational processes.

Minor Requirements

Minor Courses

CS 1521—Computer Science II (5 cr)
CS 2511—Software Analysis and Design (4 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
CS 1511—Computer Science I, LE CAT3 (5 cr)
or CS 1581—Honors: Computer Science I, H (5 cr)

Electives

CS courses must be at 35xx or above.

Take 11 or more credit(s) from the following:

CS 3xxx
CS 4xxx
CS 5xxx
ECE 3341—Digital Computer Circuits (4 cr)
ECE 4305—Computer Architecture (4 cr)
CS 2521—Computer Organization and Architecture (4 cr)
or ECE 2325—Microcomputer System Design (4 cr)

Computer Science Applied Minor

Computer Science

Required credits in this minor: 27

The computer science applied minor provides a thorough introduction to the use of computers as tools and complements studies in other disciplines.

The computer science minor and computer science applied minor are not available to computer information systems technology majors.

Minor Requirements

Minor Courses

CS 1521—Computer Science II (5 cr)

CS 2511—Software Analysis and Design (4 cr)

CS 1511—Computer Science I, LE CAT3 (5 cr)

or CS 1581—Honors: Computer Science I, H (5 cr)

Electives (13 cr)

6 credits of approved electives from computer science or other departments with a significant computing component

CS 2xxx—5xxx

Take 7 or more credit(s) from the following:

CS 2xxx

CS 3xxx

CS 4xxx

CS 5xxx

Electrical and Computer Engineering B.S.E.C.E.

Electrical and Computer Engineering

Required credits to graduate with this degree: 128

Required credits within the major: 52

The mission of the Department of Electrical and Computer Engineering (ECE) is to provide a high quality educational opportunity in electrical and computer engineering for students in the region by delivering a program with a strong hands-on laboratory and design component in conjunction with a thorough foundation in theory and to provide students with the tools and skills to be lifelong major contributors to their profession and society as a whole. The B.S.E.C.E. program combines traditional electrical engineering topics with current computer design and analysis topics. The program is concerned with the theory, design, and application of electrical phenomena and digital computers, including electronic circuits, signal analysis, system design, and computer architecture. The department displays strengths in such diverse areas as electronics, signal processing, electromagnetics, digital computer systems, communications, and controls. Faculty specialize in areas such as VLSI design, microprocessor systems, image processing, robust control, solid state devices, robotics, instrumentation, neural networks, and fuzzy logic. ECE balances theoretical and practical experience in electrical and computer engineering through analysis, synthesis, and experimentation, using facilities that include ten major instructional labs and three research labs.

Electrical and computer engineering program educational objectives:

1. Provide a high quality educational opportunity in electrical and computer engineering for students in the region.
2. Prepare students for a successful career in industry, academia, or government by learning the substance and methods of the electrical and computer engineering discipline, including technical, critical thinking, and communication skills.
3. Provide the opportunity for students to fully participate in the liberal education mission of the University.
4. Foster significant scholarly research for faculty and students.
5. Serve the well-being of the community, state, and region through the multifaceted efforts of UMD faculty and graduates.
6. Develop a foundation for lifelong learning.

Honors Requirement: Student with an overall GPA of 3.50 may apply for department honors upon graduating. Contact department for additional information.

Admission Requirements

Students who enter the electrical and computer engineering program as freshmen must follow the lower division program.

Students should complete the lower division ECE program before applying to the upper division program. Admission is competitive and on a space-available basis. A minimum GPA of 2.00 is required for admission to the upper division program. See department for details.

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

Lower Division (22 cr)

ECE 1001—Introduction to Electrical and Computer Engineering (2 cr)

ECE 1315—Digital System Design (4 cr)

ECE 2006—Electrical Circuit Analysis (4 cr)

ECE 2111—Linear Systems and Signal Analysis (4 cr)

ECE 2212—Electronics I (4 cr)

ECE 2325—Microcomputer System Design (4 cr)

Lower Division From Other Programs (40 cr)
First math course is determined by math placement exam. This schedule presupposes placement into MATH 1296.
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
COMP 1120—College Writing, LE CAT1 (3 cr)
CS 1511—Computer Science I, LE CAT3 (5 cr)
CS 1521—Computer Science II (5 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S.E.C.E. in electrical and computer engineering include:

- Liberal education requirements:
  - ECON 1022 or ECON 1023 from Category 6
  - At least one course from Category 7
  - PHIL 3242 from Category 8
  - At least one course from Category 9
  - At lease one course from Category 10, or second course from Category 9 with a different course designator (Note that one "course" in liberal education is defined as at least 2 credits with the same course designator)
  - At least one course emphasizing international perspective
  - At least one course emphasizing cultural diversity
  - Advanced writing requirement: COMP 3130

Completion of the ECE program as outlined satisfies the requirements for a computer science minor

ECE majors must meet with their advisers each semester. See department for details.

- Completion of the ECE "Exit Survey;" and a one-to-one exit interview with the ECE department head
- Completion of at least 30 degree credits at UMD
- Completion at UMD of at least 20 of the last 30 degree credits immediately before graduation
- A minimum GPA of 2.00 in all courses taken in the major, including required courses in related fields.
- ***Final Project:*** Completion of a capstone team design project integrating the knowledge from their academic career. Project must involve the design of hardware or software to meet specifications agreed upon by the student and the faculty project adviser. Oral and written reports are required.

Upper Division (30 cr)
ECE 3151—Control Systems (3 cr)
ECE 3235—Electronics II (4 cr)
ECE 3341—Digital Computer Circuits (4 cr)
ECE 3445—Electromagnetic Fields (3 cr)
ECE 3611—Introduction to Solid-State Semiconductors (3 cr)
ECE 4951—ECE Design Workshop (4 cr)
or ECE 4899—Senior Design Project I (1 cr)
ECE 4999—Senior Design Project II (3 cr)

ECE Technical Electives
NOT including 4899, 4951, 4991, 4999
Take 9 or more credit(s) from the following:
ECE 4xxx
ECE 5xxx
MUST include at least one of the following
Take 1 or more course(s) from the following:
ECE 4305—Computer Architecture (4 cr)
ECE 5315—Multiprocessor-Based System Design (3 cr)

Upper Division From Other Programs (36)
COMP 3130—Advanced Writing: Engineering (3 cr)
CS 2511—Software Analysis and Design (4 cr)
CS 5631—Operating Systems (4 cr)
ENGR 2015—Statics (3 cr)
MATH 3298—Calculus III (4 cr)
PHIL 3242—Values and Technology, LE CAT8 (3 cr)
STAT 3611—Introduction to Probability and Statistics (4 cr)
Liberal education electives in categories 7, 9, 10 (8 cr)
ECON 1023—Principles of Economics: Micro, LE CAT6 (3 cr)
or ECON 1022—Principles of Economics: Macro, LE CAT6 (3 cr)

Electrical and Computer Engineering Minor

Electrical and Computer Engineering

Required credits in this minor: 42

The electrical and computer engineering minor provides a complete introduction to both analog circuit design and digital computer circuit design and analysis.

Minor Requirements

Lower Division

For computer science majors: CS 2521 may be substituted for ECE 2325

ECE 1315—Digital System Design (4 cr)

ECE 2006—Electrical Circuit Analysis (4 cr)

ECE 2111—Linear Systems and Signal Analysis (4 cr)

ECE 2212—Electronics I (4 cr)

ECE 2325—Microcomputer System Design (4 cr)

MATH 1296—Calculus I, LE CAT2 (5 cr)

MATH 1297—Calculus II (5 cr)

PHYS 2011—General Physics I, LE CAT4 (4 cr)

PHYS 2012—General Physics II (4 cr)

Upper Division

MATH 3280—Differential Equations with Linear Algebra (4 cr)

Environmental Engineering Minor

Chemical Engineering

Required credits in this minor: 46 to 47

The environmental engineering minor develops a student's ability to understand and address environmental concerns. Coursework provides broad-based science and engineering knowledge suited to pollution prevention and waste management. The minor enhances degrees in science or other engineering fields.

Minor Requirements

Lower Division (40–41 cr)

CHE 2111—Material and Energy Balances (3 cr)

CHEM 2222—Quantitative Analysis (3 cr)

CHEM 2223—Quantitative Analysis Laboratory (1 cr)

ENGR 2015—Statics (3 cr)

MATH 1296—Calculus I, LE CAT2 (5 cr)

MATH 1297—Calculus II (5 cr)

PHYS 2011—General Physics I, LE CAT4 (4 cr)

CHE 1011—Introduction to Chemical Engineering., LE CAT5 (3 cr)

or CHE 2001—Introduction to Environmental Engineering, LE CAT4 (3 cr)

CHEM 1151—General Chemistry I, LE CAT4 (5 cr)

or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)

CHEM 1152—General Chemistry II (5 cr)

or CHEM 1162—Honors: General Chemistry II, H (5 cr)

Take exactly 1 course(s) from the following:

CHE 2011—Design of Engineering Experiments (3 cr)

STAT 2411—Statistical Methods, LE CAT2 (3 cr)

STAT 3611—Introduction to Probability and Statistics (4 cr)

Upper Division (6 cr)

Other upper division electives may be substituted subject to department approval.

CHE 4601—Biochemical Engineering (3 cr)

CHE 4612—Hazardous Waste Processing Engineering (3 cr)

CHE 4613—Air Pollution Control (3 cr)

Environmental Science B.S.

College of Science and Engineering - Adm

Required credits to graduate with this degree: 120

Required credits within the major: 98 to 102

The B.S. in environmental science is designed for students that want a multidisciplinary science education focusing on aspects of the environment. This environmental science program requires a broad base of knowledge in the basic sciences and mathematics, physics, chemistry, biology, Earth sciences, and statistics. In addition, prudent study of environmental science requires understanding of economic, political, and ethical considerations. Environmental science features an intense grounding in resource issues (including courses in renewable and non-renewable resources) and builds on the strength of UMD in freshwater issues. In addition, the capstone course deals with sources, distribution, and ultimate fate of air, water, and solid waste pollution. Elective courses from areas, such as habitats, climate processes, environmental chemistry, quantitative methods, and global resources are also required.

The program is predicated on the belief that a student graduating with a B.S. in environmental science should have a firm background in physical and life sciences and a basic understanding of (1) existing environmental policies and regulations and the legislative process of their formation; (2) the major environmental issues including water, global climate, energy, pollution, and population; (3) techniques of environmental monitoring and prediction; and (4) economics and business organization.

Admission Requirements

For entering freshmen, the only admission requirement is acceptance into the College of Science and Engineering. Transfer students must meet campus and college requirements and are

accepted into the program at the level corresponding to credits completed, based on existing transfer manuals and on faculty judgment when courses are not in existing manuals.

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in environmental science include:

- Liberal education requirements.
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3 cr)

A minor is not required

Required Environmental Science Core (24 cr)

GEOL 1110—Geology and Earth Systems, LE CAT4 (4 cr)
ESCI 2210—Science and Management of Environmental Systems (4 cr)
ESCI 3101—Nonrenewable Resources (4 cr)
ESCI 3102—Renewable Resources (4 cr)
ESCI 4101—Pollution and Technology (4 cr)
ESCI 4102—Environmental Assessment (4 cr)

Required Courses From Other Programs (56–57 cr)

BIOL 1011—General Biology I, LE CAT4 (5 cr)
BIOL 1012—General Biology II (5 cr)
BIOL 2801—General Ecology (3 cr)
BIOL 2802—Ecology Laboratory (2 cr)
CHEM 2212—Environmental Chemistry (4 cr)
ECON 1023—Principles of Economics: Micro, LE CAT6 (3 cr)
MATH 1297—Calculus II (5 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1162—Honors: General Chemistry II, H (5 cr)
GEOL 3100—Earth's Climate and Environment: Past and Future (3 cr)
or GEOG 3401—Weather and Climate (3 cr)
MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)
or MATH 1296—Calculus I, LE CAT2 (5 cr)
STAT 2411—Statistical Methods, LE CAT2 (3 cr)
or STAT 3411—Engineering Statistics (3 cr)
or STAT 3611—Introduction to Probability and Statistics (4 cr)

Water Science Electives (8–11 cr)

Must include three courses, at least one course each from Group A and B. Courses used to satisfy a water science elective may not be used to satisfy a concentration elective. At least one course used to fill the water science electives or the concentration electives must have a laboratory or field component.

Take 3 or more course(s) totaling 8–11 credit(s) from the following:

Group A Groundwater

Take 1–2 course(s) from the following:

GEOL 4240—Physical Hydrogeology (3 cr)
GEOL 4250—Environmental Hydrogeology (3 cr)
GEOL 5710—Aqueous Geochemistry/Chemical Hydrogeology (3 cr)

Group B Surface Water

Take 1–2 course(s) from the following:

BIOL 5803—Water Pollution Biology (3 cr)
BIOL 5805—Fisheries Ecology (3 cr)
BIOL 5833—Stream Ecology (4 cr)
BIOL 5861—Lake Ecology (3 cr)
BIOL 5867—Managing and Monitoring Lakes and Streams (3 cr)
GEOG 5446—Water Processes and Management (4 cr)
LIM 5004—Field Limnology (2 cr)
LIM 5101—Physical Limnology (3 cr)
LIM 5102—Chemical Limnology (3 cr)
LIM 5103—Geological Limnology (3 cr)
BIOL 5839—Coral Reef Field Studies (3 cr)
or GEOL 5839—Coral Reef Geology (3 cr)

Concentration Electives (10 cr)

Courses can be distributed among the groups in any combination. Discuss with adviser the benefits of breadth (credits in several concentrations) versus depth (credits in a particular concentration).

Take no more than 10 credit(s) from the following:

Climate Processes

Take 0–10 credit(s) from the following:

GEOG 3401—Weather and Climate (3 cr)
GEOG 3422—Natural Hazards (4 cr)
GEOG 5446—Water Processes and Management (4 cr)
GEOL 3210—Geomorphology (3 cr)
GEOL 4210—Glacial and Quaternary Geology (3 cr)
GEOL 5220—Global Climate Change (3 cr)
LIM 5103—Geological Limnology (3 cr)

Environmental Chemistry

Take 0–10 credit(s) from the following:

BIOL 5803—Water Pollution Biology (3 cr)
BIOL 5868—Ecotoxicology (3 cr)
CHE 4612—Hazardous Waste Processing Engineering (3 cr)
CHE 4613—Air Pollution Control (3 cr)
CHEM 2521—Organic Chemistry I (4 cr)
CHEM 2522—Organic Chemistry II (4 cr)

GEOL 3710—Introduction to Geochemistry (3 cr)
GEOL 5710—Aqueous Geochemistry/Chemical Hydrogeology (3 cr)
LIM 5102—Chemical Limnology (3 cr)

Global Resources
Take 0–10 credit(s) from the following:
ECON 4721—Natural Resource and Energy Economics (3 cr)
ECON 4777—Environmental Economics (3 cr)
GEOG 3461—Geography of Global Resources (3 cr)
GEOG 4451—The Geography of Soils (4 cr)
GEOL 4240—Physical Hydrogeology (3 cr)
GEOL 4250—Environmental Hydrogeology (3 cr)
GEOL 4350—Economic Geology (3 cr)

Habitats
Take 0–10 credit(s) from the following:
BIOL 4805—Ecological Invasions (2 cr)
BIOL 5777—Plankton Biology (2 cr)
BIOL 5801—Microbial Ecology (2 cr)
BIOL 5802—Microbial Ecology Laboratory (2 cr)
BIOL 5805—Fisheries Ecology (3 cr)
BIOL 5808—Landscape Ecology: Theory and Application (3 cr)
BIOL 5831—Plant Population and Community Ecology (4 cr)
BIOL 5833—Stream Ecology (4 cr)
BIOL 5861—Lake Ecology (3 cr)
BIOL 5863—Ecosystems Ecology (3 cr)
BIOL 5865—Conservation Biology (2 cr)
BIOL 5867—Managing and Monitoring Lakes and Streams (3 cr)
BIOL 5870—Wetland Ecology (3 cr)
BIOL 5839—Coral Reef Field Studies (3 cr)
or GEOL 5839—Coral Reef Geology (3 cr)

Quantitative Methods
Take 0–10 credit(s) from the following:
BIOL 5807—Mathematical Ecology (3 cr)
CHE 2111—Material and Energy Balances (3 cr)
CHE 2121—Chemical Engineering Thermodynamics (3 cr)
CHE 3111—Fluid Mechanics (3 cr)
CHE 5021—Transport Phenomena (3 cr)
CHE 5022—Transport Processes in Wells and Pipelines (3 cr)
GEOG 4563—Introduction to Geographic Information Science (3 cr)
GEOG 4564—Laboratory in Geographic Information Science (2 cr)
GEOG 4580—Introduction to Remote Sensing and Image Interpretation (4 cr)
GEOG 5541—Environmental Application of GIS (4 cr)
GEOL 5215—Glaciology (3 cr)
LIM 5004—Field Limnology (2 cr)
LIM 5101—Physical Limnology (3 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
PHYS 5043—Environmental Optics (3 cr)
PHYS 5541—Fluid Dynamics (3 cr)
STAT 5411—Analysis of Variance (3 cr)

Environmental Science Minor

College of Science and Engineering–Adm

Required credits in this minor: 30 to 34

The environmental science minor enhances a student's understanding of the scope of environmental problems, the biochemical and physical processes of environmental degradation, the sciences of non-renewable and renewable resources, and economic and political issues surrounding environmental problems. The minor provides valuable background for many environmental careers and applications.

Minor Requirements

ES Minor Requirements
GEOL 1110—Geology and Earth Systems, LE CAT4 (4 cr)
ESCI 2210—Science and Management of Environmental Systems (4 cr)
ESCI 3101—Nonrenewable Resources (4 cr)
ESCI 3102—Renewable Resources (4 cr)
Take one of the following course pairs:
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1162—Honors: General Chemistry II, H (5 cr)

Minor Electives
Two additional courses for at least four credits from the following:
ESCI 4101—Pollution and Technology (4 cr)
or ESCI 4102—Environmental Assessment (4 cr)
or ESCI Water Science Electives from Environmental Science B.S.
or ESCI Concentration Electives from Environmental Science B.S.

Geological Sciences B.A.

Geological Sciences

Required credits to graduate with this degree: 120

Required credits within the major: 54 to 56

This program requires summer terms.

Geological sciences is the scientific study of the origin, history, and structure of the Earth. The study of geology requires a broad base of knowledge in related sciences and mathematics.

The B.A. in geological sciences provides an appropriate educational background for work in areas related to environmental studies, land use planning, and other fields requiring sensitivity to Earth systems.

Honors Requirements: To attain departmental honors, students must undertake an independent research project (typically two semesters) and maintain a cumulative overall GPA of 3.00. The

research can be part of a UROP, directed research, independent study, or an internship with a faculty member. Students must make a brief oral presentation to the department summarizing their results and produce a research paper (maximum 10 pages).

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

Program Requirements

Requirements for the B.A. in geological sciences include:

- Liberal education requirements
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3 cr)
- Minor or double major
- Math courses determined by math placement

Geology Core Courses (33 cr)

GEOL 2110—Earth History (3 cr)
GEOL 2111—Earth History Laboratory (1 cr)
GEOL 2120—The Earth's Dynamic Interior (3 cr)
GEOL 2311—Mineralogy (4 cr)
GEOL 2312—Petrology (4 cr)
GEOL 3420—Sedimentology and Stratigraphy (4 cr)
GEOL 4450—Structural Geology (4 cr)
GEOL 4500—Field Geology (6 cr)

Take exactly 1 course(s) from the following:

GEOL 1110—Geology and Earth Systems, LE CAT4 (4 cr)
GEOL 1130—Introduction to Environmental Science, LEIP CAT4 (4 cr)
GEOL 1610—Oceanography, LE CAT5 (3 cr)
GEOG 1414—Physical Geography, LE CAT4 (4 cr)

Advanced Geology Electives

With the exception of GEOL 4110, electives (3xxx and above) are selected from yearly geological sciences offerings. Six credits of limnology courses may be substituted for 3 credits of geological electives. GEOG 4563 and 4564 (5 credit total) may be substituted for 3 credits of geological sciences electives.

Take 8 or more credit(s) from the following:

GEOL 3000—Geologic Maps (3 cr)
GEOL 3091—Independent Study (1–2 cr)
GEOL 3100—Earth's Climate and Environment: Past and Future (3 cr)
GEOL 3210—Geomorphology (3 cr)
GEOL 3710—Introduction to Geochemistry (3 cr)
GEOL 4210—Glacial and Quaternary Geology (3 cr)
GEOL 4240—Physical Hydrogeology (3 cr)
GEOL 4250—Environmental Hydrogeology (3 cr)
GEOL 4320—Precambrian Geology (3 cr)
GEOL 4335—Physical Volcanology (3 cr)
GEOL 4350—Economic Geology (3 cr)
GEOL 4480—Tectonics (3 cr)
GEOL 4610—Terrestrial Planets (3 cr)
GEOL 4805—Environmental Geophysics (3 cr)
GEOL 4820—Global Geophysics (3 cr)
GEOL 5091—Geologic Problems (1–2 cr)
GEOL 5095—Special Topics: (Various Titles to be Assigned) (1–2 cr)
GEOL 5100—Seminar (1–2 cr)
GEOL 5200—Geological Field Studies (2–3 cr)
GEOL 5215—Glaciology (3 cr)
GEOL 5220—Global Climate Change (3 cr)
GEOL 5310—Advanced Petrology (3 cr)
GEOL 5430—Stratigraphy and Basin Analysis (3 cr)
GEOL 5440—Depositional Environment and Stratal Architecture I: Field Methods and Applications (2 cr)
GEOL 5442—Depositional Environments, Stratal Architecture II: Conceptual, Mathematical, and Physical Modeling (2 cr)
GEOL 5450—Advanced Structure (3 cr)
GEOL 5710—Aqueous Geochemistry/Chemical Hydrogeology (3 cr)
GEOL 5730—Geochronology (3 cr)
GEOL 5839—Coral Reef Geology (3 cr)

Courses From Other Programs

Take one of the following course sequences:

CHEM 1113—Introduction to General, Organic, and Biological Chemistry I, LE CAT4 (5 cr)
CHEM 1114—Introduction to General, Organic, and Biological Chemistry II (5 cr)
or CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1162—Honors: General Chemistry II, H (5 cr)

Math

Take no more than 1 course(s) from the following:

MATH 1250—Precalculus Analysis, LE CAT2 (4 cr)
MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
STAT 2411—Statistical Methods, LE CAT2 (3 cr)

Geological Sciences B.S.

Geological Sciences

Required credits to graduate with this degree: 120

Required credits within the major: 75 to 76

This program requires summer terms.

The B.S. degree in geological sciences is designed for students interested in a career in geoscience. The study of geology requires a broad base of knowledge in related sciences (chemistry and physics) and mathematics. In addition, the program includes a solid core of geology courses, including a course in field mapping.

Honors Requirements: To attain departmental honors, students must undertake an independent research project (typically two semesters) and maintain a cumulative overall GPA of 3.00. The

research can be part of a UROP, directed research, independent study, or an internship with a faculty member. Students must make a brief oral presentation to the department summarizing their results and produce a research paper (maximum 10 pages).

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in geological sciences include:

- Liberal education requirements
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3 cr)
- Minor or double major

Geology Core Courses

GEOL 2110—Earth History (3 cr)
GEOL 2111—Earth History Laboratory (1 cr)
GEOL 2120—The Earth's Dynamic Interior (3 cr)
GEOL 2311—Mineralogy (4 cr)
GEOL 2312—Petrology (4 cr)
GEOL 3420—Sedimentology and Stratigraphy (4 cr)
GEOL 4450—Structural Geology (4 cr)
GEOL 4500—Field Geology (6 cr)
GEOL 1110—Geology and Earth Systems, LE CAT4 (4 cr)
or GEOL 1130—Introduction to Environmental Science, LEIP CAT4 (4 cr)
or GEOL 1610—Oceanography, LE CAT5 (3 cr)
or GEOG 1414—Physical Geography, LE CAT4 (4 cr)

Advanced Geology Electives

With the exception of GEOL 4110, electives (3xxx and above) are selected from yearly geological sciences offerings. Six credits of limnology courses may be substituted for geological sciences courses. GEOG 4563 and 4564 (5 credit total) may be substituted for 3 credits of geological sciences electives.

Take 15 or more credit(s) from the following:

GEOG 4451—The Geography of Soils (4 cr)
GEOL 3000—Geologic Maps (3 cr)
GEOL 3091—Independent Study (1–2 cr)
GEOL 3100—Earth's Climate and Environment: Past and Future (3 cr)
GEOL 3210—Geomorphology (3 cr)
GEOL 3710—Introduction to Geochemistry (3 cr)
GEOL 4210—Glacial and Quaternary Geology (3 cr)
GEOL 4240—Physical Hydrogeology (3 cr)
GEOL 4250—Environmental Hydrogeology (3 cr)
GEOL 4320—Precambrian Geology (3 cr)
GEOL 4335—Physical Volcanology (3 cr)
GEOL 4350—Economic Geology (3 cr)
GEOL 4480—Tectonics (3 cr)
GEOL 4610—Terrestrial Planets (3 cr)
GEOL 4805—Environmental Geophysics (3 cr)
GEOL 4820—Global Geophysics (3 cr)
GEOL 5091—Geologic Problems (1–2 cr)
GEOL 5095—Special Topics: (Various Titles to be Assigned) (1–2 cr)
GEOL 5100—Seminar (1–2 cr)
GEOL 5200—Geological Field Studies (2–3 cr)
GEOL 5215—Glaciology (3 cr)
GEOL 5220—Global Climate Change (3 cr)
GEOL 5310—Advanced Petrology (3 cr)
GEOL 5430—Stratigraphy and Basin Analysis (3 cr)
GEOL 5440—Depositional Environment and Stratal Architecture I: Field Methods and Applications (2 cr)
GEOL 5442—Depositional Environments, Stratal Architecture II: Conceptual, Mathematical, and Physical Modeling (2 cr)
GEOL 5450—Advanced Structure (3 cr)
GEOL 5710—Aqueous Geochemistry/Chemical Hydrogeology (3 cr)
GEOL 5730—Geochronology (3 cr)
GEOL 5839—Coral Reef Geology (3 cr)

Courses Required From Other Programs

MATH 1296 may be substituted for MATH 1290
MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
Take one of the following course sequences
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
CHEM 1152—General Chemistry II (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)
CHEM 1162—Honors: General Chemistry II, H (5 cr)

Geological Sciences Minor

Geological Sciences

Required credits in this minor: 25 to 27

The geological sciences minor enhances the student's understanding of and familiarity with earth materials and processes, and provides valuable background for many environmental careers and applications.

Minor Requirements

Minor Courses

GEOL 2110—Earth History (3 cr)
GEOL 2111—Earth History Laboratory (1 cr)

GEOL 2120—The Earth's Dynamic Interior (3 cr)
GEOL 2311—Mineralogy (4 cr)
GEOL 3210—Geomorphology (3 cr)
GEOL 1110—Geology and Earth Systems, LE CAT4 (4 cr)
or GEOL 1130—Introduction to Environmental Science, LEIP CAT4 (4 cr)
or GEOL 1610—Oceanography, LE CAT5 (3 cr)
or GEOG 1414—Physical Geography, LE CAT4 (4 cr)
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1113—Introduction to General, Organic, and Biological Chemistry I, LE CAT4 (5 cr)

Electives

Take exactly 1 course(s) from the following:
GEOL 2312—Petrology (4 cr)
GEOL 3420—Sedimentology and Stratigraphy (4 cr)
GEOL 4240—Physical Hydrogeology (3 cr)
GEOL 4250—Environmental Hydrogeology (3 cr)
GEOL 4450—Structural Geology (4 cr)

Industrial Engineering B.S.I.E.

Mechanical/Industrial Engineering

Required credits to graduate with this degree: 128

Required credits within the major: 128

The mission of the bachelor of science in industrial engineering program is to deliver a hands-on, laboratory-intensive undergraduate education that provides students with the tools and skills to excel in the profession, as they pursue lifelong learning and make positive contributions to society. With an emphasis on integrated systems and a strategic partnership with Luleå University of Technology in Sweden, the BSIE program offers unique opportunities for study abroad, undergraduate research, and technical electives to develop an enhanced global perspective.

The educational objectives of the Industrial Engineering program are to produce graduates who are able to:

1. Solve industrial engineering problems by applying contemporary engineering tools to propose and implement effective solutions.
2. Design, develop, implement and improve integrated systems that include people, materials, information, equipment, and energy.
3. Contribute as informed, ethical, and responsible members of the engineering profession and society as a whole.
4. Continue lifelong professional development throughout their career.
5. Collaborate and communicate effectively with others as a member or leader of an engineering or multidisciplinary team in an international setting.

Industrial engineering integrates topics from manufacturing, management, service, and traditional design. Industrial engineers are proficient in the design, improvement, and management of complex systems of people, materials, equipment, and energy. They study and adapt product designs and the associated plant facilities to optimize production, while considering economic, technical, and human factors.

The curriculum rounds out the learning experience by providing skills in the mathematical and physical sciences, economics, composition, and humanities and social sciences.

The industrial engineering program is accredited by the Engineering Accreditation Commission (EAC) of Accreditation Board for Engineering and Technology, (ABET). The program emphasizes manufacturing engineering and engineering management.

The international engineering concentration requires a senior year exchange with the Department of Materials and Manufacturing Engineering at Luleå University of Technology in Sweden and provides students with the opportunity to experience engineering in the global community.

The industrial and systems engineering concentration emphasizes the overall perspective of people and productivity, in any type of system, including manufacturing, service, healthcare, transportation, communication, and agriculture. The international engineering concentration offers a unique opportunity to study engineering in another culture; space is limited. Courses are taught in English and opportunities for travel and externally-focused projects abound.

Honors Requirements: To graduate with department honors, a student must graduate with a 3.40 GPA, be an active member of Tau Beta Pi or a professional engineering society (ASME, ASSE, IIE, or MSPE), and be nominated by a department faculty member.

Admission Requirements

Students must complete 10 courses before admission to the upper division program. Freshmen and transfer students are usually admitted to pre-major status before admission to this major.

A GPA above 2.00 is preferred for the following:

- 2.50 for students already admitted to the degree-granting college.
- 2.50 for students transferring from another University of Minnesota college.
- 2.80 for students transferring from outside the University.

Admission to the upper division B.S.I.E. program is competitive and based on performance in lower division courses and space availability. A minimum overall GPA of 2.50 is required. A C- or better is required for all program courses. In addition, the student must successfully complete (with grades of C- or above) 75 percent of all courses attempted. Transfer students from outside the University of Minnesota system must have a minimum overall GPA of 2.80 and all transfer credits must be a C or better. An application may be submitted when the student has completed at least 70 percent the following core course list: CHEM 1151 and COMP 1120 and ENGR 2015 and ENGR 2110 and [IE 1225 *OR* ENGR 1210] and MATH 1296 and MATH 1297 and MATH 3280 and PHYS 2011 and (one or more courses totalling 3 - 5 credits from the following: CS 1121, CS 1131, CS 1211, CS 1511, CS 2121). Application for admission to upper division must be filed with the department in spring semester of the sophomore year.

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S.I.E. include:

- Liberal education requirements
- Advanced writing requirement: COMP 3130—Advanced Writing: Engineering or COMP 3150—Advanced Writing: Science or COMP 3180—Honors: Advanced Writing (3 cr)
- Successful completion (with grades of C- or better or S) of all required courses and of 75 percent of all work attempted. Transfer credits must be completed with a C or better.
- File an upper division application and Academic Progress Audit (APAS). Students who fail to file this form by the time they have completed 75 credits may not be permitted to register.
- Completion of at least 30 degree credits at UMD. At least 20 of the last 30 credits taken immediately before graduation must have been taken at UMD.
- A minimum GPA of 2.50 in all courses taken in the major, including required courses in related fields

Maintenance Standards: Undergraduate students majoring in Industrial Engineering must maintain a 2.50 GPA overall. One semester with a GPA under 2.00 results in being placed on academic probation in the program. Two semesters with a GPA under 2.00 results in academic dismissal from the BSIE programs, even if the cumulative GPA is above 2.50. If the suspension occurs to an upper division student, they lose their status as a BSIE candidate and must reapply to the upper division after they have demonstrated academic improvement and consulted with their academic adviser and the department head. This policy is in addition to the academic progress policies of CSE and the University of Minnesota.

Program Sub-plans

Students are required to complete one of the following sub-plans.

Industrial and Systems Engineering

The industrial and systems engineering concentration emphasizes the overall perspective of people and productivity in any type of system, including manufacturing, service, healthcare, transportation, communication, and agriculture. Concentration electives allow students to study systems of interest to them.

One course each from liberal education categories 7, 8, and 9 and one course from 9 or 10 (12 cr); courses from categories 9 and 10 must have different designators.

Final project: Students are required to complete a final team designed project in the capstone design courses EMGT 4110—Engineering Professionalism and Practice and IE 4255—Multidisciplinary Senior Design. Completion of the junior year curriculum is a prerequisite for these courses. IE 4255 requires publication of a final report and a formal presentation to the project sponsors.

Industrial and Systems Engineering Core Courses (55 cr)

Required courses include fundamental material in engineering science, engineering management, industrial engineering, and mechanical engineering. Concepts are delivered in lecture and reinforced in lab experiences.

EMGT 4110—Engineering Professionalism and Practice (2 cr)

ENGR 2015—Statics (3 cr)

ENGR 2016—Mechanics of Materials (3 cr)

ENGR 2026—Dynamics (3 cr)

ENGR 2110—Introduction to Material Science for Engineers (3 cr)

IE 3115—Operations Research (4 cr)

IE 3122—Materials Engineering Laboratory (2 cr)

IE 3125—Engineering Economic Analysis (3 cr)

IE 3130—Materials Processing Engineering (3 cr)

IE 3140—Human Factors and Ergonomic Design (3 cr)

IE 3222—Occupational Systems Laboratory (2 cr)

IE 4010—Six Sigma Quality Control (3 cr)

IE 4020—Lean Enterprises Management (3 cr)
IE 4115—Facility Planning and Simulation (4 cr)
IE 4222—Systems Integration Laboratory (2 cr)
IE 4230—Systems Integration (3 cr)
IE 4255—Multidisciplinary Senior Design (4 cr)
IE 4993—Industrial Engineering Seminar (1 cr)
IE 1225—Introduction to Design and Manufacturing Engineering (4 cr)
or ENGR 1210—Introduction to Design and Reverse Engineering (3 cr)
IE 2222—Design Manufacturing Laboratory (2 cr)

Courses From Other Programs (73 cr)

These courses help engineers develop a foundation of mathematics, sciences, economics, statistics, and communication skills.

CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
COMP 1120—College Writing, LE CAT1 (3 cr)
ECE 2006—Electrical Circuit Analysis (4 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
STAT 3411—Engineering Statistics (3 cr)
ECON 1022—Principles of Economics: Macro, LE CAT6 (3 cr)
or ECON 1023—Principles of Economics: Micro, LE CAT6 (3 cr)
LSBE 1101—The Business Environment, LE CAT8 (3 cr)
or ACCT 2005—Survey of Accounting, LE CAT8 (3 cr)
or BLAW 2001—The Legal Environment, LE CAT8 (3 cr)
COMM 1112—Public Speaking, LE CAT3 (3 cr)
or PSY 1003—General Psychology, LE CAT6 (4 cr)
or ACCT 2001—Principles of Financial Accounting (3 cr)
or FMIS 3201 {Inactive}
or INTB 3201—International Business (3 cr)

Advanced Writing Requirement

COMP 3130 is preferred

Take exactly 1 course(s) from the following:

COMP 3130—Advanced Writing: Engineering (3 cr)
COMP 3150—Advanced Writing: Science (3 cr)
COMP 3180—Honors: Advanced Writing (3 cr)

Computer Science Elective

This course helps the industrial engineer develop proficiency in information systems and data management.

Note: CS 1511 may be used to satisfy this elective.

Take 1 or more course(s) totaling 3 or more credit(s) from the following:

CS 1121—Introduction to Programming in Visual BASIC. NET, LE CAT3 (3 cr)
CS 1131—Introduction to Programming in FORTRAN, LE CAT3 (3 cr)
CS 1521—Computer Science II (5 cr)
CS 2121—Introduction to Programming in Java, LE CAT3 (3 cr)

Industrial and Systems Engineering Electives

These courses help an industrial engineer develop systems skills in technical areas. (Cannot count credits from other requirement categories.)

Take 6 or more credit(s) from the following:

IE 4495—Special Topics: (Various Titles to be Assigned) (1–4 cr)
IE 5305—Supply Chain Management (3 cr)
IE 5315—Organizational Control Methods (3 cr)
IE 5325—Advanced Engineering Economics (3 cr)
IE 5335—Engineered Products and Services (3 cr)
SAFE 6002—Regulatory Standards and Hazard Control (3 cr)
SAFE 6051—Construction Safety (3 cr)
ME 3111—Fluid Mechanics (3 cr)
or CHE 3111—Fluid Mechanics (3 cr)

Additional Electives

(Cannot count credits from other requirement categories.)

Take 2 or more course(s) totaling 6 or more credit(s) from the following:

CHE 2111—Material and Energy Balances (3 cr)
CHE 5895—Special Topics: (Various Titles to be Assigned) (1–4 cr)
CS 1521—Computer Science II (5 cr)
CS 2121—Introduction to Programming in Java, LE CAT3 (3 cr)
ECE 1315—Digital System Design (4 cr)
ECE 2111—Linear Systems and Signal Analysis (4 cr)
ECE 2212—Electronics I (4 cr)
ECE 2325—Microcomputer System Design (4 cr)
ECE 3151—Control Systems (3 cr)
ECE 5995—Special Topics: (Various Titles to be Assigned) (1–3 cr)
HCM 4520—Healthcare Organization and Management (3 cr)
HCM 4540—Health Services Operations Management (3 cr)
IE 4196—Cooperative Education (1 cr)
IE 4491—Independent Study (1–4 cr)
IE 4495—Special Topics: (Various Titles to be Assigned) (1–4 cr)
IE 4993—Industrial Engineering Seminar (1 cr)
IE 5305—Supply Chain Management (3 cr)
IE 5315—Organizational Control Methods (3 cr)
IE 5325—Advanced Engineering Economics (3 cr)
IE 5335—Engineered Products and Services (3 cr)
IE 5991—Independent Study in Industrial Engineering (1–4 cr)
MATH 3298—Calculus III (4 cr)
MATH 3355—Discrete Mathematics (4 cr)
ME 3140—System Dynamics and Control (3 cr)
ME 3211—Thermodynamics (3 cr)
ME 4135—Robotics and Controls (4 cr)
ME 4145—CAD/CAM (4 cr)
ME 4175—Machine Design (3 cr)
ME 4245—Machining and Machine Tools (4 cr)
ME 4495—Special Topics: (Various Titles to be Assigned) (1–4 cr)

ME 5315—Nondestructive Evaluation of Engineering Materials (3 cr)
ME 5325—Sustainable Energy System (3 cr)
MGTS 4472—Entrepreneurship (3 cr)
SAFE 6002—Regulatory Standards and Hazard Control (3 cr)
SAFE 6051—Construction Safety (3 cr)
STAT 5411—Analysis of Variance (3 cr)
STAT 5511—Regression Analysis (3 cr)
ME 3111—Fluid Mechanics (3 cr)
or CHE 3111—Fluid Mechanics (3 cr)

Liberal Education Electives

Engineers need to be well-rounded to best serve society.
Hist/Phil foundations electives: 3 cr/Category 7.
Literary/artistic elective I: 3 cr/Category 9.
Literary/artistic elective II: 3 cr/ Category 9 or 10, must have a different prefix than literary and artistic elective I.

International Engineering

This sub-plan is optional and does not fulfill the sub-plan requirement for this program.

The international engineering concentration offers a unique opportunity to study engineering in another culture; space is limited. Courses are taught in English and opportunities for travel and externally-focused projects abound.

Final Project: Students taking the senior year at Luleå University of Technology must take its equivalent capstone design course.

International Engineering Core Courses (70 cr)

Required courses include fundamental material in engineering science, industrial engineering, and mechanical engineering. Courses in Sweden (IE 48xx) build on these fundamentals, frequently in the context of significant projects. IE 4801 must be taken twice (2 cr).

ENGR 2015—Statics (3 cr)
ENGR 2016—Mechanics of Materials (3 cr)
ENGR 2026—Dynamics (3 cr)
ENGR 2110—Introduction to Material Science for Engineers (3 cr)
IE 3115—Operations Research (4 cr)
IE 3122—Materials Engineering Laboratory (2 cr)
IE 3125—Engineering Economic Analysis (3 cr)
IE 3130—Materials Processing Engineering (3 cr)
IE 3140—Human Factors and Ergonomic Design (3 cr)
IE 3222—Occupational Systems Laboratory (2 cr)
IE 4010—Six Sigma Quality Control (3 cr)
IE 4020—Lean Enterprises Management (3 cr)
IE 4801—International Engineering Report (1 cr)
IE 4803—Simulation of Swedish Manufacturing (3 cr)
IE 4812—Computer Integrated Manufacturing (4 cr)
IE 4823—Project Management and Swedish Industrial Design Project (6 cr)
IE 4827—Manufacturing Systems Project (8 cr)
IE 4870—Advanced Manufacturing Processes (4 cr)
ME 4145—CAD/CAM (4 cr)
IE 1225—Introduction to Design and Manufacturing Engineering (4 cr)
or ENGR 1210—Introduction to Design and Reverse Engineering (3 cr)
IE 2222—Design Manufacturing Laboratory (2 cr)

Courses From Other Programs (58 cr)

These courses help engineers develop a foundation of mathematics, sciences, economics, statistics, and communication skills. International engineering emphasizes the culture, historical perspective, and current events and issues in a foreign setting.

CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
COMP 1120—College Writing, LE CAT1 (3 cr)
ECE 2006—Electrical Circuit Analysis (4 cr)
INTS 1070—An Introduction to Scandinavia, LEIP CAT8 (3 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
STAT 3411—Engineering Statistics (3 cr)
ECON 1022—Principles of Economics: Macro, LE CAT6 (3 cr)
or ECON 1023—Principles of Economics: Micro, LE CAT6 (3 cr)

Advanced Writing Requirement

COMP 3130 is preferred
Take exactly 1 course(s) from the following:
COMP 3130—Advanced Writing: Engineering (3 cr)
COMP 3150—Advanced Writing: Science (3 cr)
COMP 3180—Honors: Advanced Writing (3 cr)

Computer Science Elective

This course helps the industrial engineer develop proficiency in information systems and data management.

Note: CS 1511 may be used to satisfy this elective.

Take 1 or more course(s) from the following:
CS 1121—Introduction to Programming in Visual BASIC. NET, LE CAT3 (3 cr)
CS 1131—Introduction to Programming in FORTRAN, LE CAT3 (3 cr)
CS 2121—Introduction to Programming in Java, LE CAT3 (3 cr)

Liberal Education Electives

Engineers need to be well-rounded to best serve society. These electives include historical foundations, arts, and humanities.

Hist/Phil Foundations Electives: 3 cr/Category 7. Contemporary Social Issues Electives: 3 cr/Category 8. Literary/Artistic Elective I: 3 cr/Category 9. Literary/ Artistic Elective II: 3 cr/ Category 9 or 10, must have a different prefix than literary and artistic elective I.

Mathematics B.S.

Mathematics and Statistics

Required credits to graduate with this degree: 120

Required credits within the major: 50

Mathematics is fundamental to solving problems in physics, chemistry, biology, medicine, business, engineering, and technology. The mathematics major prepares students for careers in business, industry, and government and for further studies in law or graduate school. Note that the Statistics and Actuarial Science B.S. is listed separately.

Honors Requirements: To graduate with department honors, a student must complete the program with an overall and department GPA of 3.50, satisfactorily complete a research project under the guidance of a department faculty member, and convey research results in a public presentation.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in mathematics include:

- Liberal education requirements.
- Minor or second major from another area of study.
- Advanced writing requirement: COMP 31xx.

Mathematics Core Courses (34 cr)

Take one of the following three Calculus I courses:

MATH 1290—Calculus for the Natural Sciences, LE CAT2 (5 cr)

or MATH 1296—Calculus I, LE CAT2 (5 cr)

or MATH 1596—Honors: Calculus I, LE CAT2, H (5 cr)

Calculus II

Take one of the following two Calculus II courses

MATH 1297—Calculus II (5 cr)

or MATH 1597—Honors: Calculus II, H (5 cr)

MATH 3280—Differential Equations with Linear Algebra (4 cr)

MATH 3299—Intermediate Analysis (3 cr)

MATH 3355—Discrete Mathematics (4 cr)

MATH 3941—Undergraduate Colloquium (1 cr)

MATH 4326—Linear Algebra (3 cr)

STAT 3611—Introduction to Probability and Statistics (4 cr)

Required from other departments

CS 1511—Computer Science I, LE CAT3 (5 cr)

Electives (16 cr)

MATH elective courses must be at least 3100.

STAT elective courses must be at least 5000.

At least 10 credits of MATH and/or STAT electives must be 4xxx or above.

At least 6 credits of electives must have MATH prefix and be 4xxx or above.

Only one credit of MATH 3120 may count toward the math major.

MATH 4371 cannot be counted toward the major.

MATH/ STAT

Take 0 - 6 credit(s) from the following:

MATH 3xxx

STAT 3xxx

MATH/STAT 4xxx-5xxx

Take 10 - 16 credit(s) from the following:

MATH 4xxx

MATH 5xxx

STAT 4xxx

STAT 5xxx

Approved Nondepartment List (Double Majors and Minors ONLY)

A student with a second major may substitute courses from the Approved Nondepartmental List on a one elective MATH credit for two outside credits exchange basis for up to seven MATH elective credits. A student pursuing a second major in statistics and actuarial science cannot apply STAT courses as electives.

Take 0–14 credit(s) from the following:

BIOL 5807—Mathematical Ecology (3 cr)

CHE 4301—Chemical Reaction Engineering (3 cr)

CHE 4401—Process Control (3 cr)

CHE 4402—Process Dynamics and Control (3 cr)

CHEM 4641—Physical Chemistry I (3 cr)

CHEM 4642—Physical Chemistry II (3 cr)

CS 4511—Computability and Complexity (4 cr)

CS 4521—Algorithms and Data Structures (4 cr)

CS 5541—Artificial Intelligence (4 cr)

CS 5721—Computer Graphics (4 cr)

CS 5751—Introduction to Machine Learning (4 cr)

ECE 5151—Digital Control System Design (3 cr)

ECE 5741—Digital Signal Processing (3 cr)

ECE 5801—Introduction to Artificial Neural Networks (3 cr)

ECE 5831—Fuzzy Set Theory and Its Application (3 cr)

GEOL 4240—Physical Hydrogeology (3 cr)

ME 4112—Heat and Mass Transfer (3 cr)

ME 4135—Robotics and Controls (4 cr)

PHYS 4001—Classical Mechanics (4 cr)

PHYS 4011—Electromagnetic Theory (4 cr)

PHYS 4021—Quantum Physics II (4 cr)
PHYS 4031—Thermal and Statistical Physics (4 cr)
PHYS 5052—Computational Methods in Physics (3 cr)
PHYS 5501—Advanced Classical Mechanics (3 cr)
PHYS 5541—Fluid Dynamics (3 cr)

Program Areas of Emphasis

Mathematics includes a wide variety of areas in which students can specialize. Although no area of emphasis is required for the MATH major, students are encouraged to work with their advisers to develop a coherent major plan. See the Department of Mathematics and Statistics Web page: www.d.umn.edu/math for descriptions of elective course groups appropriate for emphases.

Mathematics Minor

Mathematics and Statistics

Required credits in this minor: 21 to 25

The minor in mathematics is based on the completion of the traditional core of calculus, differential equations, and elementary linear algebra commonly required of undergraduate physical science, engineering, and mathematics degrees. Additional, more advanced, elective classes are required, as well. The minor in mathematics certifies a student's quantitative, problem-solving, and critical thinking skills.

Minor Requirements

Core Courses (14 cr)

MATH 3280—Differential Equations with Linear Algebra (4 cr)

And one of the following course pairs:

MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
or MATH 1596—Honors: Calculus I, LE CAT2, H (5 cr)
MATH 1597—Honors: Calculus II, H (5 cr)

Electives

Required are 7 elective credits of MATH and/or STAT above 3097 with either:

1) at least 3 credits above 4xxx, or 2) beyond the 7 elective credits, an additional course from the Approved Course Substitution List. (See Math B.S.)

Only one credit of MATH 3120 may count toward the math minor.

Mechanical Engineering B.S.M.E.

UMD Mechanical/Industrial Engineering

Required credits to graduate with this degree: 128

Required credits within the major: 128

The mission of the bachelor of science in mechanical engineering program is to deliver a laboratory-intensive, undergraduate mechanical engineering education that provides students with the tools and skills to excel in the engineering profession, as they pursue lifelong learning and make positive contributions to society. The student learning experience offers unique opportunities for study abroad, undergraduate research, and electives outside of mechanical engineering to develop an enhanced global perspective.

Upon completion of the mechanical engineering program educational objectives, B.S.M.E. graduates will:

1. solve mechanical engineering problems by applying contemporary engineering tools to propose and implement effective solutions;
2. design, develop, implement and improve thermal and mechanical systems;
3. contribute as informed, ethical, and responsible members of the engineering profession and society as a whole;
4. continue lifelong professional development throughout their career;
5. collaborate and communicate effectively with others as a member or leader of an engineering or multidisciplinary team in an international setting.

The B.S.M.E. program integrates topics from chemistry, physics, advanced mathematics and statistics, and core engineering science to prepare graduates to work professionally in both thermal and mechanical systems, from design, development, manufacture, and use of products involving mechanical and thermal elements.

The program emphasizes the production engineering approach to mechanical and thermal systems design and development. Upper division courses provide students with a strong understanding of mechanical and thermal systems, and the skills to design, develop, and implement these systems. The mechanical engineering program is accredited by the Engineering Accreditation Commission (EAC) of ABET, Inc.

Mechanical engineering graduates are qualified for employment in a wide variety of industries including design, manufacturing, materials, aerospace, transportation, natural resources, and energy. Graduates may pursue assignments in design,

development, manufacturing, operations, project engineering, or sales, and frequently move into engineering management. They are also well qualified to continue with graduate education.

Students in the B.S.M.E. program have the opportunity to put their design and entrepreneurial skills to use in ASME design competitions, projects sponsored by regional companies, and research projects in the Undergraduate Research Opportunities Program.

Honors Requirements: To graduate with department honors, a student must have a 3.40 GPA, be an active member of Tau Beta Pi or a professional engineering society (ASME, ASSE, IIE, or MSPE), and be nominated by a department faculty member.

Admission Requirements

Students must complete 10 courses before admission to the program. Freshmen and transfer students are usually admitted to pre-major status before admission to this major.

A GPA above 2.00 is preferred for the following:

- 2.50 for students already admitted to the degree-granting college.
- 2.50 for students transferring from another University of Minnesota college.
- 2.80 for students transferring from outside the University.

Admission to the upper division B.S.M.E. program is competitive and based on performance in lower division courses and space availability. A minimum overall GPA of 2.50 is required. A C- or better is required in all program courses. In addition, the student must successfully complete (with grades of C- or above) 75 percent of all courses attempted. Transfer students from outside the University of Minnesota system must have a minimum overall GPA of 2.80 and all transfer credits must be a C or better. An application may be submitted when the student has completed at least 70 percent of the following core course list: CHEM 1151, COMP 1120, ENGR 2015, ENGR 2110, IE 1225 or ENGR 1210, MATH 1296, MATH 1297, MATH 3280, PHYS 2011 and (one course from the following: CS 1121, CS 1131, CS 1511, CS 2121).

Application for admission to the upper division must be filed with the department in spring semester of the sophomore year.

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Recommended freshman writing course(s) for this program: COMP 1120—College Writing.

Program Requirements

Requirements for the B.S.M.E. include:

- Liberal education requirements
- Advanced writing requirement: COMP 3130—Advanced Writing: Engineering or COMP 3150—Advanced Writing: Science or COMP 3180 Honors: Advanced Writing (3 cr)
- Completion of at least 30 degree credits at UMD. At least 20 of the last 30 degree credits taken immediately before graduation must be taken at UMD.
- Successful completion (with grades of C- or better or S) of all required courses and 75 percent of all work attempted.
- Major requirements: a minimum GPA of 2.50 in all courses taken in the major, including required courses in related fields.
- Admission to upper division by submitting an application and APAS form. Students who fail to file these forms by the time they have completed 75 credits may not be permitted to register.

Maintenance Standards: Undergraduate students majoring in mechanical engineering must maintain a 2.50 GPA overall. One semester with a GPA under 2.00 results in being placed on academic probation in the program. Two semesters with a GPA under 2.00 results in academic dismissal from the B.S.M.E. program, even if the cumulative GPA is above 2.50. If the suspension occurs to an upper division student, that student loses their status as a B.S.M.E. candidate and will have to reapply to the upper division after they have demonstrated academic improvement and consulted with their academic adviser and the department head. This policy is in addition to the academic progress policies of CSE and the University of Minnesota.

B.S.M.E Core Courses (57 cr)

Courses include fundamental material in engineering management, engineering science, industrial engineering, and mechanical engineering. Concepts are delivered in lecture and reinforced in lab experiences. Students are required to complete a final team design project in the

capstone design courses EMGT 4110 and ME 4255. Completion of the junior year curriculum is a prerequisite for these courses. ME 4255 requires a final report and a formal presentation to the project sponsors.

EMGT 4110—Engineering Professionalism and Practice (2 cr)
ENGR 2015—Statics (3 cr)
ENGR 2016—Mechanics of Materials (3 cr)
ENGR 2026—Dynamics (3 cr)
ENGR 2110—Introduction to Material Science for Engineers (3 cr)
IE 3122—Materials Engineering Laboratory (2 cr)
IE 3125—Engineering Economic Analysis (3 cr)
IE 3130—Materials Processing Engineering (3 cr)
IE 4993—Industrial Engineering Seminar (1 cr)
ME 3111—Fluid Mechanics (3 cr)
ME 3140—System Dynamics and Control (3 cr)
ME 3211—Thermodynamics (3 cr)
ME 3222—Controls and Kinematics Laboratory (2 cr)
ME 3230—Kinematics and Mechatronics (3 cr)
ME 4122—Heat Transfer, Thermodynamics and Fluid Mechanics Laboratory (2 cr)
ME 4145—CAD/CAM (4 cr)
ME 4175—Machine Design (3 cr)
ME 4255—Multidisciplinary Senior Design (4 cr)
IE 1225—Introduction to Design and Manufacturing Engineering (4 cr)
or the following course pair:
ENGR 1210—Introduction to Design and Reverse Engineering (3 cr)
IE 2222—Design Manufacturing Laboratory (2 cr)
ME 4112—Heat and Mass Transfer (3 cr)
or CHE 3112—Heat and Mass Transfer (3 cr)

Courses From Other Programs

These courses help engineers develop a foundation of mathematics, sciences, economics, statistics, and communication skills.

CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
COMP 1120—College Writing, LE CAT1 (3 cr)
ECE 2006—Electrical Circuit Analysis (4 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
MATH 3298—Calculus III (4 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
STAT 3411—Engineering Statistics (3 cr)
ECON 1022—Principles of Economics: Macro, LE CAT6 (3 cr)
or ECON 1023—Principles of Economics: Micro, LE CAT6 (3 cr)

Advanced Writing Requirement

Comp 3130 is preferred
Take exactly 1 course(s) from the following:
COMP 3130—Advanced Writing: Engineering (3 cr)
COMP 3150—Advanced Writing: Science (3 cr)
COMP 3180—Honors: Advanced Writing (3 cr)

Computer Science Elective

Note: CS 1511 may be used to satisfy this elective.
Take 1 or more course(s) totaling 3 or more credit(s) from the following:
CS 1121—Introduction to Programming in Visual BASIC. NET, LE CAT3 (3 cr)
CS 1131—Introduction to Programming in FORTRAN, LE CAT3 (3 cr)
CS 2121—Introduction to Programming in Java, LE CAT3 (3 cr)

Mechanical Engineering Electives

These courses help a mechanical engineer develop skills in a particular technical area.
Take 3 or more credit(s) from the following:
ME 4135—Robotics and Controls (4 cr)
ME 4245—Machining and Machine Tools (4 cr)
ME 4495—Special Topics: (Various Titles to be Assigned) (1–4 cr)
ME 5305—Computational Fluid Dynamics (3 cr)
ME 5315—Nondestructive Evaluation of Engineering Materials (3 cr)
ME 5325—Sustainable Energy System (3 cr)
ME 5335—Introduction to Finite Element Analysis (3 cr)

Mechanical Engineering Electives

Take 2 or more course(s) totaling 6 or more credit(s) from the following:
CHE 2121—Chemical Engineering Thermodynamics (3 cr)
CHE 4111—Separations (3 cr)
CHE 4301—Chemical Reaction Engineering (3 cr)
CHE 4401—Process Control (3 cr)
CHE 4613—Air Pollution Control (3 cr)
CHE 4621—Particle Technology (3 cr)
CHE 5021—Transport Phenomena (3 cr)
CHE 5022—Transport Processes in Wells and Pipelines (3 cr)
CHE 5895—Special Topics: (Various Titles to be Assigned) (1–4 cr)
ECE 2111—Linear Systems and Signal Analysis (4 cr)
ECE 2212—Electronics I (4 cr)
ECE 3151—Control Systems (3 cr)
ECE 3235—Electronics II (4 cr)
ECE 3445—Electromagnetic Fields (3 cr)
ECE 3611—Introduction to Solid-State Semiconductors (3 cr)
ECE 4501—Power Systems (4 cr)
ECE 5995—Special Topics: (Various Titles to be Assigned) (1–3 cr)
IE 3115—Operations Research (4 cr)
IE 3265—Production and Operations Management (4 cr)
IE 4495—Special Topics: (Various Titles to be Assigned) (1–4 cr)
IE 4993—Industrial Engineering Seminar (1 cr)
IE 5325—Advanced Engineering Economics (3 cr)
ME 4135—Robotics and Controls (4 cr)
ME 4196—Cooperative Education (1 cr)
ME 4245—Machining and Machine Tools (4 cr)
ME 4491—Independent Study in Mechanical Engineering (1–4 cr)

ME 4495—Special Topics: (Various Titles to be Assigned) (1–4 cr)
ME 5305—Computational Fluid Dynamics (3 cr)
ME 5315—Nondestructive Evaluation of Engineering Materials (3 cr)
ME 5325—Sustainable Energy System (3 cr)
ME 5335—Introduction to Finite Element Analysis (3 cr)
ME 5991—Independent Study in Mechanical Engineering (1–4 cr)
MGTS 4472—Entrepreneurship (3 cr)
PHYS 2021—Relativity and Quantum Physics (4 cr)
PHYS 4021—Quantum Physics II (4 cr)
PHYS 4031—Thermal and Statistical Physics (4 cr)
SAFE 6002—Regulatory Standards and Hazard Control (3 cr)
SAFE 6111—Industrial Noise and Ventilation Control (3 cr)

Liberal Education Electives

Engineers need to be well-rounded to best serve society. These electives include historical foundations, contemporary social issues and arts and humanities.

Hist/Phil Foundations Elective: 3 cr/Category 7.

Contemporary Social Issues Elective: 3 cr/Category 8.

Literary/Artistic Elective I: 3 cr/Cat 9 or 10, must have a different prefix than literary and artistic elective I.

Physics B.A.

Physics

Required credits to graduate with this degree: 120

Required credits within the major: 49

The B.A. in physics is a liberal arts degree that allows considerable freedom in the planning of upper level courses and can easily be combined with other majors and interests. The physics courses emphasize conceptual foundations, problem-solving skills, and experimental techniques.

Honors Requirements: To graduate with honors, students must participate in the department honors program, complete a research project, and maintain a GPA above 3.00. They are also expected to attend department colloquia. Interested students should contact the physics honors program coordinator.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.A. in physics include:

- Liberal education requirements
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3 cr)
- A minor or a second major from another area of study

Students interested in teaching 9–12 physics may enroll concurrently in secondary licensure requirements in the Department of Education and apply for admission to the Secondary Teacher Education Program.

Core Courses

The department also recommends the supplementary courses PHYS 2111 and PHYS 2112.

PHYS 1021—Exploring Current Topics in Physics (1 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
PHYS 2021—Relativity and Quantum Physics (4 cr)
PHYS 2022—Classical Physics (4 cr)
PHYS 2033—Classical and Quantum Physics Lab (2 cr)

Electives

Take 12 or more credit(s) from the following:

LIM 5101—Physical Limnology (3 cr)
PHYS 3061—Instrumentation (3 cr)
PHYS 4001—Classical Mechanics (4 cr)
PHYS 4011—Electromagnetic Theory (4 cr)
PHYS 4021—Quantum Physics II (4 cr)
PHYS 4031—Thermal and Statistical Physics (4 cr)
PHYS 5041—Optics (3 cr)
PHYS 5052—Computational Methods in Physics (3 cr)
PHYS 5053—Data Analysis Methods in Physics (3 cr)
PHYS 5061—Experimental Methods (3 cr)
PHYS 5531—Introduction to Solid State Physics (3 cr)
PHYS 5541—Fluid Dynamics (3 cr)

Courses From Other Programs

MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
MATH 3298—Calculus III (4 cr)

Physics B.S.

Physics

Required credits to graduate with this degree: 120

Required credits within the major: 68

The B.S. in physics is primarily for students planning to work toward an advanced degree in physics or a related area. The physics courses emphasize conceptual foundations, problem-solving skills, and experimental techniques.

Students participate in research focused primarily on theoretical physics, instrumentation, experimental solid state and high energy physics, and physical oceanography. The department also offers courses required for professional and preprofessional programs such as engineering and medicine.

Honors Requirements: To graduate with honors, students must participate in the department honors program, complete a research project, and maintain a GPA above 3.00. They are also expected to attend department colloquia. Interested students should contact the physics honors program coordinator.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in physics include:

- Liberal education requirements
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3)
- A minor or a second major in a different program

The first math course is determined by math placement exam. The sample plan presupposes placement into Math 1296.

Courses numbered above 3xxx will be offered in alternate years only. Some courses suggested in the sample plans in the junior and senior years may need to be switched to match the course offerings.

Students interested in teaching 9-12 physics may enroll concurrently in the Department of Education and apply for admission to the Secondary Teacher Education Program.

Core Courses

The department also recommends the supplementary courses PHYS 2111 and PHYS 2112.

PHYS 1021—Exploring Current Topics in Physics (1 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
PHYS 2021—Relativity and Quantum Physics (4 cr)
PHYS 2022—Classical Physics (4 cr)
PHYS 2033—Classical and Quantum Physics Lab (2 cr)
PHYS 3061—Instrumentation (3 cr)
PHYS 4001—Classical Mechanics (4 cr)
PHYS 4011—Electromagnetic Theory (4 cr)
PHYS 4021—Quantum Physics II (4 cr)
PHYS 4031—Thermal and Statistical Physics (4 cr)
PHYS 5061—Experimental Methods (3 cr)
PHYS 5090—Physics Seminar (1 cr)

Required Courses From Other Programs

Two semesters of chemistry are recommended. Any one-semester course in a programming language may be substituted for CS 1131 with department approval.

CS 1131—Introduction to Programming in FORTRAN, LE CAT3 (3 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
MATH 3298—Calculus III (4 cr)
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)

Applied Physics B.S.

Physics

Required credits to graduate with this degree: 120

Required credits within the major: 75

The B.S. in applied physics is primarily for students planning to work in industry. The physics courses emphasize conceptual foundation, problem-solving skills, and experimental and computational techniques.

Honors Requirements: To graduate with honors, students must participate in the department honors program, complete a research project, and maintain a GPA above 3.00. They are also expected to attend department colloquia. Interested students should contact the physics honors program coordinator.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Program Requirements

Requirements for the B.S. in applied physics include:

- Liberal education requirements
- Advanced writing requirement: COMP 3150—Advanced Writing: Science (3 cr)
- A minor or a second major in a different program

The first math course is determined by math placement exam. The sample plan presupposes placement into Math 1296.

Courses numbered above 3xxx are offered in alternate years only. Some courses suggested in the sample plan for the junior and senior years may need to be switched to match the course offerings.

Core Courses

The department also recommends the supplementary courses PHYS 2111 and PHYS 2112.

PHYS 1021—Exploring Current Topics in Physics (1 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
PHYS 2021—Relativity and Quantum Physics (4 cr)
PHYS 2022—Classical Physics (4 cr)
PHYS 2033—Classical and Quantum Physics Lab (2 cr)
PHYS 3061—Instrumentation (3 cr)
PHYS 5061—Experimental Methods (3 cr)
PHYS 5090—Physics Seminar (1 cr)
PHYS 5052—Computational Methods in Physics (3 cr)
or PHYS 5053—Data Analysis Methods in Physics (3 cr)

Electives

Take 8 or more credit(s) from the following:

PHYS 4001—Classical Mechanics (4 cr)
PHYS 4011—Electromagnetic Theory (4 cr)
PHYS 4021—Quantum Physics II (4 cr)
PHYS 4031—Thermal and Statistical Physics (4 cr)

Technical Electives

The computational course not selected in Core Courses may be used as a technical elective. Engineering courses approved by the department may also be used.

Take 9 or more credit(s) from the following:

PHYS 5041—Optics (3 cr)
PHYS 5531—Introduction to Solid State Physics (3 cr)
PHYS 5541—Fluid Dynamics (3 cr)
LIM 5101—Physical Limnology (3 cr)
PHYS 5052—Computational Methods in Physics (3 cr)
or PHYS 5053—Data Analysis Methods in Physics (3 cr)

Courses From Other Programs

Two semesters of chemistry are recommended.

CS 1131—Introduction to Programming in FORTRAN, LE CAT3 (3 cr)
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
MATH 3298—Calculus III (4 cr)
CHEM 1151—General Chemistry I, LE CAT4 (5 cr)
or CHEM 1161—Honors: General Chemistry I, LE CAT4, H (5 cr)

Physics Minor

Physics

Required credits in this minor: 32.

The physics minor provides an introduction to classical and quantum physics.

Minor Requirements

Physics Minor Courses (32 cr)

MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
PHYS 1021—Exploring Current Topics in Physics (1 cr)
PHYS 2011—General Physics I, LE CAT4 (4 cr)
PHYS 2012—General Physics II (4 cr)
PHYS 2021—Relativity and Quantum Physics (4 cr)
PHYS 2022—Classical Physics (4 cr)
PHYS 2033—Classical and Quantum Physics Lab (2 cr)

PHYS 3xxx–5xxx

Take 3 or more credit(s) from the following:

PHYS 3xxx
PHYS 4xxx
PHYS 5xxx

Statistics and Actuarial Science B.S.

Mathematics and Statistics

Required credits to graduate with this degree: 120

Required credits within the major: 49 to 50

Statistics and actuarial science is concerned with generating and analyzing data. The statistics and actuarial science major trains students in theoretical, applied, and computational statistics used in a wide variety of disciplines. Advisers have information on the national actuarial examinations.

Honors Requirements: To graduate with department honors, a student must complete the program with an overall and department GPA of 3.50, satisfactorily complete a research project under the guidance of a faculty member, and convey research results in a public presentation.

Admission Requirements

For information about UMD admission requirements, visit the UMD Office of Admissions Web site.

General Requirements

In addition to the program-specific requirements listed below, all students are required to complete general University and college requirements including composition and liberal education courses. For more information, see the Liberal Education Program section of this catalog, and general degree requirements listed in each college section.

Recommended freshman writing course(s) for this program: COMP 1120—College Writing.

Program Requirements

Requirements for the B.S. in statistics and actuarial science include:

- Liberal education requirements
- Advanced writing requirement: COMP 31xx
- A minor in an area other than mathematics, or a second major

Statistical and Actuarial Science Core Courses (43 cr)

CS 1511—Computer Science I, LE CAT3 (5 cr)
MATH 3280—Differential Equations with Linear Algebra (4 cr)
MATH 3298—Calculus III (4 cr)
MATH 3941—Undergraduate Colloquium (1 cr)
STAT 3611—Introduction to Probability and Statistics (4 cr)
STAT 5511—Regression Analysis (3 cr)
STAT 5531—Probability Models (4 cr)
STAT 5571—Probability (4 cr)
STAT 5572—Statistical Inference (4 cr)
And one of the following course pairs:
MATH 1296—Calculus I, LE CAT2 (5 cr)
MATH 1297—Calculus II (5 cr)
or MATH 1596—Honors: Calculus I, LE CAT2, H (5 cr)
MATH 1597—Honors: Calculus II, H (5 cr)

Electives (6–7 cr)

Take 2 or more course(s) from the following:
MATH 3299—Intermediate Analysis (3 cr)
MATH 3355—Discrete Mathematics (4 cr)
MATH 4326—Linear Algebra (3 cr)