Michigan Engineers Make a Difference

The world is facing some big challenges, ranging from public health to health care, climate change to transportation and security. We need bold ideas and breakthrough solutions. Michigan Engineering graduates are prepared to be leaders. They are intellectually curious and socially conscious. They are ready to tackle society’s “wicked problems” while simultaneously serving the common good.

Educational Programs. The University of Michigan is the only institution with highly rated engineering, law, business, performing arts and medical schools. Michigan Engineering offers an impressive range of education programs and options, including:

- Top ten ranked graduate and undergraduate programs in nearly every engineering field
- 14 departments/divisions and 60+ fields of study
- Flexible, interdisciplinary degree programs for students who choose to customize their course of study
- Combined bachelor’s/master’s programs that enable students to earn both degrees in just five years
- Unique global study, travel, and work opportunities

For more College of Engineering facts and figures, please visit [www.engin.umich.edu/college/about/facts](http://www.engin.umich.edu/college/about/facts).

Office of Student Affairs
Chrysler Center
143 Chrysler Center
Ann Arbor, MI 48109-2092

About the Bulletin

The online College of Engineering Bulletin reflects the most up-to-date information available and is updated as changes are made to the curriculum. To view past versions of the College of Engineering Bulletin in Adobe Acrobat format, please visit our archives. Note: archived College of Engineering Bulletins are only applicable to that academic year’s course requirements. Please visit your advisor for more information or if you have any questions.

Students follow the rules of the College of Engineering Bulletin in effect for the academic term in which they begin their studies in the College of Engineering at the University of Michigan-Ann Arbor campus. Students who are readmitted into the College of Engineering at the University of Michigan-Ann Arbor campus follow the Bulletin in effect for the academic term in which they resume their studies.

The College of Engineering Bulletin reflects yearly curricular changes in the various degree programs. A student in a degree program that has degree requirement changes in a Bulletin produced during their academic career at the College of Engineering at the University of Michigan-Ann Arbor may follow a subsequent Bulletin. This determination, however, should be made in conjunction with the Program Advisor.

- [Academic Calendar & Deadlines](#)
- [Introduction and General Information](#)
- [Admissions](#)
- [Academic Rules](#)
- [Undergraduate Education](#)
- [Graduate Education](#)
Introduction to the College of Engineering 2021-2022 Online Bulletin

The online Bulletin reflects the most up-to-date information available and is updated as changes are made to the curriculum. To view past versions of the College Bulletin in Adobe Acrobat format, please visit our archives. Note: Archived bulletins are only applicable to that academic year’s course requirements. Please visit your advisor for more information, or if you have questions regarding this.

Students follow the rules of the College of Engineering Bulletin in effect for the academic term in which they begin their studies in the College of Engineering at the University of Michigan-Ann Arbor campus. Students who are readmitted into the College of Engineering at the University of Michigan-Ann Arbor campus follow the Bulletin in effect for the academic term in which they resume their studies.

The College of Engineering Bulletin reflects yearly curricular changes in the various degree programs. A student in a degree program that has degree requirement changes in a Bulletin produced during their academic career at the College of Engineering at the University of Michigan-Ann Arbor, may follow a subsequent Bulletin. This determination should be made in conjunction with the Program Advisor.

University of Michigan Regents and University of Michigan/College of Engineering Administration

The University of Michigan College of Engineering 2021-2022

The University of Michigan

Mark S. Schlissel, President
Debasish Dutta, Chancellor, University of Michigan-Flint
Sally J. Churchill, Vice President and Secretary of the University
Martino Harmon, Vice President for Student Life
Kevin Hegarty, Executive Vice President and Chief Financial Officer
Rebecca Cunningham, Vice President for Research
Domenico Grasso, Chancellor, University of Michigan-Dearborn
Timothy Lynch, Vice President and General University Counsel
Tom Baird, Vice President for Development
Kallie Bila Michels, Vice President for Communications

Susan M. Collins, Provost and Executive Vice President for Academic Affairs

Ravi Pendse, Interim Vice President for Information Technology and Chief Information Officer Marschall S. Runge, Executive Vice President for Medical Affairs

Cynthia H. Wilbanks, Vice President for Government Relations

College of Engineering

Alec Gallimore, Robert J. Vlasic Dean of Engineering Steve L. Ceccio, Associate Dean for Research

Mary-Ann Mycek, Associate Dean for Graduate and Professional Education

Joanna Millunchick, Associate Dean for Undergraduate Education

Michael Wellman, Associate Dean for Academic Affairs

The Regents of the University of Michigan

Jordan B. Acker, Huntington Woods

Michael J. Behm, Grand Blanc

Mark J. Bernstein, Ann Arbor

Paul W. Brown, Ann Arbor

Shauna Ryder Diggs, Grosse Pointe

Denise Ilitch, Bingham Farms

Ron Weiser, Ann Arbor

Katherine E. White, Ann Arbor

Mark. S. Schlissel (ex officio)
Table of Contents

Academic Calendar .............................................. 7
Introduction and General Information ................. 10
Undergraduate Admissions ................................. 18
Academic Rules, Rights and Responsibilities........ 32
Undergraduate Education—Mission Statement..... 66
Graduate Education—Mission Statement..............113
Sample Schedules and Course Descriptions...... 183
Aerospace Engineering .......................................149
Applied Physics............................................... 171
Biomedical Engineering.................................... 177
Chemical Engineering...................................... 193
Civil and Environmental Engineering ............... 209
Climate and Space Engineering .......................... 241
Electrical Engineering and Computer Science ....266
Engineering Education Research......................... 289
Engineering Physics....................................................... 289
Entrepreneurship Courses............................................. 291
Industrial and Operations Engineering...................... 293
Integrative Systems + Design Engineering................... 310
Macromolecular Science and Engineering................... 325
Materials Science and Engineering............................ 329
Mechanical Engineering.............................................. 338
Naval Architecture and Marine Engineering............... 368
Nuclear Engineering and Radiological Sciences. 378
Robotics Program ...................................................... 387
Engineering Division Courses.................................. 393
Military Officer Education Program Courses.............. 400
Technical Communications Courses ......................... 405
UARTS Courses .......................................................... 406
Academic Calendar
Academic Calendar

University of Michigan – Ann Arbor Campus Registrar’s Office: (734) 764-6280

FALL TERM, 2021
Classes begin..................................................Aug 30, Mon Labor Day
(Holiday)..........................................................Sept 6, Mon
Fall Study Break ..................................Oct. 18 - 19, Mon -Tues
Thanksgiving recess, 5:00 p.m. ......................Nov 23 Tues
Classes end......................................................Dec 10, Fri
Study Days ........................................Dec 11 - 12, Sat - Sun
Examinations ............................................Dec 13 - 17, Mon – Fri; Dec 20, Mon
Commencement ........................................ Dec 19, Sun

WINTER TERM, 2022
Classes begin.................................................Jan 5, Wed
Martin Luther King, Jr. Day ......................... Jan 17, Mon
University Symposia. No Regular Classes.
Vacation begins 12:00 noon.............................Feb 26, Sat
Classes resume............................................Mar 7, Mon
University Honors Convocation.....................Mar 20, Sun
Classes end....................................................Apr 19, Tues
Study Days ........................................Apr 20, Wed; Apr 23 - 24, Sat - Sun
Examinations ........................................ Apr 21 - 23, Thurs - Fri; Apr 25 - Apr 28, Mon - Thurs
Commencement Activities ............... Apr 28 - May 1, Thurs - Sun

SPRING-SUMMER TERM, 2022
Classes begin.............................................. May 3, Tues
Memorial Day (Holiday) ............................... May 30, Mon
Classes end (Spring Half) 5:00 pm. ...............June 20, Mon
Study Days ........................................June 21 - 22, Tues - Wed
Examinations ........................................ June 23 - 24, Thurs - Fri
Spring Half Term ends................................. June 24, Fri
Summer Half Term classes begin............... June 29, Wed
Independence Day (Holiday)............................July 4, Mon
Classes end 5:00 pm ..................................Aug 16, Tues
Study Day....................................................Aug 17, Wed
Examinations ........................................ Aug 18 - 19, Thurs - Fri
Full Term and Summer Half Term end ...........Aug 19, Fri

*Students enrolling in Business Administration, Dentistry, Law, Pharmacy, Social Work, and Medicine should check with their respective schools for academic calendar information including registration dates. This calendar is subject to change. **Jewish holy days begin and end at sundown on the first and last days listed. The University’s policy concerning observance of religious holidays can be found at http://www.umich.edu/~provost/dates/hdaymemo.html
Dearborn Campus – for registration and academic calendar information, visit:
http://www.umd.umich.edu/registration Flint Campus – for registration and academic calendar information, visit: ht
Graduate Deadlines

The academic calendar and course registration dates are the same for CoE and Rackham and can be viewed at http://ro.umich.edu/calendar/.

Please see the links below for information specific to your program:

Rackham Master’s and Certificate Apply for Graduation and Graduation Deadlines: http://www.rackham.umich.edu/students/navigate-degree/apply-for-graduation

Doctoral Degree Deadlines: http://www.rackham.umich.edu/students/navigate-degree/doctoral-degree-deadlines

Please Note: Apply for Graduation deadlines for the Master of Engineering (M. Eng.) and Doctor of Engineering (D. Eng) may differ from Rackham. Please consult: engin.pro.prgms@umich.edu with any questions.
Introduction and General Information
Introduction

Michigan Engineering is a place for a special kind of engineer. We welcome students from a diversity of backgrounds, who will flourish within an environment of wide-ranging possibilities. Our breadth of outstanding opportunities is unmatched.

Beyond excellent engineering research and teaching, a global footprint and significant resources, the University of Michigan College of Engineering provides the most well-rounded intellectual experience of any engineering institution. We aim to produce graduates who combine technical depth with lateral thinking and an ability to make an impact. And, we want our graduates to be globally competent engineers, through meaningful international experiences, broad exposure to diversity and development of communication and teamwork skills. We can create this unique environment because of a very special set of assets, including:

- Fourteen highly ranked engineering departments and divisions, and growing faculty headcount and student enrollment
- Extensive collaboration with our highly rated medical and business schools, and interactions with our top-notch art and design, architecture and music programs
- The country's first engineering/arts living-learning community
- Hundreds of student organizations and competitive teams, and the opportunity to learn under the tutelage of renowned professors of practice
- Major partnership with Shanghai Jiao Tong University, and other academic institutions on six continents
- One of the nation’s most successful centers of entrepreneurship.

Michigan Engineers are expected to become more than just great engineers. As well-balanced thinkers, they are challenged to lead teams, identify opportunities and solve complex problems requiring multidisciplinary approaches. Faculty with unconventional ideas are welcome in this innovative, dynamic and diverse enterprise, where tradition and experience are respected, but talent and results are rewarded.

The College of Engineering is committed to not only making certain that students enjoy a high quality educational experience, but that personal interactions, classroom experiences and research activities are free from harassing and discriminatory behaviors. We are striving to create a community where everyone can be heard, can get involved and can achieve to their full potential. Our goal is a welcoming environment of respect and courtesy for all members of our campus community. Further, we are determined to investigate and address any allegations of misconduct that might occur. This effort can be accomplished through increased awareness of issues, access to information and prompt action. We ask each member of the College of Engineering to commit to understanding, preventing, responding to and reporting harassment and discrimination. We are certain that through awareness, knowledge and diligence, our College can become a safer community for all of us. For more information and to learn how to report an incident, please visit the Office of Student Affairs at 143 Chrysler Center.
Michigan Engineering Mission

Michigan Engineering provides scientific and technological leadership to the people of the world. We seek to improve the quality of life by developing intellectually curious and socially conscious minds, creating collaborative solutions to societal problems, and promoting an inclusive and innovative community of service for the common good.

The mission of the University of Michigan is to serve the people of Michigan and the world through preeminence in creating, communicating, preserving and applying knowledge, art and academic values, and in developing leaders and citizens who will challenge the present and enrich the future.

Read more about Michigan Engineering’s vision, mission and values.

Michigan Engineering Goals

1. We will ensure that every Michigan Engineering student benefits from an educational experience that is among the finest in the world.
   
a. To provide an improving educational and research environment in which faculty, administrators, students and staff work together to educate our students to lead, to have impact and to make significant contributions to their professions, industry, government, academia and society.
   
b. To attract diverse, outstanding students and to motivate and educate them to reach their full potential as leaders in engineering professions.
   
c. To introduce academic innovations:
      1. New pedagogical methods and advanced tools for the delivery of preeminent engineering education
      2. Creative ways to empower our students with the critical skills and beyond-the-degree experiences required of the engineers who will invent our future
      3. New educational models for professional and continuing engineering education with global impact

Degree Programs

The College of Engineering offers undergraduate and graduate programs through the doctoral level. The undergraduate program consists typically of a four-year schedule leading to a bachelor’s degree. There are 17 courses of study that lead to the Bachelor of Science in Engineering degree (B.S.E.). By careful planning, an additional bachelor’s degree (B.S. or A.B.) can be earned within the College of Engineering or in combination with another college within the University of Michigan in about one year beyond the time required for a single degree. Completion of both an engineering baccalaureate and a master’s degree in approximately five years is also possible.

Areas of undergraduate study at the College of Engineering include:

- Bachelor of Science in Engineering
  - Aerospace Engineering
• Biomedical Engineering
• Chemical Engineering
• Civil Engineering
• Space Sciences and Engineering
• Climate and Meteorology
• Computer Engineering
• Computer Science
• Data Science
• Electrical Engineering
• Engineering Physics
• Environmental Engineering
• Industrial and Operations Engineering
• Materials Science and Engineering
• Mechanical Engineering
• Naval Architecture and Marine Engineering
• Nuclear Engineering and Radiological Sciences

Areas of graduate study include:
- Master of Science (M.S.)
- Master of Science in Engineering (M.S.E.)
- Master of Engineering (M.Eng)
- Doctor of Philosophy (Ph.D.)
- Doctor of Engineering (D.Eng)

Departments:
- Aerospace Engineering
- Biomedical Engineering
- Chemical Engineering
- Civil and Environmental Engineering
- Climate and Space Sciences and Engineering
- Electrical Engineering and Computer Science
- Industrial and Operations Engineering
- Materials Science and Engineering
- Mechanical Engineering
- Naval Architecture and Marine Engineering
- Nuclear Engineering and Radiological Sciences

Programs:
- Integrative Systems and Design:
  - Automotive Engineering
o Design Science
o Energy Systems Engineering
o Global Automotive and Manufacturing Engineering
o Manufacturing Engineering
o Systems Engineering + Design

- Applied Physics
- Engineering Sustainable Systems Dual Degree Program
- Macromolecular Science and Engineering
- Robotics

**Accreditation**

The Computer Science program is accredited by the Computing Accreditation Commission of ABET, [http://www.abet.org](http://www.abet.org).

The Aerospace, Biomedical, Chemical, Civil, Computer Engineering, Electrical, Environmental, Industrial and Operations, Materials Science and Engineering, Mechanical, Naval Architecture and Marine Engineering and Nuclear Engineering and Radiological Sciences programs are accredited by the Engineering Accreditation Commission of ABET, [http://www.abet.org](http://www.abet.org).

**The University of Michigan Nondiscrimination Policy Statement**

The University of Michigan, as an equal opportunity/affirmative action employer, complies with all applicable federal and state laws regarding nondiscrimination and affirmative action. The University of Michigan is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, national origin, age, marital status, sex, sexual orientation, gender identity, gender expression, disability, religion, height, weight, or veteran status in employment, educational programs and activities, and admissions. Inquiries or complaints may be addressed to the Senior Director for Institutional Equity, and Title IX/Section 504/ADA Coordinator, Office for Institutional Equity, 2072 Administrative Services Building, Ann Arbor, Michigan 48109-1432, 734-763-0235, TTY 734-647-1388, [institutional.equity@umich.edu](mailto: institutional.equity@umich.edu). For other University of Michigan information call 734-764-1817.

**Important Residency Information for Tuition Assessment Purposes**

The University of Michigan’s tuition structure is two-tiered, reflecting resident and nonresident rates. To be eligible to pay resident classification rates, a student must demonstrate compliance with the University's Residency Classification Guidelines, which can be found at [http://ro.umich.edu/resreg.php](http://ro.umich.edu/resreg.php). The University’s Guidelines differ from those of other schools and are independent of guidelines used by state authorities to determine residency for purposes such as tax liability, driving, voting, etc. Therefore, all students who believe they are eligible to pay resident rates must review “Circumstances Under Which You Must File A Residency Application” in the Guidelines to determine if they are required to file a separate Application for Residency
Classification. An Application for Resident Classification can be downloaded from the web site.

Michigan Engineering Offices
Michigan Engineering Offices (area code 734)
General Information:  
Academic Records and Services (Withdrawal/Disenrollment), 145 A Chrysler Center
CAEN (Computing & IT), Main Office, 2161 Duderstadt Center
CAPS Embedded Counselor, Engineering
Center for Engineering Diversity and Outreach (CEDO), 1108 LEC
Center for Entrepreneurship (CFE), 3350 Duderstadt Center
Engineering Career Resource Center (students and alumni), 230 Chrysler Center
Engineering Learning Center (ELC), 273 Chrysler Center
Engineering Advising Center (EAC), 230 Chrysler Center
Engineering Scholarship Office, 143 Chrysler Center
Engineering Student Organizations, 143 Chrysler Center
Integrative Systems + Design, 2214 SI-North
International Programs in Engineering Office (IPE), 245 Chrysler Center
Multidisciplinary Design Program (MDP), 203 Gorguze Family Laboratory
Office of Student Affairs (OSA), 143 Chrysler Center
Counseling, Assistance and Resources in Engineering Center (C.A.R.E Center), 129 Chrysler Center
Recruitment and Transfer Admissions, 153 Chrysler Center
Scholastic Standing Committee, 230D Chrysler Center
Undergraduate Education, 1261 LEC
Wilson Student Team Project Center
Women in Science & Engineering Program (WISE), 3236 Undergraduate Science Building

University of Michigan
University of Michigan Offices (area code 734)
Admissions, Undergraduate, 1220 Student Activities Bldg. (SAB)
Campus Information Center 764-INFO

Career Center, 3200 Student Activities Building (SAB) 764-7460

Cashier’s Office, 2226 Student Activities Building (SAB) 764-7447

Counseling and Psychological Services, 3100 Michigan Union (Union Renovation expected through Winter 2020) 764-8312

English Language Institute, 555 S. Forrest Ave. 764-2413

Employment:
- Student, 2500 Student Activities Building (SAB) 763-4128
- Hospital, 2901 Hubbard, Suite 1100 615-2000
- Recruitment and Employment, G250 Wolverine Tower 615-2000
- Temporary Staffing Services, G250 Wolverine Tower 763-5740

Financial Aid, 2500 SAB 763-6600

Graduate School, Rackham Bldg., 915 E. Washington Admissions 764-8129

Housing Information Services, 1011 Student Activities Building (SAB): 763-3164

International Center, Central Campus, 603 E. Madison 764-9310

International Institute, 1080 South University Ave., Suite 2660 763-9200

Ombuds, 6015 Fleming Bldg. 763-3545

Office of New Student Programs, 1100 LSA 764-6413
- Orientation
- University Mentorship Program
- Arts at Michigan
- Welcome to Michigan

Office of the President, 2074 Fleming Bldg. 764-6270

Office of the Provost, 3074 Fleming Bldg. 764-9290

Office of Student Conflict Resolution, 100 SAB 936-6308

Office of the Vice President and Secretary of the University, 2013 Fleming Bldg. 763-5553

Services for Students with Disabilities (SSD), G-664 Haven Hall 763-3000

Student Financial Operations (Room, Board, and Tuition), 2226 SAB 764-7447
**Student Activities and Leadership**, 2205 Michigan Union *(Union Renovation expected through Winter 2020)*  
763-5900

**Student Legal Services**, 715 N. University, Suite 202  
763-9920

**University Health Service**, 207 Fletcher  
764-8325

- **Appointments**  
- **Information**  

**Veterans and Military Services Program (VMSP)**, 1100 LSA  
764-6413

- Veterans Benefits, **Office of the Registrar**, 1207 LSA  
763-9066

**Archived Bulletins**

- [2020-2021 Bulletin (PDF)](#)
- [2019-2020 Bulletin (PDF)](#)
- [2018-2019 Bulletin (PDF)](#)
- [2017-2018 Bulletin (PDF)](#)
- [2016-2017 Bulletin (PDF)](#)
- [2015-2016 Bulletin (PDF)](#)
- [2013-2014 Bulletin (PDF)](#)
- [2012-2013 Bulletin (PDF)](#)
- [2011-2012 Bulletin (PDF)](#)
- [2010-2011 Bulletin (PDF)](#)
- [2009-2010 Bulletin (PDF)](#)
- [2008-2009 Bulletin (PDF)](#)
- [2007-2008 Bulletin (PDF)](#)
- [2006-2007 Bulletin (PDF)](#)
- [2005-2006 Bulletin (PDF)](#)
- [2004-2005 Bulletin (PDF)](#)
- [2003-2004 Bulletin (PDF)](#)
Undergraduate Admissions
Who May Apply

Undergraduate Admissions

To be admitted at the first-year level, an applicant must be a graduate of an accredited secondary school. Graduates of unaccredited schools will be asked to take College Board Achievement Tests or the ACT.

Home-schooled students and students attending unaccredited high schools should contact the Office of Undergraduate Admissions prior to September of their senior year to determine if additional credentials such as SAT II Subject Exams should be submitted.

For older students, the results of the General Education Development (GED) test may be presented in place of a high school diploma.

Advanced Placement

Many students take Advanced Placement courses through the Advanced Placement Program in their high schools. Credit for these courses can be applied toward a degree, provided the student has performed satisfactorily on the Advanced Placement Program examination conducted nationally by the College Entrance Examination Board. Students are not eligible if they are already enrolled in college level courses. This does not apply to dual enrollment credit taken while in high school.

By Website
https://apstudent.collegeboard.org/home (U-M code is 1839)

See information of how credit will be awarded: Undergraduate Admissions

All other questions about Advanced Placement should be referred to Engineering Advising Center, 230 Chrysler Center, College of Engineering, University of Michigan, Ann Arbor, MI 48109-2092. (Phone: 734-647-7106, Email: eac.advising@umich.edu)

International Baccalaureate (IB) Examinations

To receive credit for International Baccalaureate (IB) examinations, an official transcript of examination grades must be officially sent by the IB Office directly to the Office of Undergraduate Admissions. Contact the International Baccalaureate Organization to submit scores to the University of Michigan-Ann Arbor electronically. The Office of Undergraduate Admissions only awards credit for IB Higher Level examinations. Please note: guidelines are subject to change and are current as of 2019.
**College Level Examination Program (CLEP)**

The faculty at U-M will not accept any of the CLEP general exams. However, CoE students can earn credit by taking the following CLEP subject exams:

- General Chemistry: a minimum score of 47 would allow 3 hours of Chemistry 100-level departmental credit (CHEM 101x)
- General/Introductory Psychology: a minimum score of 47 would allow 4 hours of Introductory Psychology credit (PSYCH 111)
- Human Growth and Development: a minimum score of 45 would allow 3 hours of Psychology departmental credit (PSYCH 101x)
- Introductory Sociology: a minimum score of 47 would allow 4 hours of Introductory Sociology credit (SOC 100)

Note that only the objective test needs to be taken. The test score must come from an official CLEP score report from the testing agency. U-M is NOT a testing center for any CLEP exams. Similar to AP exams, the four CLEP exams outlined above must be taken by the student before entering college in order to qualify. For any question, the Transfer Credit Evaluation Office should be consulted at engincredit@umich.edu.

**University Placement Examinations**

There are a number of courses for which credit may be received by getting a satisfactory score on a Placement Examination offered by a department of the University. Language credit earned by U-M examination will be posted under the admitted term even though the student may choose to take it at a later term.

Note: No credit is granted for math and chemistry placement exams given before or during orientation. The purpose of these exams is to determine your preparation for these entry level courses.

**Foreign Languages**

Credit by test (e.g. Advanced Placement, A-Level and International Baccalaureate) can be used to satisfy Intellectual Breadth requirements except for the 3-credit humanities requirement. Foreign language credit by test at the 200-level or higher can count toward the LAC requirement but not the 3-credit humanities requirement. Foreign language credit by test at the 100-level can be used for General Electives only. In addition, language credit by test is limited to 8 credits.

CoE will grant credit for students passing a language placement test offered by the College of LSA provided the student has previously studied that language in a course in their secondary education. This will be verified using their high school or college transcripts.

“Study of a language in a course” means a student took coursework designed to teach them the fundamental vocabulary, grammar, pronunciation and writing system of that language as a foreign language, as opposed to a class in literature, argumentative or essay writing, or creative writing in a language whose fundamentals they already knew.
The CoE values the study of language, so even when credit might not be granted, students are encouraged to take any language placement test for which they may be qualified, so that they can be properly placed in a more advanced language course.

Incoming first-year students who took a course(s) at a college or university while dually enrolled in high school may potentially receive transfer credit.

Transfer Credit for Entering First-Year Students

Incoming first-year students who took a course(s) at a college or university while dually enrolled in high school may potentially receive transfer credit. Students seeking approval to transfer credit are required to submit an official transcript from the accredited college/university. An official transcript should be mailed directly to the Office of Admissions, 1220 Student Activities Building, 515 E. Jefferson Street, Ann Arbor, MI 48109-1316, from the college/university.

More info at our website: http://www.engin.umich.edu/college/academics/undergrad/transfer/dual-enroll

An evaluation of the previous record from the transfer institution will be made at the time of application review to provide a preliminary assessment of the credit that will be transferred toward a bachelor’s degree in the program specified by the applicant. This appraisal is subject to review by representatives of the departments involved and by the student’s intended program advisor. The transfer credit may be revised if the academic progress of the student indicates that the student is unable to continue successfully because of an inadequate preparation.

Credits are granted only for transferable courses in which a grade of “C” or better is earned. A “C-” will be accepted only if earned on the University of Michigan-Ann Arbor campus for courses other than math, science, engineering or other prerequisites for admission. Classification level is determined by the number of hours transferred. Most transfer students enroll with approximately 60-65 credit hours.

Students can request that credits be transferred from their previous institution to the U-M transcript at any time, but credits will be posted on the U-M transcript under the term admitted to the College of Engineering. This can have a retroactive tuition impact. Transferred credit will not be removed from the transcript for the purpose of lowering tuition. New students are responsible for reviewing their transcript when credits are posted and asking for removal of any transferred credits within their first term at the CoE University of Michigan.

The U-M transcript of transfer students will not reflect grades earned while enrolled in an external institution. The transfer student’s GPA is determined solely by the grades earned while enrolled in the College of Engineering. This does not apply to students transferring from other academic units located on the Ann Arbor campus of the University. If, at any time, a transfer student has questions regarding the transfer of credit, the Transfer Credit Evaluation Office should be consulted at engincredit@umich.edu.
If a student is interested in taking coursework outside of the University of Michigan to complete their degree requirements, this may push back the term in which the student may confer their degree, if the student has not made reasonable effort to transfer the credit in a timely manner. Often other institutions do not share the same academic calendar as U-M and we are left waiting for the course to transfer to U-M. Please note that the work must be completed in the term in which the student has applied to graduate. For example, if the student completes a course on June 15, which is the end of the winter term at another institution, but well into spring term at U-M, this student would not have completed the work in winter term and would need to apply for a summer degree conferral.

Cross-Campus Transfer

Cross-Campus Transfer to the College of Engineering

A Cross-Campus transfer student is a student who was admitted as a first year student into another academic unit on the University of Michigan’s Ann Arbor campus and wishes to pursue studies in the College of Engineering.

To be Considered for Admission

Cross-Campus applicants are required to complete the following courses with a C+ or better: Math 115, Math 116, Math 215 (if AP credit is given for Math 115 and/or Math 116), Physics 140/141L, Chemistry 130/125L/126L or Chemistry 210/211L, Engineering 101 or EECS 183, and a course that is approved to fulfill the First Year Writing Requirement (FYWR).

Cross-Campus applicants must also maintain a minimum of a 2.5 cumulative GPA and have completed fewer than 55 credits towards their degree (excluding AP/IB credit and prerequisite courses) to be considered. An Engineering GPA, calculated exclusively from the prerequisite courses, must also be above a 2.5 to be considered for admission. Students cannot be admitted or considered for admission if they are on Academic Probation of any kind. Students that receive an incomplete grade and must go before the Scholastic Standing Committee cannot be admitted until the Scholastic Standing Committee makes a decision regarding the case and a grade is entered onto the transcript. This requirement is effective as of Fall 2019.

Note: A Cross-Campus applicant that completes the required courses and is above a 2.5 is not guaranteed admission into the College of Engineering.

Students above 55 credits, excluding AP/IB credit and the prerequisite courses must go through the Scholastic Standing Committee and petition for an exception to the College Rules: https://elc.engin.umich.edu/exceptions-to-college-rules/.
Bachelor's Degree Holders Seeking a Second Bachelor's Degree

Students already in possession of a bachelor's degree should consider a master's degree or PhD in engineering. The College of Engineering will admit second bachelor degree students in very rare and exceptional circumstances and if there is room at the transfer level. The College of Engineering will prioritize students seeking their first bachelor's degree. Before pursuing this path, please contact the Office of Recruitment and Admissions.

The Office of the Associate Dean for Undergraduate Education will have ultimate authority to decide if a candidate’s prior degrees are too similar to a proposed degree to allow admission or declaration.

For students who have previously earned a bachelor’s degree and elect to pursue admission for an additional bachelor’s degree, the following rules and policies apply:

In order to be qualified for a second bachelor’s degree, candidates should have taken Calculus 1 and 2, Physics 1, Chemistry, English Composition and Computer Programming, C++, at an institution of higher education and have an academic record that suggests high levels of accomplishment. These courses can have been completed as part of their original degree, but could also have been taken for other reasons. They should have been completed no more than ten (10) years before admission, and ideally less than seven (7) years prior to admission.

Coursework from the student’s previous academic record, including credits used to satisfy requirements for a previous degree, will be eligible for entry on the U-M academic record. Credits will not be transferred if they were used to satisfy more than one prior degree (no counting of credits between three (3) or more degrees).

To graduate, students must successfully complete all of the degree requirements in place at their term of admission, using the appropriate combination of transfer and U-M credit. Program advisors can allow substantially equivalent substitutions from transferred courses. Students with a previous engineering degree must complete an additional fourteen (14) credits hours in pertinent technical subjects in addition to meeting all degree requirements.

A bachelor’s degree holder admitted into the College of Engineering seeking a second bachelor’s degree will be a senior when there are thirty-five (35) hours or fewer to complete.

Undergraduate Readmission

A student who is not enrolled for 12 months or more must apply for readmission through the Office of Recruitment and Admissions, and should do so at least two months before the date of desired enrollment. Students can apply for Fall or Winter term readmission. Readmission into Spring or Summer terms will only be considered with the express approval of the appropriate advisor (Engineering Advising Center for undeclared...
students or the home department advisor for declared students). Readmitted students are subject to the rules in effect at the time of readmission.

Readmitted international students requesting F-1 or J-1 Visa status must also submit required documentation. For additional information on required documentation or to request an Application for Readmission, please contact the Office of Recruitment and Admissions, 153 Chrysler Center, 2121 Bonisteel Boulevard, Ann Arbor, MI 48109-2092 (734) 647-7101 or at enginrta@umich.edu.

Students who have graduated from the College and wish to elect courses for an additional term must apply as a Non-Candidate For Degree through the Office of Recruitment and Admissions.

A student whose enrollment has been withheld because of poor academic performance must first petition for Reinstatement to the Scholastic Standing Committee: https://www.engin.umich.edu/students/scholasticstanding/petitions.html.

Special Student Status ● Undergraduate Non-Candidate for Degree (NCFD) ● NCFD Status for Students from Other Colleges and Universities ● NCFD Status for Graduates of the College of Engineering ● Unclassified Status ● International Exchange Students from CoE Partner Institutions Undergraduate Non-Candidate for Degree (NCFD) The NCFD status is for those individuals who are approved to take courses in the College of Engineering in a non-degree capacity. Such students are designated as unclassified. NCFD Status for Students from Other Colleges and Universities A student from another college or university who seeks enrollment as a non-candidate for degree (NCFD) must meet the same academic standards of admission as a degree-seeking application for transfer admissions. NCFD applicants should contact the Office of Recruitment and Admissions to request an application. A complete application will include: ○ a completed application form ○ official transcripts from previous colleges or universities ○ written permission from instructors of classes in which you intend to enroll (applicant is responsible for obtaining this documentation) Instructors are responsible for assessing the academic standard of admission. Once an applicant has been evaluated and approved for admission, the applicant will be notified of their NCFD admission status. Registration for courses can only be done on or after the first day of classes for the term of admission. If more than one term is requested, the student cannot register for the subsequent term until his or her academic record has been reviewed and approved by an admissions counselor and the engineering departmental program advisor. NCFD Status for Graduates of the College of Engineering A graduate with a conferred bachelor’s degree from the College of Engineering who desires to take courses with NCFD status can request processing for enrollment by obtaining written approval from the program advisor for the department in which they intend to take course(s) and submitting an application for readmission to the Office of Recruitment and Admissions. The instructor(s) of the course(s) in which the student intends to enroll must also grant written permission. Approval to register is granted for one term only. The enrollment status is designated as unclassified. Course registration for individuals with special student status should not be done prior to the first day of classes. The engineering department from which the degree was conferred will also be notified of the NCFD status. Unclassified Status When a student is no longer a candidate for a degree from
the College of Engineering but is planning to transfer into another field of study, the student will be advised by the Engineering Advising Center to arrange for registration for an additional term in the College of Engineering on an “Unclassified” status.

International Exchange Students from CoE Partner Institutions

Undergraduate students from CoE partner institutions may apply to study at the U-M for one or two terms. The CoE also accepts exchange student applications through the Global Engineering Education Exchange (GE3) program. Prospective exchange students must be nominated by their home institutions and all applications are coordinated by the International Programs in Engineering (IPE) office, 245 Chrysler Center, 2121 Bonisteel Boulevard, Ann Arbor, MI 48109-2092. Prospective students should inquire with their home institution’s international exchange office.

Special Student Status

Undergraduate Non-Candidate for Degree (NCFD)

The NCFD status is for those individuals who are approved to take courses in the College of Engineering in a non-degree capacity. Such students are designated as unclassified.

NCFD Status for Students from Other Colleges and Universities

A student from another college or university who seeks enrollment as a non-candidate for degree (NCFD) must meet the same academic standards of admission as a degree-seeking application for transfer admissions.

NCFD applicants should contact the Office of Recruitment and Admissions to request an application. A complete application will include:

- a completed application form
- official transcripts from previous colleges or universities
- written permission from instructors of classes in which you intend to enroll (applicant is responsible for obtaining this documentation

The instructors are responsible for assessing the academic standard of admission.

Once an applicant has been evaluated and approved for admission, the applicant will be notified of their NCFD admission status.

Registration for courses can only be done on or after the first day of classes for the term of admission. If more than one term is requested, the student cannot register for the subsequent term until his or her academic record has been reviewed and approved by an admissions counselor and the engineering departmental program advisor.

NCFD Status for Graduates of the College of Engineering

A graduate with a conferred bachelor’s degree from the College of Engineering who desires to take courses with NCFD status can request processing for enrollment by
obtaining written approval from the program advisor for the department in which they
intend to take course(s) and submitting an application for readmission to the Office of
Recruitment and Admissions. The instructor(s) of the course(s) in which the student
intends to enroll must also grant written permission. Approval to register is granted for
one term only. The enrollment status is designated as unclassified. Course registration
for individuals with special student status should not be done prior to the first day of
classes. The engineering department from which the degree was conferred will also be
notified of the NCFD status.

Unclassified Status

When a student is no longer a candidate for a degree from the College of Engineering
but is planning to transfer into another field of study, the student will be advised by the
Engineering Advising Center to arrange for registration for an additional term in the
College of Engineering on an “Unclassified” status.

International Exchange Students from CoE Partner Institutions

Undergraduate students from CoE partner institutions may apply to study at the U-M for
one or two terms. The CoE also accepts exchange student applications through the
Global Engineering Education Exchange (GE3) program. Prospective exchange
students must be nominated by their home institutions and all applications are
coordinated by the International Programs in Engineering (IPE) office, 245 Chrysler
Center, 2121 Bonisteel Boulevard, Ann Arbor, MI 48109-2092. Prospective students
should inquire with their home institution’s international exchange office.

Degree Requirements

Requirements for a Bachelor’s Degree

To obtain a bachelor’s degree in the College of Engineering, Ann Arbor campus, 128 credit hours
must be earned and a student shall meet the following requirements, subject to approval of the
program advisor:

1. The student must achieve a satisfactory level in those subjects specified by the program of
his or her choice. A grade of “D” in a required course may not be considered satisfactory
unless approved by the program advisor. In some programs, a grade of “C-” is likewise not
considered satisfactory. A student may receive credit toward a degree in one or more of the
following ways:
   o By passing a course for credit on the Ann Arbor campus (“C-” or “D” grades may not
     be acceptable as a proper level of attainment for a required course, as noted above.)
   o By Advanced Placement Program examination for college-level work completed in
     high school (See “Advanced Placement,” under “Admission.”)
   o By an examination regularly offered by a department of the University, or by a
     recognized testing service,
   o By transfer of equivalent credit from another recognized college (See “Adjustment of
     Advanced Credit.”)
o By demonstrating competence in a higher-level course or series covering similar material (e.g., honors-level,)

o By demonstrating equivalent and parallel knowledge that enables the student to enroll at an advanced level. In this case, the student will not be allowed credit hours on the transcript, but may be excused from enrolling in courses in which the program advisor judges the student proficient. To qualify, the student must petition the program advisor and, as a condition, may be required to demonstrate his or her proficiency by an appropriate examination.

2. The student must accumulate a final grade point average of 2.00 or more for all credit hours not taken under the pass/fail option while enrolled in the College of Engineering. In addition, a student must earn a cumulative grade point average of 2.00 or higher in all courses taken within the student’s academic department. Consult your department for additional information.

3. The student must complete at least 50 credit hours of coursework offered by the University of Michigan-Ann Arbor campus. This course work must generate credits towards program (CTP) on the student’s transcript. A few courses, for example, ENGR 196, ENGR 301 and ENGR 400, do not generate CTP.

4. The student must complete a minimum of 30 credit hours of advanced level (300 or higher) technical courses, as required by the degree program, offered by the College of Engineering, Ann Arbor campus. This course work must generate credits towards program (CTP) on the student’s transcript. A few courses, for example, ENGR 301 and ENGR 400, do not generate CTP.

5. The College of Engineering does not allow a single class to meet the program requirements of both a CoE degree program and two or more other degree programs, regardless of school or college in which the latter degrees are offered.

6. The student must file formal application for the diploma. (See “Diploma and Commencement” below.)

Time Requirement

The time required to complete a degree program depends on the background, abilities, and interests of the individual student. Note: A full-time schedule averaging 16 hours of required subjects will allow a student to complete the degree requirements (128 credit hours) in eight terms as noted in the sample schedules appearing with the program descriptions.

A student who is admitted with advanced preparation, with demonstrated levels of attainment, or with ability to achieve at high levels may accelerate his or her progress. A student who is partially self-supporting while at the campus may find it desirable to plan a schedule longer than eight terms.

A student who plans to continue studies beyond the bachelor’s degree may (after attaining senior standing) elect a limited number of graduate-level courses concurrently with the courses required for the bachelor’s degree. A course required for the bachelor’s degree generally cannot be used for graduate credit also, except as allowed by the Sequential Undergraduate/Graduate Studies program. For details, refer to the regulations published by the University of Michigan Horace H. Rackham School of Graduate Studies.

Requirements for an Additional Bachelor’s Degree

Additional bachelor’s degrees can be conferred in the College of Engineering, Ann Arbor campus.
1. Students in other U-M schools or colleges wishing to be admitted to the College of Engineering as a dual-degree student must:
   1. Be admissible to CoE (i.e., meet cross campus admissions criteria, including prerequisite courses and minimum GPA, and be eligible to declare a major)
   2. Have completed one year on the Ann Arbor campus (one term if originally admitted as an external transfer student)
   3. Be in good academic standing

2. To obtain additional bachelor’s degrees in the College of Engineering, a student must complete the requirements of each of the degree programs. Furthermore, for each additional degree, the student must complete at least a minimum of 14 additional credit hours in pertinent technical subjects. Approval by involved departments is required.

3. Students are encouraged to carefully consider whether a relevant graduate degree would be more appropriate than a second undergraduate degree. Students are strongly discouraged from declaring three (or more) undergraduate majors, and may not use the same course to meet the program requirements of both an Engineering degree program and two or more other degree programs, regardless of school or college in which the latter degrees are offered.

4. To obtain an additional degree with a school or college on the University of Michigan-Ann Arbor campus, refer to the program requirements under Combined Programs for details.

Double Counting Courses

For Engineering Undergraduate students:

1. No course can count towards more than two degrees, such as two bachelor’s degrees or one bachelor’s degree and one master’s degree.
2. No course can count towards more than two majors, and no more than one major and one minor. A course can only count toward two minors if the credits received for that course are beyond the 128 credits required for the student’s major.
3. A course can count toward Supplemental Studies, Concentrations/Sub-Plans or Honors Programs regardless of how many majors or minors it is already counting towards.
4. SUGS (Sequential Undergraduate Graduate Studies) students who are pursuing a Rackham or College of Engineering master’s degree can only double count courses that are considered general electives or technical electives and are not part of the core requirement. The number of credits allowed to double count is determined by the individual departments, with 9 credits being the maximum allowed by Rackham. MDDP (Multiple Dependent Degree Program, typically referred to as Dual Degree) students are not eligible for the SUGS program.
5. Non-SUGS students pursuing a master’s degree from Rackham or the College of Engineering, cannot transfer any credits used for their bachelor’s degree, even free electives or tech electives, toward their master’s degree. They may only transfer credits from courses that were not used to fulfill requirements for a degree or certificate (verified by an Undergraduate Program Advisor). Furthermore, the transferred credits must be from graduate-level courses and Rackham must receive confirmation (from their Graduate Coordinator) that these courses were at the graduate level and required graduate-level effort.

Substitution
Substitution of a course for one which is a requirement for graduation must be approved by the program advisor of the student’s degree program.

Application for Graduation, Diploma and Commencement

An undergraduate student must apply for graduation through Wolverine Access and select the term in which they are reasonably certain of completing the graduation requirements for the degree. This action should be done at the beginning of said term, **but no later than the last day of classes for the term.**

An undergraduate student completing the graduation requirements for a College of Engineering degree and a second degree either from the College of Engineering or a Multiple Dependent Degree Program (MDDP) with one of the other schools/colleges on the University of Michigan – Ann Arbor campus must apply for graduation through Wolverine Access for each degree and select the same graduation term for each degree. Both degrees must be awarded in the same term or neither degree is awarded.

If a student does not meet the graduation requirements for the degree or degrees, the student must re-apply for graduation through Wolverine Access and select the appropriate term. Degrees are awarded at the end of the Fall, Winter, and Spring/Summer terms.

The Late Application for Graduation (paper form) will only be used for “extreme extenuating circumstances beyond the student’s control.” These will not include forgetting to apply for graduation, not knowing the College of Engineering policies, or waiting for transfer credits from another institution. These scenarios would require the student to apply for graduation for the next term.

Diplomas are handled by the University Office of the Registrar, Diplomas, and any questions or concerns should be directed there either by phone at (734) 764-8280 or email at ro.diploma.staff@umich.edu

The University Commencement is held twice a year in the winter and spring. The College of Engineering Graduation Ceremony is held in the spring. Students who want their names printed must apply for graduation through Wolverine Access by the posted and announced deadline; a specific date in October for the Winter University Commencement Program and a specific date in March for the Spring University Commencement Program and the College of Engineering Graduation Program.

The Winter University Commencement is intended for students who have:

- Completed their graduation requirements in the previous Spring, Spring/Summer, or Summer term
- Will complete their graduation requirements in the Fall term and have applied to graduate in the Fall term by the specific date in October
- Plan to complete their graduation requirements in the upcoming Winter term and have applied to graduate in the Winter term by the specific date in October because they cannot attend the Spring University Commencement (name will NOT be listed in the program)

For more information, please go to: [http://commencement.umich.edu](http://commencement.umich.edu)

The Spring University Commencement is intended for students who have:
• Completed their graduation requirements the previous Fall term (name will NOT be listed in the program)
• Will complete their graduation requirements in the Winter term and have applied to graduate in the Winter term by the specific date in March
• Plan to complete their graduation requirements in the Spring, Spring/Summer, or Summer term and have applied to graduate in the Summer term by the specific date in March

For more information, please go to: http://commencement.umich.edu

The Spring College of Engineering Graduation Ceremony is intended for students who have:

• Completed their graduation requirements the previous Fall term
• Will complete their graduation requirements in the Winter term and have applied to graduate in the Winter term by the specific date in March
• Plan to complete their graduation requirements in the Spring, Spring/Summer, or Summer term and have applied to graduate in the Summer term by the specific date in March

For more information, please go to: http://graduation.engin.umich.edu

Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

How to Read a Course Description

Courses and course descriptions are listed under each degree program. Course titles and numbers, prerequisites, other notes, credit hours and descriptions approved by the College of Engineering Curriculum Committee are included in this Bulletin.

Schedules of classes are issued separately by the office of the Registrar, giving hours and room assignments for the courses and sections offered each term. The schedule of classes can be found at: http://www.umich.edu/~regoff/schedule/

What the Course Number Indicates

The number of each course is designated to indicate the general level of maturity and prior training expected.

<table>
<thead>
<tr>
<th>100</th>
<th>First-year-level courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>Sophomore-level courses</td>
</tr>
<tr>
<td>300</td>
<td>Junior-level courses</td>
</tr>
<tr>
<td>400*</td>
<td>Senior-level courses</td>
</tr>
<tr>
<td>500</td>
<td>Predominantly Graduate-level courses</td>
</tr>
<tr>
<td>600</td>
<td>Graduate-level courses and above</td>
</tr>
</tbody>
</table>

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

In general, the prerequisites listed for a course designate specific subject materials and/or skills the
student is expected to have mastered before electing the course (or, in some cases, concurrently
with it).

*A 400-level course listed in the Bulletin of the Horace H. Rackham School of Graduate Studies may
be elected for graduate credit when this is approved by the student’s graduate program advisor.

Course Equivalency

Unless otherwise stated, the phrase “or equivalent” may be considered an implicit part of the
prerequisite for any course. When a student has satisfactorily completed a course that is not listed
but is believed to be substantially equivalent to one specified as a prerequisite for a course that the
student wants to elect, the individual may consult the program advisor and upon determining if
equivalency has been satisfied, election may be approved.

Permission of Instructor

The phrase “or permission of instructor (or department)” may be considered an implicit part of the
statement of prerequisites for any course. When permission is a stated requirement, or when a
student does not have the stated prerequisite for a course but can give evidence of background,
training, maturity or high academic record, the student should present to the program advisor a note
of approval from the instructor or department concerned.
Academic Rules, Rights and Responsibilities
Academic Rules, Rights and Responsibilities

General Standards of Conduct for Engineering Students

In establishing a standard of student conduct, the University of Michigan is committed to the basic principles of entrusting all students with a high degree of freedom to govern their lives and conduct while enrolled at the University.

Being a successful member of the College of Engineering community involves intense, spirited and innovative collaboration with groups of people from diverse backgrounds. Therefore, the College of Engineering embraces a spirit of acceptance and understanding so that our community enjoys a high quality educational and work experience that contributes not only to our technical expertise and accomplishments, but to our ability to interact effectively as a team across disciplines, perspectives, cultures and around the globe. Our goal is a welcoming environment of respect and courtesy for all members of our campus community. This goal depends on the active involvement of all of our community members to create an environment that values diversity and fosters intercultural skills.

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

Students are expected to respect the rights and property of others and to comply with University regulations and public laws.

The College of Engineering welcomes the participation of students in decision making relevant to their affairs and provides channels of communication, both at the College and department level, for that purpose. To benefit from such activity, each student should recognize the responsibility to fellow students and to the faculty and staff, and should discharge all duties with the standards that make such student-college relationships effective and valuable.

The College of Engineering reserves the right to discipline, exclude from participation in relevant activities, or dismiss any student whose conduct or performance it considers in violation of its standards. Such a decision will be made only after review by the appropriate student and faculty committees. During this review, the student will have full opportunity to present his/her/their position. A student also has the right of appeal to the Executive Committee of the College.

The Honor Code of the College of Engineering (below) bears witness to the deep trust that characterizes student-faculty relationships in one of the most important aspects of student conduct.

Honor Code

The engineering profession has a long-standing record of fostering high standards of integrity in the performance of professional services. Not until the 1930s, however, was the first Canon of Ethics for Engineers developed and adopted by national professional
engineering societies. The Fundamental Canons, as they appear on the National Society of Professional Engineers website (http://www.nspe.org/Ethics/CodeofEthics/index.html) states “Engineers, in the fulfillment of their professional duties, shall:

**Fundamental Canons**

1. Hold paramount the safety, health and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically and lawfully so as to enhance the honor, reputation and usefulness of the profession.”

In 1915, the students of the College of Engineering proposed an Honor Code. This was approved by the faculty in 1916 and has been in effect since its inception. The Honor Code is a distinguishing feature of the College of Engineering.

**Applications of the Honor Code**

The Honor Code holds that students are honorable, trustworthy people and encourages them to behave with integrity in all phases of University life. By conforming to the Code, students do their work in an environment conducive to establishing high standards of personal integrity, professional ethic, and mutual respect.

As a basic feature of the Code, students are placed upon their honor during all examinations, written quizzes, computer questions, homework, laboratory reports and any other work turned in for credit, as required by the instructor. During examinations, the instructor is available for questions, but the examination is not proctored. As a reminder of the Honor Code, the student is asked to write and sign the following pledge on the examination paper:

“I have neither given nor received aid on this examination, nor have I concealed a violation of the Honor Code.”

The Honor Code remains in force whether or not the student signs the pledge, but an instructor is not obligated to grade an examination without a signature.

With regard to assignments made in class, each class/professor may have a different policy regarding what constitutes an Honor Code violation and this policy should be clearly outlined in the syllabus for the course. If a student is in doubt, the professor responsible for the course should be asked for clarification. In particular, be aware that some professors allow and/or encourage group work, while others may not even allow discussion of homework problems.

In general, the principles of the Honor Code also apply to homework when the instructor requires that the material be turned in for grading. While independent study is recognized as a primary method of effective learning, some students may find that they benefit from studying together and discussing homework assignments and laboratory
experiments. When any material is turned in for inspection and grading, the students should clearly understand whether, and to what degree, collaboration among students is permitted by the instructor. In some courses, full collaboration is allowed, while in other courses each student must work completely independently. The instructor may require the signing of the pledge on homework assignments and expect the same high standards of integrity as during examinations.

It is always required that ideas and materials obtained from another student or from any other source be acknowledged in one’s work. The latter is particularly important, because material is so freely available on the Internet. According to Merriam-Webster online dictionary, to plagiarize is “To steal and pass off (the ideas or words of another) as one’s own.” To avoid plagiarism, it is necessary to cite all sources of both ideas and direct quotations, including those found on the Internet. The Department of English web site and the University Library handout provide thorough discussions of plagiarism: https://lsa.umich.edu/english/undergraduate/advising/note-on-plagiarism.html

The Honor Code Process

Either a student or the instructor may report a suspected Honor Code violation by contacting the Honor Code Representative to the Associate Dean for Undergraduate Education: Tomika White, Office of Retention and Academic Support Services, 273 Chrysler Center 2029, honorcouncil-admin@umich.edu. Suspected Honor code violations must be reported no later than two months after the term in which the violation occurred.

The accusation is then investigated by the Engineering Honor Council, and if wrongdoing is found, a recommendation is sent to the Faculty Committee on Discipline (FCD). The FCD holds a hearing at which the student is asked to appear and testify on his/her/their own behalf. After the hearing (whether or not the student attends), the FCD reviews the recommendation made by the Honor Council, decides if an Honor Code violation has occurred and determines an appropriate sanction, if so. The Honor Code Representative to the Associate Dean for Undergraduate Education then notifies the student of the FCD’s decision.

Typical sanctions for a first violation may include a zero on the assignment, a reduction in grade for the course and community service. For especially serious or repeated violations of the Honor Code, the sanctions may also include suspension or expulsion from the College of Engineering. The student may appeal the FCD’s decision to the Executive Committee of the College of Engineering.

A student wishing to admit responsibility may elect to participate in an expedited process:

1. A respondent with no previous Honor Code violations that resulted in a finding of responsibility, who also accepts responsibility for the alleged violation, may elect an expedited hearing process.
2. This process is available to any student in a College of Engineering course who has not already been found responsible for an Honor Code violation.
3. A student electing to participate in the expedited hearing process is accepting responsibility formally for the alleged violation.
4. A standard punitive sanctioning policy will be used in developing restorative action plans for student respondents. (Typically a 0 on the assignment(s) in question and 1/3 letter grade reduction.)
5. All decisions and action plans are subject to the review for final approval by the Faculty Committee on Discipline.
6. In an expedited hearing meeting facilitated by a member of the Office of Retention and Academic Support Services, a respondent will provide details about their alleged violation.
7. A finding of “responsible” as a result of the expedited or non-expedited (Honor Code Formalized) adjudication process will count as a first violation and will make a respondent ineligible for an expedited process as the result of any future.
8. Expedited review of potentially “Not Responsible” respondents as the result of expedited hearing information collected.
9. In a case with multiple students, the respondent may identify those students they believe to be potentially not responsible.
10. In a case with multiple students, if at such time it becomes likely that a student is not responsible for an alleged Honor Code violation as the result of testimony and evidence collected in expedited hearings, those individuals may be eligible for their case to be considered for an expedited Honor Council review of their potential violation.
11. This expedited review is conducted by an approved investigator as designated by the Honor Council, and a staff member of the Office of Retention and Academic Support Services. These reviews will be conducted weekly as needed.
12. A determination of not responsible can be made at this time similar to the investigation phase of the current Honor Council review process.

Any finding other than “not responsible” will result in the case being processed through the full Honor Code process, with this meeting serving as an investigation whereas a formal hearing will be scheduled at a later non-expedited date.

The Honor Council has prepared a booklet that explains the principles and operation of the Honor Code. The Honor Code booklet is available in the Office of Retention and Academic Support Services, 273 Chrysler Center and on the College of Engineering website: Honor Code Pamphlet

Statement of Student Rights and Responsibilities

Introduction

The University of Michigan-Ann Arbor (the University) is dedicated to supporting and maintaining a scholarly community. As its central purpose, this community promotes intellectual inquiry through vigorous discourse. Values which undergird this purpose include civility, dignity, diversity, education, equality, freedom, honesty and safety.
When students choose to accept admission to the University, they accept the rights and responsibilities of membership in the University’s academic and social community. As members of the University community, students are expected to uphold its previously stated values by maintaining a high standard of conduct. Because the University establishes high standards for membership, its standards of conduct, while falling within the limits of the law, may exceed federal, state or local requirements.

Within the University, entities (such as schools and colleges; campus, professional, and student organizations) have developed policies that outline standards of conduct governing their constituents and that sometimes provide procedures for sanctioning violations of those standards. This Statement of Student Rights and Responsibilities (the Statement) does not replace those standards; nor does it constrain the procedures or sanctions provided by those policies. This Statement describes possible behaviors which are inconsistent with the values of the University community; it outlines procedures to respond to such behaviors; and it suggests possible sanctions which are intended to educate and to safeguard members of the University community.

**Student Rights**

Students at the University have the same rights and protections under the constitutions of the United States and the State of Michigan as other citizens. These rights include freedom of expression, press, religion and assembly. The University has a long tradition of student activism and values freedom of expression, which includes voicing unpopular views and dissent. As members of the University community, students have the right to express their own views, but must also take responsibility for according the same right to others.

Students have the right to be treated fairly and with dignity regardless of age, color, creed, disability, marital status, national origin or ancestry, race, religion, sex (including gender identity and gender expression), sexual orientation or veteran status. The University has a long-standing tradition of commitment to pluralistic education. Accordingly, the University, through this Statement, will not discriminate on the basis of group status.

Students have the right to be protected from capricious decision making by the University and to have access to University policies which affect them. The University has an enduring commitment to provide students with a balanced and fair system of dispute resolution. Accordingly, this Statement will not deprive students of the appropriate due process protections to which they are entitled. This Statement is one of the University’s administrative procedures and should not be equated with procedures used in civil or criminal court.

Students also have a right to be educated about this Statement, and the University has a responsibility to provide education to students about the contents of this Statement. Students shall be made aware of their rights as outlined in this Statement, in addition to their responsibilities. Specifically, beginning in Winter 2017, the Division of Student Life must inform new students of the violations of this Statement and potential sanctions/interventions they may face if found responsible for violating this Statement.
The University’s commitment to providing students appropriate dispute resolution avenues means that in addition to formal conflict resolution processes the University also provides informal, Adaptable Conflict Resolution pathways.

**Student Responsibilities**

Along with rights come certain responsibilities. Students at the University are expected to act consistently with the values of the University community and to obey local, state and federal laws.

For complete information on Students Rights and Responsibilities see the Office of Student Conflict Resolution, Division of Student Affairs at: [http://www.oscr.umich.edu/](http://www.oscr.umich.edu/).

**Registration and Programs**

**Registration (Official Enrollment)**

All students must register to be officially enrolled in classes. This process includes meeting with a departmental advisor (for first-year students, advising is mandatory) so that appropriate classes are selected. This is followed by the actual registration process on Wolverine Access. To be considered as full-time students, undergraduate students must enroll for a minimum of 12 hours per semester.

Completion of both the advising and registration procedures are required before a student attends any classes or uses any University facilities. The tuition and registration fees for full-time enrollment as an undergraduate student in the College of Engineering may be found on the Registrar's website. As of the first day of class, a late registration fee of $50 will be assessed. Exceptions to the Late Registration Fee are late admissions, non-degree students, Ph.D. students registering to defend their dissertations, or students who have an official waiver based on a University action. The Late Registration Fee is increased by $25 at the beginning of each subsequent month.

Unless a student is registered, there is no obligation on the part of faculty members to permit attendance in their classes.

A student who completes the registration procedure (including early registration) and fails to attend classes must officially withdraw at the Registrar’s Office of the College of Engineering, for undergraduate students, 145A Chrysler Center. The student is responsible for the usual registration and disenrollment fees as stated in the current Schedule of Classes.

Students should be aware that receiving transfer, test and/or course credit can have an impact on tuition fees as tuition increases once a student reaches Upper Class Standing (55 credit hours or more). Students are responsible for reviewing their transcript when credits are posted. Credits can be removed no later than the end of the semester in which the student reaches Upper Level tuition. Note that credit is always posted for the term in which it was earned, not the term in which it was posted; the posting of credit can therefore have a retroactive impact on tuition owed. Current students should
carefully consider this issue before asking for credit to be posted on their transcript. It is highly recommended that students consult with their academic advisor prior to requesting the removal of transfer test and/or course credit. To request credit removal, students should email engincredit@umich.edu directly including in the request their UMID, specifying which transfer credit should be removed, and including a statement acknowledging that once credit is removed from their transcript it will not be reposted.

**Class Standing**

The number of credit hours accumulated toward graduation at the close of a given term is used to determine a student’s class standing for statistical purposes.

Questions concerning class-level designations for undergraduate students should be referred to the CoE Registrar’s Office, 145A Chrysler Center:

<table>
<thead>
<tr>
<th>Class</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Division</td>
<td>Freshman 0 to 24</td>
</tr>
<tr>
<td>Upper Division</td>
<td>Junior 55 to 84</td>
</tr>
</tbody>
</table>

**Indebtedness to the University**

Students shall pay all accounts due the University in accordance with regulations set forth for such payments by the Executive Vice President and Chief Financial Officer. When a student’s account shows indebtedness, no transcript of academic record or diploma will be issued, nor will future registration be permitted.

**7 Week Term Courses During Fall or Winter Terms (2 credits)**

Begin and End dates:

- All departments will have the same begin and end dates for classes.
- For Fall and Winter Terms the first 7 week period course will begin on the regular first day of classes.
- For Fall, the second 7 week period will start at the beginning of the 8th week whenever possible.
- For Winter, the start of the second 7 week period will be the Monday immediately following Spring Break.
- Beginning days will be adjusted so that no class will begin on a Friday.

*Drop/Edit Schedule:* Drop/Edit periods without a “W” will end by the end of the 2nd week for both 7 week period. The third week through the fifth week, students can submit an online late Drop/Add/Edit/Swap request through Wolverine access. Students must petition the Scholastic Standing Committee to drop or modify a class after the fifth week of a 7 week period.

*Fee Adjustments:* There is a two-week deadline (coinciding with Drop/Edit (Modify) deadlines) for fee adjustments. Documentation is needed for fee adjustments after the
Important Note: Students should register for the second 7 week period classes during the normal full-term registration period.

Add/Drop/Edit/Swap & Course Withdrawals

Add/Drop/Edit/Swap Policy (Change of Elections)

During the first three weeks of classes (first two weeks in a Spring or Summer half term), students may drop without a “W” or add courses using Wolverine Access.

Third week through ninth week (Fall term) or tenth week (Winter term):

After the third week deadline through the ninth week of classes (second week through fifth week in a Spring or Summer half term), students should submit a Late Drop/Add/Edit/Swap Request through Wolverine Access. Online requests are automatically routed to instructors (if required), advisors, the CoE Registrar’s Office and finally to the University Registrar’s Office for approval and processing. Students can track the progress of their request from a status page in Student Business. A “W” will appear for courses dropped during this time period. Please note that all requests to audit a course should be submitted via the Add/Drop paper form. The deadline for auditing a course was changed, beginning Fall 2017. The deadline is the third week for full term courses, second week for half-term courses, as well as first and second seven week courses.

Ninth week (Fall term) or tenth week (Winter term) through last day of classes:

After the ninth week (fifth week for a Spring or Summer half term, tenth week for Winter term), course additions, and credit modifications are processed using an Add/Drop/Edit/Swap form obtained from the program advisor (for undeclared students, these forms must be signed by an advisor in the Engineering Advising Center). Forms must be signed by the program advisor and instructor. Students should submit them to the College Registrar’s Office, for undergraduate students, 145A Chrysler Center. Certain of these changes will be approved only in exceptional circumstances.

Please note that all requests to audit a course should be submitted via the Add/Drop paper form. The deadline for auditing a course was changed, beginning Fall 2017. The deadline is the third week for full term courses, second week for half-term courses, as well as first and second seven week courses.

For Late Add/Drop, or Pass/Fail modifications after the deadlines, students will need to petition the Scholastic Standing Committee (SSC) 273 Chrysler Center. Documentation will need to be submitted with the Exceptions to College Rules Petitions. Petitions are available online at: https://elc.engin.umich.edu/petitions.

International students need to meet with the International Center (Central Campus: 515 E. Jefferson St.) to determine if a withdrawal will impact their visa status.
Student athletes must contact their advisor in the Academic Success Program regarding all changes to their election for written approval. This is in addition to the signatures required by the College of Engineering (advisor & instructor signatures).

**Course Withdrawals**

1. The incomplete (I) should be the default mechanism for addressing a disruption that arises late in the term.
2. Only the most serious circumstances warrant dropping a course after the ninth week of the term. In order for the SSC to grant a drop at this time, some non-academic, extraordinary event (like severe health issues, prolonged family illness or a severe personal disruption) would have occurred after the ninth-week (fifth week of a half-term) drop deadline and would make completion of a course or courses very difficult if not impossible; the SSC assumes that the student’s academic performance up to the point of the disruptive event has been satisfactory.
3. Approved drops will be posted to the official record with a “W”.

Petitions are available online at https://elc.engin.umich.edu/petitions and will need to be submitted to the Scholastic Standing Committee in 273 Chrysler Center.

Pass/fail or audit modifications after the last day of classes or the term has ended, students will need to petition the Scholastic Standing Committee (SSC). Documentation will need to be submitted with the Exceptions to College Rules petition. Petitions are available at 273 Chrysler Center or on the web at https://elc.engin.umich.edu/petitions.

Late withdrawal of courses after the term has ended:

- Will be rare and discouraged
- Only the most serious circumstances warrant dropping a course after the end of a term. In order for the SSC to grant a withdrawal at this time, some non-academic, extraordinary event (like serious illness or a severe personal disruption) must have occurred after the ninth-week (fifth week of half-term) drop deadline and that would make completion of a course or courses very difficult if not impossible; the SSC assumes that the student’s academic performance up to the point of the disruptive event has been satisfactory.
- Adverse circumstances that occur during most of a term generally have foreseeable consequences on performance that should be addressed by students’ seeking advice and help, by advisors and faculty reaching out to students, and when necessary through the rules for dropping courses during the term. In addition, the incomplete (I) should be the default mechanism for dealing with a disruption that arises late in the term.
- Additional documentation will need to be provided regarding the reason the petition for a late withdrawal was not submitted during the term in which the student took the courses.
- A clear rationale should be provided for not giving a “W” in all courses, addressing why the extenuating circumstances did not impact all work.
- A 12-month deadline will apply to petition for retroactive withdrawal from courses from a past term.
- If a petition to late withdraw after the end of term is granted, the instructing faculty member whose grade has been changed to “W” will be notified.

The grade for any course dropped without completing the proper procedures will be recorded as “ED” (unofficial drop) and computed as “E” in grade-point averages.

Junior and senior students enrolled in a Military Officer Education Program must also have approval of the Chair in charge of the unit before they can drop a Military Officer Education Program course or be relieved of the obligation assumed when enrolling in the program.

**Academic Definitions**

**Visit**

With permission of the advisor and course instructor, a student from the University of Michigan Ann Arbor may enroll in a College of Engineering course as a visitor, also referred informally as auditing a course. The student is expected to attend classes regularly but is not required to complete any course requirements, (e.g., homework sets, laboratory assignments, test, and the final examination.) In such a case, the course will be entered on the permanent record with a “VI” instead of a letter grade. If the student does not attend the class regularly, the faculty has the option to enter a grade of “NR” for no report. The same fee will be charged whether the student enrolls for credit or as a visitor. A course elected as “VI” does not count toward a student’s full time status.

Please note that all requests to audit a course should be completed via the Add/Drop paper form. The deadline for this will change beginning Fall 2017 (third week for full term courses, second week for half term and first and second seven week courses). Note that advisors typically will not approve changes in Visit elections after the third week (second week in Spring and Summer half terms). In such cases, withdrawing or changing to an election of Pass/Fail is generally more appropriate. After the deadlines, students must petition for an exception to College Rules to change Visit status. Required courses may not be elected as a visit.

**Term**

A term (semester) extends over approximately four months, including examinations. The University's year-round calendar, by months, is approximately as follows:

<table>
<thead>
<tr>
<th>Term</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring/Summer</td>
<td>May, June, July, Aug.</td>
</tr>
</tbody>
</table>
The Spring-Summer term may be scheduled as two half terms, approximately as follows:

<table>
<thead>
<tr>
<th>Term</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>May, June</td>
</tr>
<tr>
<td>Summer</td>
<td>July, Aug.</td>
</tr>
</tbody>
</table>

**Course Offerings**

The appropriate Bulletin and the Schedule of Classes (http://www.umich.edu/~regoff/schedule/) prepared for each term will serve the student as a guide in planning each term’s schedule. The College of Engineering reserves the right to withdraw the offering of any elective course not chosen by at least eight students.

**Credit Hour**

A credit hour (semester hour) generally represents one hour of recitation or lecture per week for a term, or two for a half term; preparation for each credit hour normally requires a minimum of three hours of study per week. Generally, one period of laboratory work is considered to be equal to one hour of credit.

**CoE Policy for the Assignment of Credit Hours**

Course credit is based on contact hours (time spent by students engaged with the course instructor) for all Engineering courses. This means one contact hour per credit hour in a week for Lectures, Discussions, and Recitations.

For each credit earned per full academic term, students are expected to receive at least one contact hour of instruction and perform at least two to three hours of work outside of class each week.

Independent Study, Special Topics, Experiential and Seminar courses have the same total engagement requirements (contact hours plus hours of additional work) as listed above with the understanding that engagement may not be scheduled on a weekly basis as determined at the department level.

Laboratory sections are expected to meet for at least two hours for each credit earned.

Hybrid and Online courses require an equivalent amount of instruction and student work as required by in-person courses.

**Workload**

The number of credit hours a student is able to carry in any one term depends upon a number of factors, including abilities, health, and the amount of time devoted to extracurricular activities or to outside work. Twelve credit hours are considered a
minimum full-time academic schedule for a full term (six for half term). Reduced program fees apply to 11 credit hours or fewer for undergraduate students.

Unless approved by the program advisor (for undeclared students, the Director of the Engineering Advising Center), the student may not elect courses (or change elections) for which the total number of hours for a term is fewer than 12 or more than 18, and for a half term, fewer than six or more than nine. A student should have a 3.0 average or more for the previous term to be permitted to carry a term load of more than 18 hours.

Attention is called to the section on “Time Requirements” for a statement on estimating the time needed for a bachelor’s degree.

**Attendance and Absences**

Regular and punctual attendance in classes is one of a number of expressions of interest and maturity. The reasons for good attendance should be obvious, and students may expect unexcused absences to be reflected in their final grade.

All students should account for their absences to their instructors. A student who has been absent from studies for more than one week because of illness or other emergency should consult the program advisor to determine the advisability of reducing course loads.

**Examinations**

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

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

**Transfer Credit Information**

**Transfer Credit for Enrolled Students (Transfer Credit Approval Form)**

Currently enrolled students can receive transfer credit from classes taken at other institutions by following the instructions on the website for the Transfer Credit Approval Form. The Transfer Credit Approval Form can be accessed online at [http://tcaf.engin.umich.edu/](http://tcaf.engin.umich.edu/). An evaluation typically takes two to four weeks and results in the notification of course transferability and the credit hours that will be earned upon completion of the course(s) with a grade of “C” or better. Online courses will be evaluated for transfer credit in the same manner and should also be submitted for approval via the Transfer Credit Approval Form. The College of Engineering allows a maximum of 12 credits for online transfer coursework. Transfer evaluations are generally conducted by the Department that owns the equivalent course. Note that some Departments do not accept online courses.
For CoE undergraduate enrolled students, please send your official transcript to:

College of Engineering, Office of Recruitment and Admissions  
153 Chrysler Center  
2121 Bonisteel Boulevard  
Ann Arbor, MI 48109-2092

Please note that students that are **transferring in credit for their final term prior to graduation** must be an active participant in the transfer credit process by contacting the other institution’s Transfer Credit Office/Registrar’s Office for approximate dates of grade posting and transcript processing. If the dates do not coincide with the College of Engineering’s deadline that all transcripts must be received by the first day of the next term’s classes to be counted toward graduation, the impact could possibly delay the degree conferral. It is the student’s responsibility to stay on top of their transfer credit.

This information along with important rules to keep in mind can be found on the website shown above. Questions can be emailed to Credit Evaluation at engincredit@umich.edu or answered in-person at 1240B LEC (Lurie Engineering Center).

**Transfer Credit for International Programs**

Currently enrolled students must consult with the International Programs in Engineering (IPE) office regarding course approvals, transfer credit and registration for all study abroad programs. Any student participating in an international experience must have a record in M-Compass.

Transcripts for IPE-Sponsored Programs should be sent to:

International Programs in Engineering  
245 Chrysler Center  
2121 Bonisteel Boulevard  
Ann Arbor, MI 48109-2092

**Cross-Campus Transfer Re-Registration Policy**

Admitted Cross-Campus transfer students to the CoE are held accountable to the following policy:

1. Admitted Cross-Campus students must re-register under their Engineering program status. The re-registration of courses must be done no later than 3 weeks after the first day of classes of the admitted term:
   - Students who do not re-register their classes may have their enrollment discontinued from the College of Engineering.
   - Once a student is discontinues they will then have to reapply to the College of Engineering, which may involve being held accountable to new admissions standards.
   - A student who reapplies after being discontinued and is admitted must be reinstated to the original term of the College of Engineering admission. This will involve having all of the student's classes re-registered to that original
term of admission and the student being billed for the differences in tuition and College of Engineering fees accordingly.

2. Students who want to be admitted to the College of Engineering who are near graduation and receive approval from an Engineering department are held to the following:
   - The Engineering department will determine under which past term the student should have been admitted. The student’s classes will then be re-registered back to that term for admission and the student will be billed for the differences in tuition and College of Engineering fees accordingly.
   - A department will have the authority to go back as many past terms as they deem appropriate for the student’s admission.

Declaring (or Changing) a Major

Students may declare a major as early as their second term in the College, and are urged to declare a specific engineering major by the start of their 3rd term of enrollment. Undeclared students cannot register for a 4th term in the College unless they have met with an advisor and developed a plan to select and declare a major within a reasonable time. This plan can be developed in coordination with the EAC advisors and departmental program advisors.

Students who meet all of the criteria below can declare any undergraduate engineering major. Students not meeting these criteria must meet with a departmental program advisor to establish any specific steps they must take in order to declare that major.

Students can declare or change into any undergraduate engineering major if they:

1. Have completed at least one full term of courses on the U-M Ann Arbor campus.
2. Have an overall U-M GPA of 2.0 or better in courses taken at the U-M Ann Arbor campus and are in good standing.
3. Have completed or earned credit by exam or transfer for one or more courses in each of these categories:
   - Calculus (e.g. Math 115, 116, 156)
   - Calculus-based physics lectures (e.g. Physics 140, 160) or chemistry lectures (e.g. Chemistry 130)
   - Required engineering courses (Engr 100, 101, 151)

A student must have a grade of C or better in every math course, science lecture and engineering course taken at U-M Ann Arbor to declare, unless waived by the program advisor, including 1-3 above. For repeated courses the most recent grade counts.
Transfers, Withdrawals, Readmission

Transferring Out

A student who wishes to pursue studies in another unit of the University must apply for admission to that unit and be accepted in order to continue enrollment in the University. In most cases, a student must be in good scholastic standing to be eligible for admission to other colleges/schools.

Term Withdrawals

The rules and procedures for term withdrawals vary based on when the withdrawal takes place, as outlined below:

- **Before the first day of classes**: Students must withdraw through the University of Michigan Office of the Registrar. This may be done in-person at 2202 Pierpont Commons or Rm 2200 Student Activities Building; via e-mail (ro.registration.questions@umich.edu); by fax (734-763-9053 or 734-763-7961); or by mail (University of Michigan Office of the Registrar, Room 2200 SAB, Ann Arbor, MI 48109-1382). The term in question is fully removed from the academic record.

- A student who withdraws after registration shall pay a disenrollment fee according to the rules in effect at the time of withdrawal as found on the Office of the Registrar’s website.

- **First day of classes to third-week deadline**: Student must report to the College Registrar’s Office (145A Chrysler Center); The term is fully removed from the academic record. No documentation is needed.

- **Third-week deadline to ninth-week deadline**: Student must report to the College Registrar’s Office (145A Chrysler Center); a “W” will appear for each course. No documentation is needed.

- **Ninth-week deadline to last day of classes**: Student must report to the Scholastic Standing Committee Office (273 Chrysler Center); a “W” will appear for each course. The student is not eligible to enroll in next full term. “Not to Register” is denoted on the record.

- **After last day of classes (retroactive)**: Student must petition the Scholastic Standing Committee (273 Chrysler Center).
  - Late drop of courses after the last day of classes:
    - Will be rare and discouraged.
    - Only the most serious circumstances warrant dropping a course after the end of a term. In order for the SSC to grant a withdrawal at this time, some non-academic, extraordinary event (like serious illness or a severe personal disruption) must have occurred after the ninth-week (four and a half week of a half-term) drop deadline and that would make completion of a course or courses very difficult if not impossible; the SSC assumes that the student’s academic performance up to the point of the disruptive event has been satisfactory.
- Adverse circumstances occurring during most of a term generally have foreseeable consequences on performance that should be addressed by students’ seeking advice and help, by advisors and faculty reaching out to students, and when necessary through the rules for dropping courses during the term. In addition, the incomplete “I” should be the default mechanism for dealing with a disruption that arises late in the term.
- Additional documentation will need to be provided regarding the reason the petition for a late withdrawal was not submitted during the term in which the student took the courses.
- If the student wishes to withdraw from only some of the courses in the term, a clear rationale should be provided for not giving a “W” in all courses, addressing why the extenuating circumstances did not impact all work. Such partial withdrawals are approved very rarely.
- A 12-months deadline will apply to petition for retroactive withdrawal from courses from a past term.
- If a petition to late withdraw after the end of term is granted, the instructing faculty member whose grade has been changed to “W” will be notified.

*If you are not looking to withdraw from all courses, please proceed [here](#) for information on how to submit a late course withdrawal

**Petitions are available on the web.**

Students withdrawing after the ninth-week deadline are not eligible to enroll in the next full term. A “Not to Register” designation will be placed on their academic record. If they are already registered they will be disenrolled. (Students with extenuating circumstances may petition the Scholastic Standing Committee. *Note: exceptions are rarely granted). When they are eligible to return, students will need to contact the Scholastic Standing Committee to inform of their intent to return at which point a “Permission to Register” designation will be placed on their academic record and the registration hold will be lifted.

**All students withdrawing from the College of Engineering will be asked to complete an exit survey.** Tuition and fee adjustments are in accordance with the Office of the Registrar.

International students need to meet with the International Center (Central Campus: 515 E. Jefferson St.) to determine if a withdrawal will impact their visa status.

Student athletes must contact their advisor in the Academic Success Program regarding the term withdrawal.
Undergraduate Readmission

A student who is not enrolled for 12 months or more must apply for readmission through the Office of Recruitment and Admissions, and should do so at least two months before the date of desired enrollment. Students can apply for Fall or Winter term readmission. Readmission into Spring or Summer terms will only be considered with the express approval of the appropriate advisor (Engineering Advising Center for undeclared students or the home department advisor for declared students). Readmitted students are subject to the rules in effect at the time of readmission.

Readmitted international students requesting F-1 or J-1 Visa status must also submit required documentation. For additional information on required documentation or to request an Application for Readmission, please contact the Office of Recruitment and Admissions, 153 Chrysler Center, 2121 Bonisteel Boulevard, Ann Arbor, MI 48109-2092 (734) 647-7101 or at enginrta@umich.edu.

Students who have graduated from the College and wish to elect courses for an additional term must apply as a Non-Candidate For Degree through the Office of Recruitment and Admissions.

A student whose enrollment has been withheld because of poor academic performance must first petition for Reinstatement to the Scholastic Standing Committee:
https://www.engin.umich.edu/students/scholasticstanding/petitions.html.

Fee Regulations, Expenses, Indebtedness

A non-refundable application fee will be required of each applicant for admission to the University. The application fee is currently $75 for U.S. citizens, U.S. permanent residents, and international applicants. The application fee is non-refundable.

To be considered as full-time students, undergraduate students must enroll for a minimum of 12 hours per semester.

Students enrolled as special students or guest students in the College of Engineering will be assessed upper-division fees. Fees are subject to change at any time by the Regents of the University. Detailed information relating to fees, deposits, payments, and refunds may be obtained in the Engineering Student Records Office and/or may be found on the Registrar’s website.

Indebtedness to the University

Students shall pay all accounts due the University in accordance with regulations set forth for such payments by the Executive Vice President and Chief Financial Officer. When a student’s account shows indebtedness, no transcript of academic record or diploma will be issued, nor will future registration be permitted.
Grades and Scholastic Standing

Unofficial Transcript

Each student’s transcript is the cumulative record of courses elected and grades earned while enrolled at the University of Michigan.

Unless withheld for infringement of rules, an individual may obtain an official copy of his/her/their transcript from the University Office of the Registrar at no charge. An unofficial copy of the transcript may be obtained through Wolverine Access.

Grades

The term grade point average (GPA) and the cumulative GPA are computed for each student at the end of each term and become part of the academic record. The grades are valued per hour of credit as follows:

<table>
<thead>
<tr>
<th>Letter Grades</th>
<th>Honor Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>4.0</td>
</tr>
<tr>
<td>A (excellent)</td>
<td>4.0</td>
</tr>
<tr>
<td>A-</td>
<td>3.7</td>
</tr>
<tr>
<td>B+</td>
<td>3.3</td>
</tr>
<tr>
<td>B (good)</td>
<td>3.0</td>
</tr>
<tr>
<td>B-</td>
<td>2.7</td>
</tr>
<tr>
<td>C+</td>
<td>2.3</td>
</tr>
<tr>
<td>C (satisfactory)</td>
<td>2.0</td>
</tr>
<tr>
<td>C-</td>
<td>1.7</td>
</tr>
<tr>
<td>D+</td>
<td>1.3</td>
</tr>
<tr>
<td>D</td>
<td>1.0</td>
</tr>
<tr>
<td>D-</td>
<td>0.7</td>
</tr>
<tr>
<td>E (not passed)</td>
<td>0.0</td>
</tr>
</tbody>
</table>
These items do not affect grade point averages:

- **Pass/Fail**
  - P (passed) credit, no honor points
  - F (failed) no credit, no honor points

- **Credit/No Credit**
  - CR (credit) credit, no honor points
  - NC (no credit) no credit, no honor points

- **Satisfactory/Unsatisfactory**
  - S (satisfactory) credit, no honor points
  - U (unsatisfactory) no credit, no honor points

- **Withdrawal/Drop**
  - W (official withdrawal) no credit, no honor points
  - ED (dropped unofficially) no credit, no honor points
    - A notation of ED for a graded election has the same effect on the grade point average as does an E.

- **Incomplete/Work in Progress, “Y” grading for approved courses only**
  - I (incomplete) no credit, no honor points
  - Y (work in progress for no credit, no honor points, project approved to extend for two successive terms)
    - “Y” can only be used with courses specially approved by College of Engineering Curriculum Committee as “two-term” sequence courses.

- **Official Audit (VI)**
  - VI (Visitor) no credit, no honor points

- **Miscellaneous Notation (NR)**
  - NR (no report) no credit, no honor points
    - A notation of “NR” becomes an “ED” and has the same effect on the grade point average as does an “E.” In the remainder of this section of the Bulletin, the term “a grade” applies to any of the grades “A+” through “E.”

The grade point average is computed by dividing the grade points (Michigan Honor Points or MHP) by the graded hours attempted (Michigan Semester Hours or MSH).

Grades associated with transfer credit are neither recorded nor used in computing the cumulative average. The only exception to this rule is for courses elected on the Ann Arbor campus.

### Pass/Fail Information

#### Pass/Fail Option (Elective)

*Due to Covid-19, Pass/Fail Limitations for Winter 2020, Fall 2020 and Winter 2021 will not be enforced.*

Elective courses used to satisfy the Intellectual Breadth requirement or courses to be used as General Electives can be taken pass/fail. A maximum of fourteen (14) credit hours can be used toward CoE degree(s) requirements. Pass/fail course elections are limited to two courses per full term (Fall or Winter) or one course in a half term (Spring or Summer). Course elections exceeding the full/half term limits will be reverted to the grade earned. Course/credit limits will be calculated in...
Any course that is offered only on a pass/fail basis will not be counted in the above totals.

1. The decision to elect a course on a pass/fail basis or on a graded basis must be made within the first nine weeks of the term (or first five weeks of a Spring or Summer half term). No changes in election as a graded course or as a pass/fail course can be made after the ninth week of a term, (or first five weeks of a half term).

2. Instructors are not notified of pass/fail elections; they will report grades as usual, “A+” through “E.” The University of Michigan Registrar’s Office will then translate grades as follows:
   - A grade of “C-” through “A+” in a course elected on a pass/fail basis is considered satisfactory and will be recorded as “P” (pass—for credit toward the degree and no effect on the grade point average).
   - A grade of “D+” or lower in a course elected on a pass/fail basis is considered unsatisfactory and will be recorded as “F” (fail, no credit and no effect on grade point average).

3. To be eligible for the Dean’s Honor List, a minimum of 12 credit hours (6 for a half term) must be elected for letter grades, with a grade point average of 3.5 or better.

4. To be eligible for Recognition on the Diploma, a minimum of 45 hours of credit with grades must be completed with a grade point average of 3.2 or better.

5. If a student completes a course for pass/fail and subsequently changes the degree program of study to one in which the course comes into conflict with the stated constraints for pass/fail elections in the new program, the course will be accepted in the new program as follows:
   - A record of “P” (pass) is regarded as a satisfactory completion of the program requirement.
   - A record of “F” (fail) is regarded as unsatisfactory completion and the course must be repeated for grades.

Pass/Fail course elections are limited to the following combinations:

**Full time** student 12-18 credits, NOT to exceed a total of TWO courses:
1. Two courses in a full term (Fall or Winter)
2. One course in a full term (Fall or Winter) **AND** one course in a 7-week period (First or Second)
3. One course in a 7-week period (First and Second)

**Full time** student 12-18 credits, NOT to exceed a total of TWO courses:
1. Two courses in a full term (Spring/Summer)
2. One course in a full term (Spring/Summer) **AND** one course in a 7-week period (Spring or Summer)
3. One course in a half term (Spring and Summer)

**Full time** student 6-9 credits, NOT to exceed a total of ONE course:
1. One course in a half term (Spring or Summer)

**Part time** student 1-11 credits in Fall, Winter, Spring/Summer, 1-5 credits in Spring or Summer NOT to exceed a total of ONE course:
1. One course in a full term (Fall, Winter, Spring/Summer)
2. One course in a 7-week period (First 7-wk or Second 7-wk, Spring or Summer)

NOTE: A course offered only on a mandatory pass/fail basis is not included in the elective pass/fail maximum of fourteen (14) credit hours.

**Courses Offered on a Pass/Fail Basis Only (Mandatory)**
A department or instructor may offer an undergraduate pass/fail course on the following basis:

1. The instructor will report the grade as pass/fail for each student enrolled.
2. The grade will be treated the same as when the student chooses to elect a course on a pass/fail basis if the following conditions are satisfied:
   o The course is not required for any program or department.
   o It is the type of course which might be considered appropriate to a pass/fail grading system. Examples of such courses may include design, survey-type, individual directed research, laboratory, or undergraduate seminars.
3. The pass/fail nature of the course is announced by the instructor at the beginning of the term, with the exception of individual instruction courses. See the University Registrar’s Office schedule of classes website (http://www.umich.edu/~regoff/schedule).

C- and D Grades
Credit is generally allowed for a course in which a grade of “C-” or “D” is earned while enrolled in the College of Engineering, but there are restrictions:

- The “D” level of performance (“D+” or lower) is not considered satisfactory for a course that is a prerequisite for a later-elected course; in this case, the course must be repeated before electing the next course unless waived by the program advisor.
- A grade of “D+” and lower is not acceptable in any program for Engineering 100, Engineering 101.
- A grade of “C-” is not a satisfactory level of performance in some programs for any required course.
- “C-” grades in math, science or introductory engineering courses may negatively impact a student’s eligibility to declare a degree program. Please consult the rules for declaring a major.
- It is the student’s responsibility to review course performance with their advisor as soon as the grade is known in order to make any changes that may be necessary in future course elections.

Transfer credit will be granted for courses taken outside the University of Michigan, Ann Arbor campus, provided a grade of “C” or better is earned. Transfer credit will be granted for courses, other than math, science, engineering, or other prerequisites for admission into the College of Engineering, taken in any academic unit at the University of Michigan, Ann Arbor campus, provided a grade of “C-” or better is earned.

Students should be aware that some programs limit the number of “C-” grades or require that courses completed with a “C-” or lower grade be repeated. Some programs may have a higher minimum grade requirement for some courses.

E Grades
Neither credit nor Michigan Honor Points are granted for a course in which a student earns the grade of “E.” A course required by the student’s program must be repeated as soon as possible.

“Y” Grades
Due to Covid-19, Y grades will automatically be converted to the P/NRC system for Winter 2020. After the July 1 deadline, students will not be able to uncover the grade unless an exception is made. The exception process is still being determined by the University Registrar.
The "Y" grade can be assigned only for an approved extended multi-term class. “Y” grades are used if there is enrollment in the class spanning two terms, such as year-long research or design courses. The student is assigned a grade of “Y” for the first term and then at the end of second term is assigned the same final grade for both semesters, which replaced the “Y” in the first term.

**Incompletes**

*Due to Covid-19, Incompletes during the Winter 2020 term will need to be finished by the last day of Fall 2020 classes. The grade will then be translated to the Pass/No Record Covid grade scale, and no record of Incomplete will remain. After the July 1 deadline, students will not be able to uncover the grade unless an exception is made. The exception process is still being determined by the University Registrar.*

When a student is prevented by illness, or by any other cause beyond the student’s control, from taking an examination or from completing any part of a course, or if credit in a course is temporarily withheld for good reason, the mark “I” may be reported to indicate the course has not been completed. This mark should be used only when there is a good probability that the student can complete the course. The instructor and student should mutually understand the reasons for the “I” mark and agree on methods and timeline for completing the work.

No qualifying grade will be recorded on the student’s academic record. The “I” mark will not be used in computing either the term or cumulative grade point averages. Scholastic standing at the end of any term is determined on the basis of work graded as “A+” through “E,” or “ED.”

The required work may be completed, and the grade submitted by the instructor whether or not the student is enrolled in the subsequent term. The student should plan to complete the work as soon as possible. To secure credit, the required work must be completed by the end of the first full term (not including Spring or Summer terms) in which the student is enrolled after the term in which the “I” mark was recorded. It is the student’s responsibility to remind the instructor to submit a grade report through the grading system in Wolverine Access when the work is completed. If the student does complete the work within the allowed period, the Registrar will post the final grade on the transcript; however, the “I” will remain next to the grade on the transcript. If the final grade is not reported by the last day of classes, the University Registrar will automatically change the “I” to an “ILE.” Incomplete extensions must be arranged with the instructor. Forms are available at the College Registrar’s Office, 145A Chrysler Center.

Any grade changes made to the student record as a result of Incompletes either being completed or lapsed will result in re-evaluation of a student’s academic record by the Scholastic Standing Committee and may result in changes to their academic standing.

The deadline for incomplete work to be completed, when it is the student’s expected graduation term, is the first day of classes for the following term. If the work is not complete and the grade posted, the student will need to reapply for the following degree conferral term.

**Other Irregularities**

Irregularities associated with a failure to submit changes in academic status are identified on the student’s transcript by an appropriate designation such as “ED” (unofficial drop) or “NR” (no report). “NR” (no reports) are automatically converted to “ED” when entered into the grading system in Wolverine Access. An unofficial drop will be considered the same as an “E” in computing the term and cumulative averages and will affect the scholastic standing.
Repeating Courses

For “C-,” “D” and “E” grades, see above. Except as provided for grades “C-” through “D-,” a student may not repeat a course one has already passed. In exceptional cases, this rule may be waived by the student’s program advisor (for undeclared students, the Director of the Engineering Advising Center) after consultation with the department of instruction involved. If the rule is waived, the course and grade will appear on the transcript, but no additional credit or Michigan Honor Points (MHPs) will be granted.

A student repeating a course in which a “C-” through “D-” was previously earned will receive MHPs but no additional credit. All attempts (with grades of a C- through D-) at a course are used in computing the overall grade point average.

Grade Point Averages

The term grade point average (GPA) and the cumulative GPA are computed for each student at the end of each term and become part of the academic record.

The grade point average is computed by dividing the grade points (Michigan Honor Points or MHP) by the graded hours attempted (Michigan Semester hours or MSH).

Grades associated with transfer credit are neither recorded nor used in the cumulative average. The only exception to this rule is for courses elected on the Ann Arbor campus (effective November 1986).

Honor Point Deficit Calculator

\[(\text{Michigan Semester Hours} \times 2) – \text{Michigan Honor Points} = \text{Honor Point Deficit}\]

Use cumulative totals to calculate cumulative deficit; use term totals to calculate term deficit. The result reflects the number of “B” credits needed to raise cumulative or semester GPA above 2.0.

The GPA is figured by dividing Michigan Honor Points (MHP) by Michigan Semester Hours (MSH):

\[
\frac{25.6 \text{ MHP}}{16.00 \text{ MSH}} = 1.600 \text{ GPA}.
\]

The term honor point deficit is calculated by multiplying MSH by 2 and subtracting MHP:

\[
(16.00 \text{ MSH} \times 2) – 25.60 \text{ MHP} = 6.4 \text{ honor point deficit}.
\]

Thus, this student needs 6.4 credits of “B” grades to raise his/her term GPA above 2.00.

Academic Honors and Awards

Due to Covid-19, students may want to choose to convert to a letter grade to be eligible for certain honors and other awards.

The Dean’s List (College of Engineering)

Students pursuing an undergraduate degree who elect courses and complete a minimum of 12 credit hours with grades (6 for a half Spring or Summer term) and earn a 3.50 GPA term average or better, attain the distinction of the Dean’s List for the term.
University Honors (University of Michigan)

Students who earn a minimum of 14 credits in courses which include 12 credits elected on a graded basis (“A” through “E”), and who earn a 3.5 grade point average are eligible for University Honors. This Honor will be awarded each full term of classes (Fall & Winter terms). This distinction is posted on a student’s transcript by the University of Michigan Registrar’s Office. Students who receive this honor for two consecutive terms will be invited to attend the annual Honors Convocation.

James B. Angell Scholars (University of Michigan)

James B. Angell Scholars are students who earn all “A+,” “A,” or “A-” grades for two or more consecutive terms based on a minimum of 14 credits earned in courses which include 12 credits earned on a graded (“A”-“E” basis elected each term); all other grades must be “P,” “S,” or “CR”. Terms of fewer than 14 credits completed with grades of “A+,” “A,” “A-,” “P,” “S,” or “CR” enable a student to maintain standing as an Angell Scholar. Any other grades earned during a full or half-term make a student ineligible for this honor. Angell Scholar Honors are posted on a student’s transcript by the University Office of the Registrar, and recipients of this honor are invited to attend the annual Honors Convocation. Angell Scholars are selected and honored annually.

William J. Branstrom Freshman Prize (University of Michigan)

Students in the top five percent of the freshman class are eligible for this honor, administered by the University Registrar’s Office, if they have earned at least 14 graded credits at Michigan. A book with an inscribed nameplate is presented to each student. Recipients of this award are invited to attend the annual Honors Convocation.

Marian Sarah Parker Scholars (College of Engineering)

The Marian Sarah Parker Scholars Program is a joint program of the College of Engineering and the U-M Women in Science and Engineering (WISE) Program. The Marian Sarah Parker Scholars Program invites high-achieving women, by Fall Term of their junior year, to participate in a two-year exploration of graduate school. Participation as a Marian Sarah Parker Scholar leads to a greater understanding of the graduate school process by means of seminars, panel discussions, and an academic research project.

Special Awards (College of Engineering)

The College gives special recognition to students with high scholastic achievement, with records of service to the College and its student organizations, or with evidence of extraordinary potential for leadership. Information on qualification requirements can be obtained in the Office of Student Affairs, 143 Chrysler Center.

Society Recognition (College of Engineering)

Distinguished scholarship and service to the College are also recognized by election to a number of honor societies.

Recognition on Diploma (College of Engineering)

A student graduating with at least 45 hours of credit completed, with grades, while enrolled in this College will be recommended for a degree(s) with recognition on the diploma if the student qualifies according to the following:

Grade Point Average Distinction

3.20 – 3.499........ cum laude
3.50 – 3.749…… magna cum laude
3.75 – 4.00…… summa cum laude

Grievances Procedures

Grade Grievances Procedure

If there is justification to question the accuracy of an assigned grade, the student should first pursue the matter with the instructor. The responsibility for the assignment of grades is primarily that of the instructor and should be settled between the student and instructor whenever possible. Further pursuit of a grade grievance should be addressed with the instructor’s Department Chair. The final appeal at the College level is by petition to the Associate Dean for Undergraduate Education or the Associate Dean for Graduate and Professional Education.

Student Grievances

The College of Engineering has a grievance procedure to address student complaints.

Undergraduate and graduate students should follow these steps until a resolution is achieved:

1. Attempt to resolve the grievance directly with the individual involved (faculty member, staff member, or fellow student).
2. If the matter is unresolved, and the grievance is with a faculty member or teaching assistant, discuss the grievance with the appropriate Department Chair.
3. If the issue is still unresolved, undergraduate students should see the Associate Dean for Undergraduate Education and graduate students should see the Associate Dean for Graduate Education who are both located in the Robert H. Lurie Engineering Center.
4. All students have the right to appeal to the Dean of the College if they feel their grievances have not been resolved satisfactorily by another dean.

Scholastic Standing Committee

Scholastic Standing Committee

273 Chrysler Center
Phone: (734) 764-4139
Fax: (734) 764-6056
sscresponse@umich.edu

The Scholastic Standing Committee (SSC) is comprised of faculty representatives and academic services staff members. Faculty members are appointed for a three-year term. The SSC studies problems related to, and defines criteria for, scholastic performance. The College of Engineering is committed to your success and our Scholastic Standing Academic Status Indicators are no exception. These notations and restrictions were created to ensure students get individually crafted support and instructions in developing a successful continuing educational experience.

In addition the SSC reviews all petitions within the College, including the Petition for Reinstatement, the Petition for Late Drop, the Petition for Exception to College Rules, and the Petition for Retroactive Term Withdrawal.
Standards Governing Scholastic Standing for Unsatisfactory Performance

All students will be in one of the following classifications:

- **Good Standing**: 2.00 GPA or better for both the term and the cumulative average.
- **Probation**: a deficiency of up to 10 MHP for the term or cumulative average.
- **Enrollment Withheld**: a deficiency of 10 MHP* or above for the term or cumulative average; or the third or greater incidence of probation. Students will have to petition for reinstatement in order to continue taking courses.
- **Reinstated on Probation**: Students who have been reinstated after being placed on Enrollment Withheld or Mandatory Leave. **Enrollment Withheld Continued**: Reinstated student who was given two or more semesters to meet conditions. Enrollment Withheld Continued will show on transcript until all conditions have been fulfilled.
- **Mandatory Leave**: SSC decision requiring a leave from the College of Engineering based upon unsatisfactory academic performance. Students will have to petition for reinstatement to return after their required leave has been fulfilled.
- **Dismissal**: SSC decision based upon failure to meet the conditions of reinstatement. Student is no longer eligible to enroll in the College of Engineering or petition the Scholastic Standing Committee for reinstatement.

Scholastic standing actions are put in place in order to bring attention to students who may be experiencing academic difficulties, due to various reasons, with the intention of providing support and resources to help restore the student to good academic standing. The various scholastic standing actions will be determined as follows:

**Probation**

*Due to Covid-19, for Winter 2020: Students on Probation I or II who have an overall GPA over a 2.0 and pass all of their classes will return to good standing. Students who do not pass all of their classes will maintain their current scholastic standing for the Fall 2020 term.*

When a student has a deficiency between 0 and 10 MHPs for either the term or cumulative GPA, the student is placed on probation. The notation “Probation” will be entered on the unofficial transcript.

A student on probation may continue enrollment, but is required to meet with a program advisor (undeclared students are required to meet with an advisor in the Engineering Advising Center) regarding course selection for the following term and to develop a plan for academic improvement. Failure to do so will result in an academic hold on his or her account, preventing enrollment in future terms. Probation is a warning that there is a need to improve scholastic performance or further enrollment may be jeopardized.

**Enrollment Withheld**

*Due to Covid-19, for Winter 2020: Students on Probation III, Enrollment Withheld, or Facing Dismissal will maintain their current scholastic standing for the Fall 2020 term and can make progress towards Good Standing on a case by case basis. Please contact the Scholastic Standing Committee by June 15, 2020.*

A student will have the notation “Enrollment Withheld” placed on his/her/their transcript and will not be allowed to enroll in classes if: a) on Probation for the third or more times; or, b) has a deficiency of 10 or more MHP in either the term or the cumulative GPA. Enrollment Withheld is a serious warning that the student’s continued academic progress is in jeopardy, and the student should seek out appropriate resources and support in order to continue.
When a student is on Enrollment Withheld, the student must submit a petition to the Scholastic Standing Committee (SSC, Petitions – Office of Retention & Academic Support Services) requesting reinstatement. The student must meet with his/her/their program advisor to discuss the petition (undeclared students must meet with their advisor in the Engineering Advising Center). The petition must document the reasons for the unsatisfactory performance, as well as offer sufficient and convincing evidence that another opportunity is warranted. If illness has been a factor, students must include supporting information, including a statement (with dates) from their physician. Documentation supporting other contributing factors must also be included.

Reinstatement petitions must be submitted to the Scholastic Standing Committee via the online petition system. Failure to petition the SSC in time and follow the correct procedure will result in a forfeiture of the right to petition for reinstatement for that term and disenrollment from the College.

Students who were enrolled in the previous term as well as those returning from time away from College must submit their reinstatement petitions in accordance with the reinstatement deadlines which can be found at Petitions – Office of Retention & Academic Support Services. Reinstatement petitions will not be accepted after the deadline.

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

Petitions submitted by students seeking reinstatement will be reviewed by two members of the SSC. The Committee will either approve the student’s reinstatement, or require a permanent or temporary dismissal. When a student is reinstated, one is required to sign a contract that states the conditions necessary to meet in order to continue in future terms.

Reinstated students are not permitted to register for future terms unless they can demonstrate they have met their conditions of reinstatement. Students must wait until grades are posted or complete a progress report, before early registration, available on the web. The progress report must be submitted to the SSC, 273 Chrysler Center, once completed.

Questions, appointments and petition forms are handled by the SSC Administrator, 273 Chrysler Center, (734) 764-4139. All petitions are available online at Petitions – Office of Retention & Academic Support Services. It is recommended that students submit petitions and documentation via the online petition tool.

Students who are not reinstated or choose not to submit a reinstatement petition by the deadline will be placed on suspension and disenrolled.

Mandatory Leaves: Two (2) Enrollment Withheld (EW) notations require a student to take a leave from the College of Engineering for one (1) full term (Fall or Winter).* Any time a student’s GPA falls below a 2.0 after having been placed on Enrollment Withheld, they are subject to the next level of negative academic standing. (A student may also be required to take a mandatory leave with less than two EW notations if they have a very large deficit and/or have issues that need immediate attention.)

If a student with two EW’s intends to return to the College after the required leave, that individual is required to petition the Scholastic Standing Committee for reinstatement. The deadlines for submitting reinstatement petitions can be found at Petitions – Office of Retention & Academic Support Services.
* Students receiving their second EW at the end of the Winter term will not be eligible to enroll in the Spring, Summer, Spring-Summer or Fall terms at the University of Michigan.

**Dismissal**

Permanent dismissal from the College of Engineering is a Scholastic Standing Committee decision, with the final decision made by the Associate Dean of Undergraduate Education, based upon a student’s failure to meet the conditions of reinstatement. Students are no longer eligible to enroll in or attend the College of Engineering. Students also lose the privilege of petitioning the Scholastic Standing Committee for reinstatement.

---

**Transfers, Withdrawals, Readmission**

**Transferring Out**

A student who wishes to pursue studies in another unit of the University must apply for admission to that unit and be accepted in order to continue enrollment in the University. In most cases, a student must be in good scholastic standing to be eligible for admission to other colleges/schools.

**Term Withdrawals**

The rules and procedures for term withdrawals vary based on when the withdrawal takes place, as outlined below:

- **Before the first day of classes:** Students must withdraw through the University of Michigan Office of the Registrar. This may be done in-person at 2202 Pierpont Commons or Rm 2200 Student Activities Building; via e-mail (ro.registration.questions@umich.edu); by fax (734-763-9053 or 734-763-7961); or by mail (University of Michigan Office of the Registrar, Room 2200 SAB, Ann Arbor, MI 48109-1382). The term in question is fully removed from the academic record.

- A student who withdraws after registration shall pay a disenrollment fee according to the rules in effect at the time of withdrawal as found on the Office of the Registrar’s website.

- **First day of classes to third-week deadline:** Student must report to the College Registrar’s Office (145A Chrysler Center) or email engineering-ro@umich.edu from their umich account to request a term withdrawal; a “W” will appear for each course. No documentation is needed.

- **Third-week deadline to ninth-week deadline:** Student must report to the Scholastic Standing Committee Office (273 Chrysler Center) or email SSCResponse@umich.edu from their umich account to request a term withdrawal; a “W” will appear for each course. No documentation is needed. The student is not eligible to enroll in next full term, and needs to note on their email that they understand this. “Not to Register” is denoted on the record.

- **After the last day of classes (retroactive):** Student must petition the Scholastic Standing Committee (273 Chrysler Center).
Late drop of courses after the last day of classes:
  - Will be rare and discouraged.
  - Only the most serious circumstances warrant dropping a course **after the end of a term**. In order for the SSC to grant a withdrawal at this time, some non-academic, extraordinary event (like serious illness or a severe personal disruption) must have occurred after the ninth-week (four and a half week of a half-term) drop deadline and that would make completion of a course or courses very difficult if not impossible; the SSC assumes that the student’s academic performance up to the point of the disruptive event has been satisfactory.
  - Adverse circumstances occurring during most of a term generally have foreseeable consequences on performance that should be addressed by students’ seeking advice and help, by advisors and faculty reaching out to students, and when necessary through the rules for dropping courses during the term. In addition, the incomplete “I” should be the default mechanism for dealing with a disruption that arises late in the term.
  - Additional documentation will need to be provided regarding the reason the petition for a late withdrawal was not submitted during the term in which the student took the courses.
  - If the student wishes to withdraw from only some of the courses in the term, a clear rationale should be provided for not giving a “W” in all courses, addressing why the extenuating circumstances did not impact all work. Such partial withdrawals are approved very rarely.
  - A 12-months deadline will apply to petition for retroactive withdrawal from courses from a past term.
  - If a petition to late withdraw after the end of term is granted, the instructing faculty member whose grade has been changed to “W” will be notified.

*If you are not looking to withdraw from all courses, please proceed here for information on how to submit a late course withdrawal

**Petitions are available on the web.**

Students withdrawing after the ninth-week deadline are not eligible to enroll in the next full term. A “Not to Register” designation will be placed on their academic record. If they are already registered they will be disenrolled. (Students with extenuating circumstances may petition the Scholastic Standing Committee, though note that exceptions are rarely granted). When they are eligible to return, students will need to contact the Scholastic Standing Committee to inform them of their intent to return, at which point a “Permission to Register” designation will be placed on their academic record and the registration hold will be lifted.

**All students withdrawing from the College of Engineering will be asked to complete an exit survey.** Tuition and fee adjustments are in accordance with the Office of the Registrar.

International students need to meet with the International Center (Central Campus: 515 E. Jefferson St.) to determine if a withdrawal will impact their visa status.

Student athletes must contact their advisor in the Academic Success Program regarding the term withdrawal.
Undergraduate Readmission

A student who is not enrolled for 12 months or more must apply for readmission through the Office of Recruitment and Admissions, and should do so at least two months before the date of desired enrollment. Students can apply for Fall or Winter term readmission. Readmission into Spring or Summer terms will only be considered with the express approval of the appropriate advisor (Engineering Advising Center for undeclared students or the home department advisor for declared students). Readmitted students are subject to the rules in effect at the time of readmission. Students seeking readmission should email enginrta@umich.edu to request an application.

Students who have graduated from the University of Michigan – Ann Arbor campus and wish to elect courses for an additional term must apply as a Non-Candidate For Degree through the Office of Recruitment and Admissions.

A student whose enrollment has been withheld because of poor academic performance must first petition for Reinstatement to the Scholastic Standing Committee: Petitions – Office of Retention & Academic Support Services. Students that are cleared through the Scholastic Standing Committee do not need to fill out the Readmission Application. Accounts are reactivated, typically, 48-72 hours after a student is cleared by the Scholastic Standing Committee.

Special Student Status

Undergraduate Non-Candidate for Degree (NCFD)

The NCFD status is for those individuals who are approved to take courses in the College of Engineering in a non-degree capacity. Such students are designated as unclassified.

NCFD Status for Students from Other Colleges and Universities

A student from another college or university who seeks enrollment as a non-candidate for degree (NCFD) must meet the same academic standards of admission as a degree-seeking application for transfer admissions.

NCFD applicants should contact the Office of Recruitment and Admissions to request an application. A complete application will include:

- a completed application form
- official transcripts from previous colleges or universities
- written permission from instructors of classes in which you intend to enroll (applicant is responsible for obtaining this documentation
The instructors are responsible for assessing the academic standard of admission.

Once an applicant has been evaluated and approved for admission, the applicant will be notified of their NCFD admission status.

Registration for courses can only be done on or after the first day of classes for the term of admission. If more than one term is requested, the student cannot register for the subsequent term until their academic record has been reviewed and approved by an admissions counselor and the engineering departmental program advisor.

NCFD Status for Graduates of the College of Engineering

A graduate with a conferred bachelor's degree from the College of Engineering who desires to take courses with NCFD status can request processing for enrollment by obtaining written approval from the program advisor for the department in which they intend to take course(s) and submitting an application for readmission to the Office of Recruitment and Admissions. The instructor(s) of the course(s) in which the student intends to enroll must also grant written permission. Approval to register is granted for one term only. The enrollment status is designated as unclassified. Course registration for individuals with special student status should not be done prior to the first day of classes. The engineering department from which the degree was conferred will also be notified of the NCFD status.

Unclassified Status

When a student is no longer a candidate for a degree from the College of Engineering but is planning to transfer into another field of study, the student will be advised by the Engineering Advising Center to arrange for registration for an additional term in the College of Engineering on an “Unclassified” status.

International Exchange Students from CoE Partner Institutions

Undergraduate students from CoE partner institutions may apply to study at the U-M for one or two terms. The CoE also accepts exchange student applications through the Global Engineering Education Exchange (GE3) program. Prospective exchange students must be nominated by their home institutions and all applications are coordinated by the International Programs in Engineering (IPE) office, 245 Chrysler Center, 2121 Bonisteel Boulevard, Ann Arbor, MI 48109-2092. Prospective students should inquire with their home institution’s international exchange office.

Undergraduate Readmission

A student who is not enrolled for 12 months or more must apply for readmission through the Office of Recruitment and Admissions, and should do so at least two months before the date of desired enrollment. Students can apply for Fall or Winter term readmission. Readmission into Spring or
Summer terms will only be considered with the express approval of the appropriate advisor (Engineering Advising Center for undeclared students or the home department advisor for declared students). Readmitted students are subject to the rules in effect at the time of readmission.

Readmitted international students requesting F-1 or J-1 Visa status must also submit required documentation. For additional information on required documentation or to request an Application for Readmission, please contact the Office of Recruitment and Admissions, 153 Chrysler Center, 2121 Bonisteel Boulevard, Ann Arbor, MI 48109-2092 (734) 647-7101 or at enginrta@umich.edu.

Students who have graduated from the College and wish to elect courses for an additional term must apply as a Non-Candidate For Degree through the Office of Recruitment and Admissions.

A student whose enrollment has been withheld because of poor academic performance must first petition for Reinstatement to the Scholastic Standing Committee: [https://www.engin.umich.edu/students/scholasticstanding/petitions.html](https://www.engin.umich.edu/students/scholasticstanding/petitions.html).

---

**Bachelor’s Degree Holders Seeking a Second Bachelor’s Degree**

Students already in possession of a bachelor's degree should consider a master's degree or PhD in engineering. The College of Engineering will admit second bachelor degree students in very rare and exceptional circumstances and if there is room at the transfer level. The College of Engineering will prioritize students seeking their first bachelor’s degree. Before pursuing this path, please contact the Office of Recruitment and Admissions.

The Office of the Associate Dean for Undergraduate Education will have ultimate authority to decide if a candidate’s prior degrees are too similar to a proposed degree to allow admission or declaration.

For students who have previously earned a bachelor’s degree and elect to pursue admission for an additional bachelor’s degree, the following rules and policies apply:

In order to be qualified for a second bachelor’s degree, candidates should have taken Calculus 1 and 2, Physics 1, Chemistry, English Composition and Computer Programming, C++, at an institution of higher education and have an academic record that suggests high levels of accomplishment. These courses can have been completed as part of their original degree, but could also have been taken for other reasons. They should have been completed no more than ten (10) years before admission, and ideally less than seven (7) years prior to admission.

Coursework from the student’s previous academic record, including credits used to satisfy requirements for a previous degree, will be eligible for entry on the U-M academic record. Credits will not be transferred if they were used to satisfy more than one prior degree (no counting of credits between three (3) or more degrees).

To graduate, students must successfully complete all of the degree requirements in place at their term of admission, using the appropriate combination of transfer and U-M credit. Program advisors can allow substantially equivalent substitutions from transferred courses. Students with a previous engineering degree must complete an additional fourteen (14) credits hours in pertinent technical subjects in addition to meeting all degree requirements.

A bachelor's degree holder admitted into the College of Engineering seeking a second bachelor's degree will be a senior when there are thirty-five (35) hours or fewer to complete.
Cross-Campus Transfer Re-Registration Policy

Admitted Cross-Campus transfer students to the College of Engineering are held accountable to the following policy:

1. Admitted Cross-Campus students must re-register under their Engineering program status. The re-registration of courses must be done no later than 3 weeks after the first day of classes of the admitted term:

   - Students who do not re-register their classes may have their enrollment discontinued from the College of Engineering.
   - Once a student is discontinued, they will then have to reapply to the College of Engineering, which may involve being held accountable to new admissions standards.
   - A student who reapplies after being discontinued and is admitted must be reinstated to the original term of the College of Engineering admission. This will involve having all of the student’s classes re-registered to that original term of admission and the student being billed for the differences in tuition and College of Engineering fees accordingly.

1. Students who want to be admitted to the College of Engineering who are near graduation and receive approval from an Engineering department are held to the following:

   - The Engineering department will determine under which past term the student should have been admitted. The student’s classes will then be re-registered back to that term for admission and the student will be billed for the differences in tuition and College of Engineering fees accordingly.
   - A department will have the authority to go back as many past terms as they deem appropriate for the student’s admission.
Undergraduate Education
Mission

Michigan Engineering aspires to create an educational experience for engineering graduate students that is among the finest in the world. We serve a diverse population of top students from around the globe by preparing them for successful careers in academia, industry, and the public sector through access to world-class facilities, cutting edge research, and innovations in graduate education.

We offer dozens of top-ranked Master’s and doctoral degree programs, along with a range of specialized graduate certificates, to help students meet their academic and professional goals. Several degrees are available entirely online by design, offering students the opportunity to pursue a high-quality graduate engineering education that is flexible and convenient. With over 600 faculty members who are leaders in their fields, Michigan Engineering provides an inclusive and collaborative environment that challenges its students to find innovative and impactful solutions to global problems.

Core Requirements

Planning the Student’s Program

Students vary in their goals and objectives, in their level of achievement and in their high school or pre-engineering preparation. Considerable variety and flexibility are provided to plan each student’s schedule so that the individual may reach graduation as efficiently as possible. The objective is to place each new student in courses commensurate with his or her academic profile, previous experience and potential for academic success.

Most courses have prerequisites. The completion of courses on schedule and with satisfactory grades is essential to the student’s progress.

The appropriate schedule for each student in each term will depend on a number of factors such as: past scholastic record; placement test results; extracurricular activities; election of co-op, international or Military Office Education Programs; health; and need for partial self-support. A schedule of 12 to 18 hours is considered full-time.

All College of Engineering B.S.E. programs require successful completion of a program of 128 credit hours. An average of 16 credit-hours per term allows a student to complete these programs in 8 terms, generally requiring 4 years of study.

First- and Second-Year Programs

At the time of each student’s first advising session, all of the high school and advance placement records may not yet be in the student’s file. It is the entering student’s responsibility to make certain that all pertinent information is brought to the attention of an Engineering Advising Center (EAC) Advisor. Any changes in test scores or transfer credits will affect final course selection and need to be discussed with an advisor.
With complete information available, the advisor and the student will be able to make carefully considered adjustments in course elections for the first-term course schedule.

**First Year**

Assuming the necessary academic preparation and no Advanced Placement credit, each student will be expected to complete some combination of the following courses:

1. Mathematics 115 and 116 or one of the honors Math sequences
2. Chemistry 130 and 125/126, or, for some, 130, 210, and 211
3. Engineering 100 (Any course satisfying the First Year Writing Requirement (FYWR) for LSA is an acceptable substitution for ENGR 100 for transfer students only. A list of available courses that meet the FYWR is available through the LSA Course Guide website at: [https://www.lsa.umich.edu/cg/default.aspx](https://www.lsa.umich.edu/cg/default.aspx)
4. Engineering 101 or Engineering 151 (ENGR 151 is an approved alternative to ENGR 101 for all CoE programs)
5. Physics 140 and 141

Additional course information will be available during the advising session.

**Second Year**

All students will continue with the mathematics, physics and intellectual breadth courses common to all programs. A second-term student who has selected a degree program should be meeting with that program advisor for third-term elections.

Students who have not selected a degree program should consult the Engineering Advising Center for their course selections.

**LSA Honors-Level Courses**

Some math and science courses in LSA are considered honors level equivalents of the core math and science requirements. A student whose record indicates qualifications to perform at an advanced level should discuss this option with an advisor in the Engineering Advising Center.

**Minimum Common Requirements**

Each of the degree programs offered by the College includes credit hours that are common to all programs, subject to appropriate adjustment for equivalent alternatives. See individual sample schedules for required programs in each program section of this Bulletin. Some programs may have a higher minimum grade requirement for some courses.

**Double Counting Courses**

For Engineering Undergraduate students:
1. No course can count towards more than two degrees, such as two bachelor’s degrees or one bachelor’s degree and one master’s degree.
2. No course can count towards more than two majors, and no more than one major and one minor. A course can only count toward two minors if the credits received for that course are beyond the 128 credits required for the student’s major.
3. A course can count toward Supplemental Studies, Concentrations/Sub-Plans or Honors Programs regardless of how many majors or minors it is already counting towards.
4. SUGS (Sequential Undergraduate Graduate Studies) students who are pursuing a Rackham or College of Engineering master’s degree can only double count courses that are considered general electives or technical electives and are not part of the core requirement. The number of credits allowed to double count is determined by the individual departments, with 9 credits being the maximum allowed by Rackham. MDDP (Multiple Dependent Degree Program, typically referred to as Dual Degree) students are not eligible for the SUGS program.
5. Non-SUGS students pursuing a master’s degree from Rackham or College of Engineering, cannot transfer any credits used for their bachelor’s degree, even free electives or tech electives, toward their master’s degree. They may only transfer credits from courses that were not used to fulfill requirements for a degree or certificate (verified by an Undergraduate Program Advisor). Furthermore, the transferred credits must be from graduate-level courses and Rackham must receive confirmation (from their Graduate Coordinator) that these courses were at the graduate level and required graduate-level effort.

**Engineering 100: Introduction to Engineering**

Engineering 100 introduces students to the professional skills required of engineers and provides them with an overview of engineering at the beginning of their program. An important component of the course is the real-world engineering project. Important engineering skills developed in Engineering 100 include:

- Preparation of written technical reports and oral presentations to communicate ideas to a broad audience
- Technical problem solving and the creative engineering design process
- Teamwork and team management
- Professional responsibility
- The influence of engineers on society
- Sustainable engineering
- Decision-making skills

Numerous sections are offered both Fall and Winter semesters, featuring a variety of design projects. Students are strongly encouraged to select a section that aligns with their interests. Details on each of the sections can be found at the Engineering 100 website: [http://eng100.engin.umich.edu](http://eng100.engin.umich.edu)

**Important Note:** You must receive a grade of C or better in Engineering 100 to fulfill the requirement, however earning a grade lower than C may negatively impact a student’s
eligibility to declare a program and may require repeating the course. Transfer students must complete English composition or a course equivalent to ENGR 100 as a prerequisite for transfer admission. Any course satisfying the First Year Writing Requirement (FYWR) for LSA is an acceptable substitution for ENGR 100 for transfer students only. A list of available courses that meet the FYWR is available through the LSA Course Guide website at: https://www.lsa.umich.edu/cg/default/aspx. Be sure to consult with the Office of Recruitment and Admissions if you have questions.

Advanced Placement English Credit

Advanced Placement (AP) English Literature credit is assessed as English departmental credit and can be used towards the Liberal Arts Courses (LACs) of the Intellectual Breadth Requirement. You will not receive credit for Sweetland Writing Center courses.

Engineering 101: Introduction to Computers and Programming

The objective of Engineering 101 is to introduce students in Engineering to the algorithmic method that drives the information age. Algorithms are an organized means to construct the solution of a problem, structured as a well-defined set of steps that can be carried out by a mechanism such as a computer.

Engineering 101 focuses on the development of algorithms to solve problems of relevance in engineering practice and on the implementation of these algorithms using high-level computer languages. It is centered on quantitative and numerical problems that are suited to computational solutions. These often arise as part of larger, more complex problems in engineering practice.

Engineering 101 also ties itself to the introductory physics and math courses, and provides concrete examples of some of the concepts being covered in those classes. Sample problem types might include:

- Finding area and volume
- Simulating statistical processes
- Data analysis
- Physical simulation
- Simulating complex systems with simple rules
- Minimization and optimization
- Computer graphics
- Logic Puzzles

In addition to the problem-solving component, students who take Engineering 101 will learn aspects of the C++ programming languages and be exposed to the MATLAB programming language. C++ and MATLAB are used today in many fields of engineering. MATLAB is also popular and has powerful capabilities for handling computation involving matrices and for visualizing data using 2-D and 3-D graphics. It is important to note that MATLAB will be useful in future math and engineering courses.
Students entering Engineering 101 are not expected to know how to program; this skill will be taught as part of the class. Visit the Engineering 101 website for detailed information on specific sections of the class.

Engineering 151: Accelerated Introduction to Computers and Programming

Engineering 151 provides an accelerated alternative to Engineering 101 for students either with previous programming experience or with strong motivation and natural intuition for algorithms. It introduces students to the algorithm development, procedural programming concepts and languages covered in Engineering 101 but at a faster pace. It also introduces object-oriented programming, engineering analysis methods and additional topics such as parallel computing or embedded systems. Visit the Engineering 151 website for more detailed information.

Important notes (1) You must receive a grade of “C–” or better in Engineering 101 or Engineering 151 to fulfill the requirement, however earning a grade lower than C may negatively impact a student’s eligibility to declare a program and may require repeating the course.

Mathematics

The mathematics courses of 115 (4 credits), 116 (4 credits), 215 (4 credits), and 216 (4 credits) provide an integrated 16-credit-hour sequence in college mathematics that includes analytic geometry, calculus, elementary linear algebra and elementary differential equations.

All students with strong preparation and interest in mathematics are encouraged to consider one of the honors-level math sequences. Qualified and interested students should consult their engineering advisor about these options. It is not necessary to be in an honors program to enroll in these courses.

Earning a grade lower than C may negatively impact a students’ eligibility to declare a program and may require repeating the course. Experience indicates that students earning a grade of C- or below in a math class may have an insufficient foundation for further study in the quantitative field of engineering.

Advanced Placement Math Credit

Effective Date Winter Term 2017:

AP Math Credit – Double Counting Policies

The following rules apply to CoE undergraduate students:

1. Credit CANNOT be received for both AP MATH 120 and MATH 115. NOTE: If a student decides to enroll in or receives credit for MATH 115, then AP MATH 120 credit will be removed as students should not receive credit for both. Advisors can email engincredit@umich.edu to request removal if credit is not automatically
updated. AP MATH 120 credit may be reissued in the situation that the student decides to drop or withdraw from MATH 115.

2. Credit can be received for both AP MATH 120 and MATH 185, or both AP MATH 120 and MATH 295 as no double counting rules apply in these situations.

3. Credit can be received for both AP MATH 121 and MATH 116; however, AP MATH 121 will be reduced from four credit hours to two credit hours.

4. Credit may be received for both AP MATH 121 and MATH 156; however, AP MATH 121 will be reduced from four credit hours to two credit hours.

5. Credit may be received for both AP MATH 121 and MATH 176, or both AP MATH 121 and MATH 186, or both AP MATH 121 and MATH 296 as no double counting rules apply in these situations.

Chemistry

Chem 130 (3 credits) with laboratory Chem 125/126 (2 credits) is required by most degree programs. Students will normally elect these courses during the freshman year. The following degree programs require additional chemistry: Chemical Engineering and Environmental Engineering. Students expecting to enter Chemical Engineering normally elect Chem 130 (3 credits) and/or Chem 210 (3 credits) with Chem 211 laboratory (2) during the freshman year, depending on U-M placement exam results. Students expecting to enter Environmental Engineering normally elect Chem 130/125/126 and/or Chem 210 during the first year, depending on U-M placement exam results.

**Important Notes:**
(1) If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution, you will have met the Chemistry Core Requirement for CoE. (2) Students who place into Chem 210/211 will not be given credit for Chem 130. (3) Earning a grade lower than C may negatively impact a student’s eligibility to declare a program and may require repeating the course. (4) The Chemistry Placement Exam will be waived for students who score a 4 or higher on the AP Chemistry (effective Fall 2021).

Physics

The usual first-year schedule includes Physics 140 (4 credits) with laboratory, Physics 141 (1 credit). This course requires completion of Calculus I. A second course, Physics 240 (4 credits) with laboratory, 241 (1 credit), is required by all programs and is normally scheduled in the third term.

**Important Notes:**
(1) If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit for Physics 140/141 and 240/241 from another institution you will have met the Physics Core Requirement for CoE. (2) All students with strong preparation and interest in physics are encouraged to consider the honors-level physics sequence. (3) Earning a grade lower than C may negatively impact a student’s eligibility to declare a program and may require repeating the course.

Transfer Credits for Core Math and Science
Students who through use of transfer credit or credit-by-test have fewer than 31 credits total in: math covering the introductory sequence (equivalent to Math 115 – 214/216); introductory physics (Phys 140, 141, 240, 241); and introductory chemistry (Chem 130, 125/126); but have learned the required content as assessed by the math, physics or chemistry department must never-the-less makeup the difference in credit hours. This can be done using any number of elective courses in math or science, or, at the discretion of the program advisor, using engineering courses with a mathematical or science focus (e.g. engineering statistics, solid state or nuclear physics, etc.), to make up the total of 31 credits.

Note: ABET Criterion 5 requires all students to have a minimum of 32 credits of college level math and basic sciences, some with an experimental experience. They must also have 48 credits of engineering topics (engineering science and design). All of our programs provide at least one additional credit of math or science within departmental curricula, and in applying this policy for missing math and science credits “basic science” and “engineering science” will be appropriately distinguished.

**Intellectual Breadth**

Note: For students matriculated into the College of Engineering before September 2011, the Humanities and Social Science Requirements as appropriate to your year of matriculation apply. For more information, please refer to the edition of the Bulletin for your year of matriculation.

For students matriculated for Fall term 2011 and after the following requirements apply:

It is important that our students learn about modes of thought and areas of human accomplishment beyond the purely technical. This breadth can be designed by students to provide context to their engineering work by learning about human modes of thought, the structure and history of the human societies that they serve as engineers, how humans behave and interact, and how humans express their aspirations in the arts, literature and music. This breadth will help students to understand the impact of engineering solutions in a global, economic, environmental and societal context. This breadth makes our students more flexible, creative and better able to work with diverse groups.

We cannot precisely define all of these possibilities for every student so we strive to create a broad intellectual opportunity for students to pursue their interests both beyond and within engineering. Students are encouraged to use these credits in a coherent way to build a foundation of understanding in both the liberal arts and other disciplines that might contribute to their development of creativity or professional foundation.

The College of Engineering requires all students to complete 16 credits of Intellectual Breadth coursework, and between 9 and 16 credits of General Electives (depending on engineering major). To satisfy the Intellectual Breadth requirement, students must complete the following:

- **Humanities:** At least 3 credits of Humanities classes marked HU in the LSA course guide; credit by test cannot be used to meet this requirement.
• **Professional & Creative Development Courses (PCDC):** no more than 4 credits of PCDC (defined below).

• **Liberal Arts Courses (LACs):** The remainder of the 16 credits are drawn from any of the LACs (defined below).

• At least 3 credits in the Humanities or LACs must be at the 300 level or higher.

The currently approved numbers of general elective hours for each degree program are:

<table>
<thead>
<tr>
<th>Degree Program</th>
<th>Credits of General Electives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace Engineering</td>
<td>9</td>
</tr>
<tr>
<td>Biomedical Engineering</td>
<td>11</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>12</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>11</td>
</tr>
<tr>
<td>Climate and Meteorology</td>
<td>9</td>
</tr>
<tr>
<td>Computer Engineering</td>
<td>13-16</td>
</tr>
<tr>
<td>Computer Science</td>
<td>15</td>
</tr>
<tr>
<td>Data Science</td>
<td>15</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>11</td>
</tr>
<tr>
<td>Engineering Physics</td>
<td>12</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td>11</td>
</tr>
<tr>
<td>Industrial and Operations Engineering</td>
<td>9-12</td>
</tr>
<tr>
<td>Materials Science Engineering</td>
<td>12</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>9</td>
</tr>
<tr>
<td>Naval Architecture and Marine Engineering</td>
<td>9</td>
</tr>
<tr>
<td>Nuclear Engineering and Radiological Sciences</td>
<td>12</td>
</tr>
<tr>
<td>Space Science and Engineering</td>
<td>12</td>
</tr>
</tbody>
</table>

**Definition of Liberal Arts Courses**

Liberal Arts Courses (LACs) are intended to give students the broader education in qualitative critical thinking and human society that can give context to their engineering practice and to their contributions as citizens. For the sake of the College of Engineering intellectual breadth requirements, Liberal Arts Courses (LACs) are meant to exclude mathematics and science courses, as well as some courses that are considered...
preparatory to the CoE experience. Student’s elections of LACs are expected to be in this spirit. The precise operational definition of a LAC is:

- Any course offered by any UM-Ann Arbor unit marked as HU or SS in the LSA course guide is considered a LAC.
- For a course not marked as HU or SS but offered under one of the LSA subjects listed below, it is considered a LAC if it is not marked BS, NS, QR/1 or QR/2 in the LSA course guide.
- In addition, if a course is not marked HU or SS in the LSA course guide, but is marked EXPERIENTIAL or INDEPENDENT, then explicit permission of a CoE program advisor is needed to use it for a LAC course.
- Study Abroad Courses (STDABRD) might be counted as LACs, but only by explicit permission of a CoE program advisor. This is not meant to discourage study abroad, but reflects the broad nature of the STDABRD designation, which otherwise defies classification. As described below, transfer credit from US and foreign institutions may also be accepted as LACs credit.
- Please note that not all courses listed under the departments or divisions in the table are HU. Students must be sure that the courses they choose have the HU marked in the LSA Course Guide and be 300 and above.

**Please note:** This list is not a comprehensive list of LSA subjects with humanities (HU) or social science (SS) courses. For the current guide please visit the LSA Course Guide website: [http://www.lsa.umich.edu/CG](http://www.lsa.umich.edu/CG)

<table>
<thead>
<tr>
<th>Department</th>
<th>Code</th>
<th>Department</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afroamerican &amp; African Studies</td>
<td>(AAS)</td>
<td>Judiac Studies</td>
<td>(JUDIAC)</td>
</tr>
<tr>
<td>American Culture</td>
<td>(AMCULT)</td>
<td>Latin</td>
<td>(LATIN)</td>
</tr>
<tr>
<td>Anthropological Archaeology</td>
<td>(ANTHRARC)</td>
<td>Latin American &amp; Caribbean Studies</td>
<td>(LACS)</td>
</tr>
<tr>
<td>Arab American Studies</td>
<td>(ARABAM)</td>
<td>Linguistics</td>
<td>(LING)</td>
</tr>
<tr>
<td>Arabic Language</td>
<td>(ARABIC)</td>
<td>Lloyd Hall Scholars Program</td>
<td>(LHSP)</td>
</tr>
<tr>
<td>Armenian Language</td>
<td>(ARMENIAN)</td>
<td>Medieval &amp; Early Modern Studies</td>
<td>(MEMS)</td>
</tr>
<tr>
<td>Asian Languages</td>
<td>(ASIANLAN)</td>
<td>Middle Eastern &amp; North African Studies</td>
<td>(MENAS)</td>
</tr>
<tr>
<td>Asian Studies</td>
<td>(ASIAN)</td>
<td>Modern Greek</td>
<td>(MODGREEK)</td>
</tr>
<tr>
<td>Bosnian, Croatian and Serbian</td>
<td>(BCS)</td>
<td>Museum Studies</td>
<td>(MUSEUMS)</td>
</tr>
<tr>
<td>Program</td>
<td>Code</td>
<td>Discipline</td>
<td>Code</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------------</td>
<td>---------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Classical Archaeology</td>
<td>CLARCH</td>
<td>Near Eastern Studies</td>
<td>NEAREST</td>
</tr>
<tr>
<td>Classical Civilization</td>
<td>CLCIV</td>
<td>Organizational Studies</td>
<td>ORGSTUDY</td>
</tr>
<tr>
<td>Classical Linguistics</td>
<td>CLLING</td>
<td>Persian Language</td>
<td>PERSIAN</td>
</tr>
<tr>
<td>College Honors</td>
<td>HONORS</td>
<td>Philosophy</td>
<td>PHIL</td>
</tr>
<tr>
<td>Communication Studies</td>
<td>COMM</td>
<td>Polish</td>
<td>POLISH</td>
</tr>
<tr>
<td>Comparative Literature</td>
<td>COMPLIT</td>
<td>Political Science</td>
<td>POLSCI</td>
</tr>
<tr>
<td>Complex Systems</td>
<td>CMPLXSYS</td>
<td>Portuguese</td>
<td>PORTUG</td>
</tr>
<tr>
<td>Comprehensive Studies Program</td>
<td>CSP</td>
<td>Psychology</td>
<td>PSYCH</td>
</tr>
<tr>
<td>Cultural Anthropology</td>
<td>ANTHRCUL</td>
<td>Religion</td>
<td>RELIGION</td>
</tr>
<tr>
<td>Czech</td>
<td>CZECH</td>
<td>Romance Languages and Literatures</td>
<td>ROMLANG</td>
</tr>
<tr>
<td>Dutch</td>
<td>DUTCH</td>
<td>Romance Linguistics</td>
<td>ROMLING</td>
</tr>
<tr>
<td>Economics</td>
<td>ECON</td>
<td>Russian</td>
<td>RUSSIAN</td>
</tr>
<tr>
<td>English Language and Literature</td>
<td>ENGLISH</td>
<td>Russian, East European &amp; Eurasian Studies</td>
<td>REEES</td>
</tr>
<tr>
<td>Environment</td>
<td>ENVIRON</td>
<td>Scandinavian</td>
<td>SCAND</td>
</tr>
<tr>
<td>French</td>
<td>FRENCH</td>
<td>Film, Television, and Media</td>
<td>FTVM</td>
</tr>
<tr>
<td>Geography</td>
<td>GEOG</td>
<td>Slavic</td>
<td>SLAVIC</td>
</tr>
<tr>
<td>German</td>
<td>GERMAN</td>
<td>Sociology</td>
<td>SOC</td>
</tr>
<tr>
<td>Greek</td>
<td>GREEK</td>
<td>South Asian Studies</td>
<td>SAS</td>
</tr>
<tr>
<td>History</td>
<td>HISTORY</td>
<td>Southeast Asian Studies</td>
<td>SEAS</td>
</tr>
<tr>
<td>History of Art</td>
<td>HISTART</td>
<td>Spanish</td>
<td>SPANISH</td>
</tr>
</tbody>
</table>
Note: Chemical Engineering, Civil & Environmental Engineering, Mechanical Engineering and Materials Science & Engineering each requires one course in economics. This economics requirement can overlap with the LAC requirement.

Professional or Creative Development Courses (PCDC)

Professional and creative development courses offer a student the opportunity to build on non-engineering and non-technical courses to develop their creativity and professional capabilities as engineers. PCDC courses include any course from the following subjects in the indicated units, provided they are not marked BS or NS in the LSA course guide:

- Taubman College of Architecture and Urban Planning: Architecture (ARCH), Urban Design (UD), Urban Planning (UP), Urban and Regional Planning (URP—Effective FA 17)
- Stamps School of Art & Design (ARTDES, UARTS)
- Ross School of Business: Accounting (ACC), Business Administration (BA), Business Economics and Public Policy (BE), Entrepreneurial Studies (ES), Business Law & Business Communication (BL&BCOM), Marketing (MKT), Management and Organization (MO), Strategy (STRATEGY)
- School of Music, Theatre & Dance: Music Composition (COMP), Musicology (MUSICOL), Music Theory (THEORY), Theater & Drama (THTREMUS) and MUSPERF 300/PAT 305 (this course is an exception, no other PAT/MUSPERF courses will satisfy PCDC requirement)
- School of Natural Resources and Environment (NRE)
- Ford School of Public Policy (PUBPOL)
- School of Public Health: Health Behavior & Health Education (HBEHED), Health Management & Policy (HMP)
- College of Engineering: Center for Entrepreneurship (ENTR) – Effective WN 2018 (ENTR coursework taken FA 2013 and later can be used to satisfy PCDC requirements)

Transfer Credit and Credit by Test

College course credit transferred as any course meeting these requirements will be accepted as an HU, LAC or PCDC. Courses transferred as departmental credit can be accepted at the discretion of a CoE program advisor. Courses evaluated for transfer credit may also be marked HU or SS, in which case they are considered humanities or liberal arts courses, as described above. In addition, courses transferred as English
Composition (ENGCMPTC) also count as an LAC. Credit by test (e.g. Advanced Placement, A-Level and International Baccalaureate) can be used to satisfy any of these requirements except for the 3 credit humanities requirement. Foreign language credit by test at the 200 level or higher can count toward the LAC requirement but not the 3-credit humanities requirement. Foreign language credit by test at the 100 level can be used for General Electives only. In addition, language credit by test is limited to 8 credits.

Credit for Foreign Language
Effective for the incoming Fall 2021 incoming class, the CoE will no longer grant credit for students passing a language placement test offered by the College of LSA. Students seeking to continue in the study of a foreign language will, however, be eligible to earn retroactive language credits in certain languages if they completed an upper-level language course with a grade of B or better. Please see LSA’s Retroactive Language Credit Policy for general rules regarding this policy. Contact your academic advisor with questions about taking language placement exams.

The CoE values the study of language, so even when credit might not be granted, students are encouraged to take any language placement test for which they may be qualified, so that they can be properly placed in a more advanced language course or demonstrate proficiency for language-related opportunities (i.e. minor, study abroad).

Incoming first-year students who took a course(s) at a college or university while dually enrolled in high school may potentially receive transfer credit.

General Electives
General electives are intended to allow students to explore any dimension of intellectual endeavor that they elect, in both technical (including engineering) and non-technical fields. This requirement can be met by any course offered by the UM-Ann Arbor, subject to the following restrictions, or by transfer credit subject to the same restrictions in spirit.

Restrictions: Courses that require tutoring of other students enrolled in courses are limited to a maximum of 3 credits, with the exception of Physics 333 & Physics 334 which are both allowed for a maximum of 6 credits.

All undergraduate degree programs in the College of Engineering will accept credits earned in 200-, 300- and 400-level courses in military, naval or air science.

Tutorial courses are not acceptable for credit of grade points but will be included on the student’s official record.
Degree Options

Undergraduate Engineering Degrees

The College of Engineering offers 17 undergraduate programs of study, all of which lead to a Bachelor of Science in Engineering (B.S.E.) degree. Thirteen of these programs have specialized accreditation by ABET.

The available undergraduate degree programs and the major department responsible for each are:

<table>
<thead>
<tr>
<th>Degree Program</th>
<th>Major Department</th>
<th>ABET Accreditation</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.S.E. in Aerospace Engineering</td>
<td>Aerospace Engineering (AEROSP)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Biomedical Engineering</td>
<td>Biomedical Engineering (BME)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Chemical Engineering</td>
<td>Chemical Engineering (ChE)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Civil Engineering</td>
<td>Civil and Environmental Engineering (CEE)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Climate and Meteorology</td>
<td>Climate and Space Sciences and Engineering (CLaSP)</td>
<td>No</td>
</tr>
<tr>
<td>B.S.E. in Computer Engineering</td>
<td>Electrical Engineering &amp; Computer Science (EECS)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Computer Science</td>
<td>Electrical Engineering &amp; Computer Science (EECS)</td>
<td>CAC</td>
</tr>
<tr>
<td>B.S.E. in Data Science</td>
<td>Electrical Engineering &amp; Computer Science (EECS)</td>
<td>No</td>
</tr>
<tr>
<td>B.S.E. in Electrical Engineering</td>
<td>Electrical Engineering &amp; Computer Science (EECS)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Engineering Physics</td>
<td>Nuclear Engineering and Radiological Sciences (NERS)</td>
<td>No</td>
</tr>
<tr>
<td>B.S.E. in Environmental Engineering</td>
<td>Civil and Environmental Engineering (CEE)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Industrial and Operations Engineering</td>
<td>Industrial and Operations Engineering (IOE)</td>
<td>EAC</td>
</tr>
<tr>
<td>Degree Program</td>
<td>Program Description</td>
<td>Accreditation</td>
</tr>
<tr>
<td>----------------------------------------------------</td>
<td>-----------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>B.S.E. in Materials Science and Engineering</td>
<td>Materials Science and Engineering (MSE)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Mechanical Engineering</td>
<td>Mechanical Engineering (ME)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Naval Architecture and Marine Engineering</td>
<td>Naval Architecture and Marine Engineering (NAME)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Nuclear Engineering and Radiological Sciences</td>
<td>Nuclear Engineering and Radiological Sciences (NERS)</td>
<td>EAC</td>
</tr>
<tr>
<td>B.S.E. in Space Science and Engineering</td>
<td>Climate and Space Sciences and Engineering</td>
<td>No</td>
</tr>
</tbody>
</table>

**EAC:** These programs are accredited by the Engineering Accreditation Commission of ABET, [http://www.abet.org](http://www.abet.org).

**CAC:** This program is accredited by the Computing Accreditation Commission of ABET, [http://www.abet.org](http://www.abet.org).

Each of the undergraduate degree programs has core requirements that are common to all programs. These common requirements include 16 credits of math (calculus, differential equations and linear algebra), 15 credits of science (physics and chemistry), 16 credits of Intellectual Breadth and 8 credits of first year engineering courses. In addition, each program has between 9 and 15 credits of general electives. The remaining credit hours are specific to the B.S.E. degree program that the student elects to pursue.

Many of the courses required for one program may be used to meet the requirements of another. This opportunity to obtain additional undergraduate engineering degrees must be discussed with the pertinent program advisor. See “Requirements for an Additional Bachelor’s Degree.”

**Declaring One of the Degree Programs**

To give students the opportunity to explore the numerous engineering degrees offered by the College, first-year undergraduate engineering students not transferring from another institution of higher education enter the College without declaring a specific engineering major. None of the majors require any 100-level courses to be taken by a student other than those in the common engineering, math and science core. Students are urged to declare a specific engineering major by the start of their 3rd term of enrollment. Undeclared students cannot register for a 4th term in the College unless they have met with their advisor and developed a plan to select and declare a major within a reasonable time. This plan can be developed in coordination among the EAC advisors and departmental program advisors.

Criteria to declare a degree program are described in the Rules section of the Bulletin: [https://bulletin.engin.umich.edu/rules/registration/](https://bulletin.engin.umich.edu/rules/registration/)
Dual Baccalaureate Degree Opportunities

Students with interest in more than one program offered by the College may work for an additional bachelor’s degree concurrently if they plan their course elections carefully. Students will find that it is possible to satisfy the subject requirements of both programs in a minimum amount of time by conferring early with the respective program advisors. Approval by involved departments is required. See the Rules section of the Bulletin: https://bulletin.engin.umich.edu/rules/graduation/. The College generally recommends that students consider pursuing some of the many co- and extracurricular activities offered as an alternative to a second CoE degree.

Students in other U-M schools or colleges wishing to be admitted to the College of Engineering as a dual degree student must:

- Be admissible to CoE (i.e., meet cross-campus admissions criteria, including prerequisite courses and minimum GPA, and be eligible to declare a major)
- Have completed onCore Requirements
- Planning the Student’s Program
- Students vary in their goals and objectives, in their level of achievement and in their high school or pre-engineering preparation. Considerable variety and flexibility are provided to plan each student’s schedule so that the individual may reach graduation as efficiently as possible. The objective is to place each new student in courses commensurate with his or her academic profile, previous experience and potential for academic success.
- Most courses have prerequisites. The completion of courses on schedule and with satisfactory grades is essential to the student’s progress.
- The appropriate schedule for each student in each term will depend on a number of factors such as: past scholastic record; placement test results; extracurricular activities; election of co-op, international or Military Office Education Programs; health; and need for partial self-support. A schedule of 12 to 18 hours is considered full-time.
- All College of Engineering B.S.E. programs require successful completion of a program of 128 credit hours. An average of 16 credit-hours per term allows a student to complete these programs in 8 terms, generally requiring 4 years of study.
- First- and Second-Year Programs
- At the time of each student’s first advising session, all of the high school and advance placement records may not yet be in the student’s file. It is the entering student’s responsibility to make certain that all pertinent information is brought to the attention of an Engineering Advising Center (EAC) Advisor. Any changes in test scores or transfer credits will affect final course selection and need to be discussed with an advisor.
- With complete information available, the advisor and the student will be able to make carefully considered adjustments in course elections for the first-term course schedule.
- First Year
Assuming the necessary academic preparation and no Advanced Placement credit, each student will be expected to complete some combination of the following courses:
- Mathematics 115 and 116 or one of the honors Math sequences
- Chemistry 130 and 125/126, or, for some, 130, 210, and 211
- Engineering 100 (Any course satisfying the First Year Writing Requirement (FYWR) for LSA is an acceptable substitution for ENGR 100 for transfer students only. A list of available courses that meet the FYWR is available through the LSA Course Guide website at: https://www.lsa.umich.edu/cg/default/aspx)
- Engineering 101 or Engineering 151 (ENGR 151 is an approved alternative to ENGR 101 for all CoE programs)
- Physics 140 and 141
- Additional course information will be available during the advising session.

Second Year
- All students will continue with the mathematics, physics and intellectual breadth courses common to all programs. A second-term student who has selected a degree program should be meeting with that program advisor for third-term elections.
- Students who have not selected a degree program should consult the Engineering Advising Center for their course selections.

LSA Honors-Level Courses
- Some math and science courses in LSA are considered honors level equivalents of the core math and science requirements. A student whose record indicates qualifications to perform at an advanced level should discuss this option with an advisor in the Engineering Advising Center.

Minimum Common Requirements
- Each of the degree programs offered by the College includes credit hours that are common to all programs, subject to appropriate adjustment for equivalent alternatives. See individual sample schedules for required programs in each program section of this Bulletin. Some programs may have a higher minimum grade requirement for some courses.

Double Counting Courses
- For Engineering Undergraduate students:
  - No course can count towards more than two degrees, such as two bachelor’s degrees or one bachelor’s degree and one master’s degree.
  - No course can count towards more than two majors, and no more than one major and one minor. A course can only count toward two minors if the credits received for that course are beyond the 128 credits required for the student’s major.
  - A course can count toward Supplemental Studies, Concentrations/Sub-Plans or Honors Programs regardless of how many majors or minors it is already counting towards.
  - SUGS (Sequential Undergraduate Graduate Studies) students who are pursuing a Rackham or College of Engineering master’s degree can only double count courses that are considered general electives or technical electives and are not
part of the core requirement. The number of credits allowed to double count is
determined by the individual departments, with 9 credits being the maximum
allowed by Rackham. MDDP (Multiple Dependent Degree Program, typically
referred to as Dual Degree) students are not eligible for the SUGS program.

- Non-SUGS students pursuing a master's degree from Rackham or College of
  Engineering, cannot transfer any credits used for their bachelor’s degree, even
  free electives or tech electives, toward their master’s degree. They may only
  transfer credits from courses that were not used to fulfill requirements for a degree
  or certificate (verified by an Undergraduate Program Advisor). Furthermore, the
  transferred credits must be from graduate-level courses and Rackham must
  receive confirmation (from their Graduate Coordinator) that these courses were at
  the graduate level and required graduate-level effort.

- Engineering 100: Introduction to Engineering
  Engineering 100 introduces students to the professional skills required of
  engineers and provides them with an overview of engineering at the beginning of
  their program. An important component of the course is the real-world engineering
  project. Important engineering skills developed in Engineering 100 include:
  - Preparation of written technical reports and oral presentations to communicate
    ideas to a broad audience
  - Technical problem solving and the creative engineering design process
  - Teamwork and team management
  - Professional responsibility
  - The influence of engineers on society
  - Sustainable engineering
  - Decision-making skills
  - Numerous sections are offered both Fall and Winter semesters, featuring a variety
    of design projects. Students are strongly encouraged to select a section that
    aligns with their interests. Details on each of the sections can be found at the
    Engineering 100 website: http://eng100.engin.umich.edu

  - Important Note: You must receive a grade of C or better in Engineering 100 to
    fulfill the requirement, however earning a grade lower than C may negatively
    impact a student’s eligibility to declare a program and may require repeating the
    course. Transfer students must complete English composition or a course
    equivalent to ENGR 100 as a prerequisite for transfer admission. Any course
    satisfying the First Year Writing Requirement (FYWR) for LSA is an acceptable
    substitution for ENGR 100 for transfer students only. A list of available courses
    that meet the FYWR is available through the LSA Course Guide website at:
    https://www.lsa.umich.edu/cg/default/aspx. Be sure to consult with the Office of
    Recruitment and Admissions if you have questions.

- Advanced Placement English Credit
  Advanced Placement (AP) English Literature credit is assessed as English
  departmental credit and can be used towards the Liberal Arts Courses (LACs) of
  the Intellectual Breadth Requirement. You will not receive credit for Sweetland
  Writing Center courses.

- Engineering 101: Introduction to Computers and Programming
• The objective of Engineering 101 is to introduce students in Engineering to the algorithmic method that drives the information age. Algorithms are an organized means to construct the solution of a problem, structured as a well-defined set of steps that can be carried out by a mechanism such as a computer.

• Engineering 101 focuses on the development of algorithms to solve problems of relevance in engineering practice and on the implementation of these algorithms using high-level computer languages. It is centered on quantitative and numerical problems that are suited to computational solutions. These often arise as part of larger, more complex problems in engineering practice.

• Engineering 101 also ties itself to the introductory physics and math courses, and provides concrete examples of some of the concepts being covered in those classes. Sample problem types might include:
  - Finding area and volume
  - Simulating statistical processes
  - Data analysis
  - Physical simulation
  - Simulating complex systems with simple rules
  - Minimization and optimization
  - Computer graphics
  - Logic Puzzles

• In addition to the problem-solving component, students who take Engineering 101 will learn aspects of the C++ programming languages and be exposed to the MATLAB programming language. C++ and MATLAB are used today in many fields of engineering. MATLAB is also popular and has powerful capabilities for handling computation involving matrices and for visualizing data using 2-D and 3-D graphics. It is important to note that MATLAB will be useful in future math and engineering courses.

• Students entering Engineering 101 are not expected to know how to program; this skill will be taught as part of the class. Visit the Engineering 101 website for detailed information on specific sections of the class.

• Engineering 151: Accelerated Introduction to Computers and Programming
  - Engineering 151 provides an accelerated alternative to Engineering 101 for students either with previous programming experience or with strong motivation and natural intuition for algorithms. It introduces students to the algorithm development, procedural programming concepts and languages covered in Engineering 101 but at a faster pace. It also introduces object-oriented programming, engineering analysis methods and additional topics such as parallel computing or embedded systems. Visit the Engineering 151 website for more detailed information.

• Important notes (1) You must receive a grade of “C–” or better in Engineering 101 or Engineering 151 to fulfill the requirement, however earning a grade lower than C may negatively impact a student’s eligibility to declare a program and may require repeating the course.

• Mathematics
The mathematics courses of 115 (4 credits), 116 (4 credits), 215 (4 credits), and 216 (4 credits) provide an integrated 16-credit-hour sequence in college mathematics that includes analytic geometry, calculus, elementary linear algebra and elementary differential equations.

All students with strong preparation and interest in mathematics are encouraged to consider one of the honors-level math sequences. Qualified and interested students should consult their engineering advisor about these options. It is not necessary to be in an honors program to enroll in these courses.

Earning a grade lower than C may negatively impact a student’s eligibility to declare a program and may require repeating the course. Experience indicates that students earning a grade of C- or below in a math class may have an insufficient foundation for further study in the quantitative field of engineering.

Advanced Placement Math Credit
Effective Date Winter Term 2017:

AP Math Credit – Double Counting Policies
The following rules apply to CoE undergraduate students:

Credit CANNOT be received for both AP MATH 120 and MATH 115. NOTE: If a student decides to enroll in or receives credit for MATH 115, then AP MATH 120 credit will be removed as students should not receive credit for both. Advisors can email engincredit@umich.edu to request removal if credit is not automatically updated. AP MATH 120 credit may be reissued in the situation that the student decides to drop or withdraw from MATH 115.

Credit can be received for both AP MATH 120 and MATH 185, or both AP MATH 120 and MATH 295 as no double counting rules apply in these situations.

Credit can be received for both AP MATH 121 and MATH 116; however, AP MATH 121 will be reduced from four credit hours to two credit hours.

Credit may be received for both AP MATH 121 and MATH 156; however, AP MATH 121 will be reduced from four credit hours to two credit hours.

Credit may be received for both AP MATH 121 and MATH 176, or both AP MATH 121 and MATH 186, or both AP MATH 121 and MATH 296 as no double counting rules apply in these situations.

Chemistry
Chem 130 (3 credits) with laboratory Chem 125/126 (2 credits) is required by most degree programs. Students will normally elect these courses during the freshman year. The following degree programs require additional chemistry: Chemical Engineering and Environmental Engineering. Students expecting to enter Chemical Engineering normally elect Chem 130 (3 credits) and/or Chem 210 (3 credits) with Chem 211 laboratory (2) during the freshman year, depending on U-M placement exam results. Students expecting to enter Environmental Engineering normally elect Chem 130/125/126 and/or Chem 210 during the first year, depending on U-M placement exam results.

Important Notes: (1) If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution, you will have met the Chemistry Core Requirement for CoE. (2) Students who place into Chem 210/211 will not be given credit for Chem 130. (3) Earning a grade lower than C may
negatively impact a student’s eligibility to declare a program and may require repeating the course. (4) The Chemistry Placement Exam will be waived for students who score a 4 or higher on the AP Chemistry (effective Fall 2021).

- **Physics**
  - The usual first-year schedule includes Physics 140 (4 credits) with laboratory, Physics 141 (1 credit). This course requires completion of Calculus I. A second course, Physics 240 (4 credits) with laboratory, 241 (1 credit), is required by all programs and is normally scheduled in the third term.
  - Important Notes: (1) If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit for Physics 140/141 and 240/241 from another institution, you will have met the Physics Core Requirement for CoE. (2) All students with strong preparation and interest in physics are encouraged to consider the honors-level physics sequence. (3) Earning a grade lower than C may negatively impact a student’s eligibility to declare a program and may require repeating the course.

- **Transfer Credits for Core Math and Science**
  - Students who through use of transfer credit or credit-by-test have fewer than 31 credits total in: math covering the introductory sequence (equivalent to Math 115 – 214/216); introductory physics (Phys 140, 141, 240, 241); and introductory chemistry (Chem 130, 125/126); but have learned the required content as assessed by the math, physics or chemistry department must never-the-less makeup the difference in credit hours. This can be done using any number of elective courses in math or science, or, at the discretion of the program advisor, using engineering courses with a mathematical or science focus (e.g. engineering statistics, solid state or nuclear physics, etc.), to make up the total of 31 credits.
  - Note: ABET Criterion 5 requires all students to have a minimum of 32 credits of college level math and basic sciences, some with an experimental experience. They must also have 48 credits of engineering topics (engineering science and design). All of our programs provide at least one additional credit of math or science within departmental curricula, and in applying this policy for missing math and science credits “basic science” and “engineering science” will be appropriately distinguished.

- **Intellectual Breadth**
  - Note: For students matriculated into the College of Engineering before September 2011, the Humanities and Social Science Requirements as appropriate to your year of matriculation apply. For more information, please refer to the edition of the Bulletin for your year of matriculation.
  - For students matriculated for Fall term 2011 and after the following requirements apply:
  - It is important that our students learn about modes of thought and areas of human accomplishment beyond the purely technical. This breadth can be designed by students to provide context to their engineering work by learning about human modes of thought, the structure and history of the human societies that they serve as engineers, how humans behave and interact, and how humans express their aspirations in the arts, literature and music. This breadth will help students to
understand the impact of engineering solutions in a global, economic, environmental and societal context. This breadth makes our students more flexible, creative and better able to work with diverse groups.

- We cannot precisely define all of these possibilities for every student so we strive to create a broad intellectual opportunity for students to pursue their interests both beyond and within engineering. Students are encouraged to use these credits in a coherent way to build a foundation of understanding in both the liberal arts and other disciplines that might contribute to their development of creativity or professional foundation.

- The College of Engineering requires all students to complete 16 credits of Intellectual Breadth coursework, and between 9 and 16 credits of General Electives (depending on engineering major). To satisfy the Intellectual Breadth requirement, students must complete the following:
  - Humanities: At least 3 credits of Humanities classes marked HU in the LSA course guide; credit by test cannot be used to meet this requirement.
  - Professional & Creative Development Courses (PCDC): no more than 4 credits of PCDC (defined below).
  - Liberal Arts Courses (LACs): The remainder of the 16 credits are drawn from any of the LACs (defined below).
  - At least 3 credits in the Humanities or LACs must be at the 300 level or higher.
  - The currently approved numbers of general elective hours for each degree program are:

<table>
<thead>
<tr>
<th>Degree Program</th>
<th>Credits of General Electives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace Engineering</td>
<td>9</td>
</tr>
<tr>
<td>Biomedical Engineering</td>
<td>11</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>12</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>11</td>
</tr>
<tr>
<td>Climate and Meteorology</td>
<td>9</td>
</tr>
<tr>
<td>Computer Engineering</td>
<td>13-16</td>
</tr>
<tr>
<td>Computer Science</td>
<td>15</td>
</tr>
<tr>
<td>Data Science</td>
<td>15</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>11</td>
</tr>
<tr>
<td>Engineering Physics</td>
<td>12</td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td>11</td>
</tr>
<tr>
<td>Industrial and Operations Engineering</td>
<td>9-12</td>
</tr>
<tr>
<td>Materials Science Engineering</td>
<td>12</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>9</td>
</tr>
<tr>
<td>Naval Architecture and Marine Engineering</td>
<td>9</td>
</tr>
<tr>
<td>Nuclear Engineering and Radiological Sciences</td>
<td>12</td>
</tr>
<tr>
<td>Space Science and Engineering</td>
<td>12</td>
</tr>
</tbody>
</table>

- Definition of Liberal Arts Courses
Liberal Arts Courses (LACs) are intended to give students the broader education in qualitative critical thinking and human society that can give context to their engineering practice and to their contributions as citizens. For the sake of the College of Engineering intellectual breadth requirements, Liberal Arts Courses (LACs) are meant to exclude mathematics and science courses, as well as some courses that are considered preparatory to the CoE experience. Student’s elections of LACs are expected to be in this spirit. The precise operational definition of a LAC is:

- Any course offered by any UM-Ann Arbor unit marked as HU or SS in the LSA course guide is considered a LAC.
- For a course not marked as HU or SS but offered under one of the LSA subjects listed below, it is considered a LAC if it is not marked BS, NS, QR/1 or QR/2 in the LSA course guide.
- In addition, if a course is not marked HU or SS in the LSA course guide, but is marked EXPERIENTIAL or INDEPENDENT, then explicit permission of a CoE program advisor is needed to use it for a LAC course.
- Study Abroad Courses (STDABRD) might be counted as LACs, but only by explicit permission of a CoE program advisor. This is not meant to discourage study abroad, but reflects the broad nature of the STDABRD designation, which otherwise defies classification. As described below, transfer credit from US and foreign institutions may also be accepted as LACs credit.
- Please note that not all courses listed under the departments or divisions in the table are HU. Students must be sure that the courses they choose have the HU marked in the LSA Course Guide and be 300 and above.
- Please note: This list is not a comprehensive list of LSA subjects with humanities (HU) or social science (SS) courses. For the current guide please visit the LSA Course Guide website: http://www.lsa.umich.edu/CG

- Afroamerican & African Studies (AAS)
- Judiac Studies (JUDIAC)
- American Culture (AMCULT)
- Latin (LATIN)
- Anthropological Archaeology (ANTHRARC)
- Latin American & Caribbean Studies (LACS)
- Arab American Studies (ARABAM)
- Linguistics (LING)
- Arabic Language (ARABIC)
- Lloyd Hall Scholars Program (LHSP)
- Armenian Language (ARMENIAN)
- Medieval & Early Modern Studies (MEMS)
- Asian Languages (ASIANLAN)
- Middle Eastern & North African Studies (MENAS)
- Asian Studies (ASIAN)
- Modern Greek (MODGREEK)
• Bosnian, Croatian and Serbian (BCS)
• Museum Studies (MUSEUMS)
• Classical Archaeology (CLARCH)
• Near Eastern Studies (NEAREST)
• Classical Civilization (CLCIV)
• Organizational Studies (ORGSTUDY)
• Classical Linguistics (CLLING)
• Persian Language (PERSIAN)
• College Honors (HONORS)
• Philosophy (PHIL)
• Communication Studies (COMM)
• Polish (POLISH)
• Comparative Literature (COMPLIT)
• Political Science (POLSCI)
• Complex Systems (CMPLXSYS)
• Portuguese (PORTUG)
• Comprehensive Studies Program (CSP)
• Psychology (PSYCH)
• Cultural Anthropology (ANTHRCUL)
• Religion (RELIGION)
• Czech (CZECH)
• Romance Languages and Literatures (ROMLANG)
• Dutch (DUTCH)
• Romance Linguistics (ROMLING)
• Economics (ECON)
• Russian (RUSSIAN)
• English Language and Literature (ENGLISH)
• Russian, East European & Eurasian Studies (REEES)
• Environment (ENVIRON)
• Scandinavian (SCAND)
• French (FRENCH)
• Film, Television, and Media (FTVM)
• Geography (GEOG)
• Slavic (SLAVIC)
• German (GERMAN)
• Sociology (SOC)
• Greek (GREEK)
• South Asian Studies (SAS)
• History (HISTORY)
• Southeast Asian Studies (SEAS)
• History of Art (HISTART)
- Spanish (SPANISH)
- International Studies (INTLSTD)
- Turkish Language (TURKISH)
- Islamic Studies (ISLAM)
- Ukrainian (UKRAINE)
- Italian (ITALIAN)
- Women’s Studies (WOMENSTD)

Note: Chemical Engineering, Civil & Environmental Engineering, Mechanical Engineering and Materials Science & Engineering each requires one course in economics. This economics requirement can overlap with the LAC requirement.

- Professional or Creative Development Courses (PCDC)
- Professional and creative development courses offer a student the opportunity to build on non-engineering and non-technical courses to develop their creativity and professional capabilities as engineers. PCDC courses include any course from the following subjects in the indicated units, provided they are not marked BS or NS in the LSA course guide:
  - Taubman College of Architecture and Urban Planning: Architecture (ARCH), Urban Design (UD), Urban Planning (UP), Urban and Regional Planning (URP—Effective FA 17)
  - Stamps School of Art & Design (ARTDES, UARTS)
  - Ross School of Business: Accounting (ACC), Business Administration (BA), Business Economics and Public Policy (BE), Entrepreneurial Studies (ES), Business Law & Business Communication (BL&BCOM), Marketing (MKT), Management and Organization (MO), Strategy (STRATEGY)
  - School of Music, Theatre & Dance: Music Composition (COMP), Musicology (MUSICOL), Music Theory (THEORY), Theater & Drama (THTREMUS) and MUSPERF 300/PAT 305 (this course is an exception, no other PAT/MUSPERF courses will satisfy PCDC requirement)
  - School of Natural Resources and Environment (NRE)
  - Ford School of Public Policy (PUBPOL)
  - School of Public Health: Health Behavior & Health Education (HBEHED), Health Management & Policy (HMP)
  - College of Engineering: Center for Entrepreneurship (ENTR) – Effective WN 2018 (ENTR coursework taken FA 2013 and later can be used to satisfy PCDC requirements)

- Transfer Credit and Credit by Test
- College course credit transferred as any course meeting these requirements will be accepted as an HU, LAC or PCDC. Courses transferred as departmental credit can be accepted at the discretion of a CoE program advisor. Courses evaluated for transfer credit may also be marked HU or SS, in which case they are considered humanities or liberal arts courses, as described above. In addition, courses transferred as English Composition (ENGCMPTC) also count as an LAC.
- Credit by test (e.g. Advanced Placement, A-Level and International
Baccalaureate) can be used to satisfy any of these requirements except for the 3 credit humanities requirement. Foreign language credit by test at the 200 level or higher can count toward the LAC requirement but not the 3-credit humanities requirement. Foreign language credit by test at the 100 level can be used for General Electives only. In addition, language credit by test is limited to 8 credits.

- Credit for Foreign Language

- Effective for the incoming Fall 2021 incoming class, the CoE will no longer grant credit for students passing a language placement test offered by the College of LSA. Students seeking to continue in the study of a foreign language will, however, be eligible to earn retroactive language credits in certain languages if they completed an upper-level language course with a grade of B or better. Please see LSA’s Retroactive Language Credit Policy for general rules regarding this policy. Contact your academic advisor with questions about taking language placement exams.

- The CoE values the study of language, so even when credit might not be granted, students are encouraged to take any language placement test for which they may be qualified, so that they can be properly placed in a more advanced language course or demonstrate proficiency for language-related opportunities (i.e. minor, study abroad).

- Incoming first-year students who took a course(s) at a college or university while dually enrolled in high school may potentially receive transfer credit.

- General Electives

- General electives are intended to allow students to explore any dimension of intellectual endeavor that they elect, in both technical (including engineering) and non-technical fields. This requirement can be met by any course offered by the UM-Ann Arbor, subject to the following restrictions, or by transfer credit subject to the same restrictions in spirit.

- Restrictions: Courses that require tutoring of other students enrolled in courses are limited to a maximum of 3 credits, with the exception of Physics 333 & Physics 334 which are both allowed for a maximum of 6 credits.

- All undergraduate degree programs in the College of Engineering will accept credits earned in 200-, 300- and 400-level courses in military, naval or air science.

- Tutorial courses are not acceptable for credit of grade points but will be included on the student’s official record.

- Be in good academic standing

Opportunities for CoE students to obtain an additional bachelor’s degree in the College of Literature, Science, and the Arts, the Ross School of Business Administration, the School of Music, Theatre & Dance and other academic units are also available under Multiple Dependent Degree Program options and are described below. These programs may take 11 to 12 terms to complete because of the differences in degree requirements between the degrees offered in different colleges.
Multiple Dependent Degree Programs (MDDP)

*Please note that students earning more than one degree are not eligible for SUGS programs.

Current process for becoming an MDDP student:

1. Student emails enginrta@umich.edu for the required MDDP Form
2. The CoE Office of Recruitment and Admissions reviews the student for eligibility
3. If the student is admissible, recommend meeting with the departmental advisor (if they haven’t already done so)
4. Completed MDDP Form is sent to the College of Engineering Office of the Registrar for processing.

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

Students enrolled for a bachelor’s degree in the College of Engineering or the College of Literature, Science, and the Arts (LS&A) may obtain the degrees in both colleges simultaneously by enrolling in the Combined Degree Program that has been established by the two colleges, and by fulfilling the requirements as outlined below. This program has been developed to make it convenient for students to obtain a broader education than would normally be possible by enrolling in only one college.

It is particularly advantageous for students who wish to develop some depth of understanding in both the technically oriented studies offered in the College of Engineering and the physical, natural, or social sciences and humanities available in LS&A. Such a combination can provide a truly liberal education for the 21st century and should be excellent preparation for meeting the challenges of modern society, which involve, to an ever-increasing extent, both technical and sociological issues.

Program Requirements

Candidates for a Bachelor of Science in Engineering (B.S.E.) in the College of Engineering combined with a Bachelor of Arts (B.A.) in LS&A must:

- Satisfy the requirements of one of the degree programs in the College of Engineering;
- Take a minimum of 90 credit hours of work in LS&A, satisfy the distribution requirements of LS&A, and fulfill the concentration requirements for one of the LS&A programs; and
- Have a cumulative grade point average of 2.00 or higher.

Candidates for a Bachelor of Science in Engineering (B.S.E.) in the College of Engineering, combined with a Bachelor of General Studies (B.G.S.) in LS&A must:

- Satisfy the requirements of one of the degree programs in the College of Engineering;
- Take a minimum of 90 credit hours of work in LS&A of which 40 credit hours must be for courses numbered 300 or higher and are passed with a grade of “C” or
higher, with no more than 15 of these 40 credit hours to consist of courses in any one department; and

- Have a cumulative grade point average of 2.00 or higher.

Students transferring to the University of Michigan with advanced standing and entering a Combined Degree Program must complete a minimum of 60 credit hours of work in LS&A in residence.

All students should consult the program advisors in their field of specialization in every college each term to develop an optimum set of courses for the particular combination of fields of specialization of interest to them.

In general, advisors working with students in this Combined Degree Program will, whenever possible, attempt to minimize the total number of courses required by recommending those that will contribute toward fulfilling requirements in both colleges. Thus, many of the courses needed to fulfill the requirements in mathematics, chemistry and physics in the College of Engineering will contribute toward fulfilling natural science distribution requirements and prerequisites for concentration in fields such as astronomy, chemistry, geology-mineralogy, mathematics and physics in LS&A.

Likewise, requirements in humanities and liberal arts courses for the College of Engineering can be selected from courses taken to fulfill distribution requirements in LS&A. In this way, it is usually possible for students carrying average loads of 16 credit hours per term to complete the requirements of this Combined Degree Program in 10 or 11 terms.

In order to ensure that the courses selected apply effectively and efficiently to both degrees, students must assume responsibility for maintaining contact between their two advisors. They should become thoroughly familiar with the general regulations and procedures of both colleges and with the academic requirements and course offerings in both fields of specialization as set forth in the Bulletin of each college. If unusual difficulties or special problems arise, students should consult the Combined Degree Program advisors who will work with the students and their faculty advisors in attempting to find a solution.

**Regulations**

The following regulations for enrollment will apply:

1. Students initially enrolled in either the College of Engineering or LS&A may enter this Combined Degree Program.
2. To be qualified for admission, students normally should have completed 30 credit hours of the appropriate coursework. LS&A students must have an overall grade point average equal to, or higher than, the current minimum grade point average for cross-campus transfer for the particular engineering degree sought. Engineering students must have an overall grade point average of at least 2.7.
3. Students considering this program must obtain the signature of the College of Engineering Registrar to apply for admission and to establish advising procedures as soon as their interests are firmly established, preferably by the end of the first
Upon applying for admission, students must choose a field of specialization in each college. Application for admission must then be approved by the Associate Dean’s Office of each college and by the academic advisor in each of these fields of specialization.

4. After being admitted to this program, students will continue to register in the college in which they first enrolled, and that college will be responsible for maintenance of their primary academic records.

5. Students participating in this program should consult with the program advisor for their field of specialization in each college prior to registration each term, to obtain approval of course elections. To be permitted to continue in this Combined Degree Program, students must satisfy the requirements of both colleges with regard to good scholastic standing.

6. Students in good scholastic standing who wish to withdraw from this Combined Degree Program may continue to enroll for a single degree in their original college. If they wish to transfer, they may do so provided their record is acceptable to the other college. For instructions regarding transfers, students should consult the appropriate officials of the college in which they are registered. Students not in good scholastic standing will normally remain in the college in which they initially enrolled and be subject to the rules of that college.

7. Upon satisfying the program requirements of both colleges, students will receive both degrees on the same date. At the beginning of the term in which they expect to graduate, they must apply for graduation through Student Business in Wolverine Access in each college.

**College of Engineering and the Ross School of Business**

Students originally enrolled in an undergraduate degree program in the College of Engineering who are admitted to the Ross School of Business may obtain degrees in both simultaneously by enrolling in the Multiple Dependent Degree Program (MDDP) that has been established between the two. This program is designed to allow students to develop a course of study that offers broader academic opportunities than would normally be possible by enrolling in only one college. These combined degrees are open to students initially enrolled in Engineering who are accepted into the Ross School of Business BBA program.

In order to ensure that the courses selected apply efficiently to both degrees, students must maintain coordination between their College of Engineering and Ross School advisors. The students must consult the program advisors in their degree disciplines for specific requirements for the appropriate degrees.

Degree requirements must be met for both colleges simultaneously to be eligible to receive the appropriate undergraduate degrees. Upon satisfying the program requirements of both colleges, students will receive both degrees on the same date. At the beginning of the term in which they expect to graduate, students must apply for graduation through Student Business in Wolverine Access in each college/school and must ask their program advisor in each unit to submit an appropriate notification of their eligibility for graduation to the appropriate office in the College or School.
Students who are admitted to the BBA program and wish to pursue the MDDP must make this clear to both colleges. Unless this is done, admission to the BBA program can result in the student being disenrolled from the College of Engineering. Like most other dual degree programs, this program will generally require 11 to 12 terms to complete both degrees.

**College of Engineering and the School of Music, Theatre & Dance**

This program is designed to allow students to develop a course of study that offers broader academic opportunities than those offered by the College of Engineering or the School of Music, Theatre & Dance individually. The program is intended for students who seek the technical studies associated with the College of Engineering in combination with the professional training in applied or academic studies associated with the School of Music, Theatre & Dance. These dual degrees are open to students enrolled in the College of Engineering or the School of Music, Theatre & Dance. They lead to concurrent bachelor’s degrees from both units.

Each student should consult faculty advisors in both units to develop the best plan of study. Primary responsibility for planning the academic program and continued contact with academic advisors in the two fields rests with the student, who is also responsible for becoming familiar with the academic policies and procedures of both units and the academic requirements in both fields as described in the Bulletins of both the College of Engineering and of the School of Music, Theatre & Dance. The student is responsible for maintaining contact with the appropriate engineering department (or, if undeclared, the Engineering Advising Center) in order to receive proper advising for course selection, etc.

Candidates for the combined Bachelor of Science in Engineering (B.S.E.) in the College of Engineering and appropriate degree (B.Mus., B.M.A., or B.F.A.) in the School of Music, Theatre & Dance must:

- Complete one of the degree programs in the College of Engineering;
- Complete one of the degree programs in the School of Music, Theater & Dance (usually 90 credits); and
- Maintain a minimum cumulative grade point average of 2.0 and good scholastic standing in both the College of Engineering and the School of Music, Theatre & Dance.

It is usually possible for students electing 16-17 credits per term to meet all requirements in 11 or 12 terms.

Students who are dually enrolled and decide not to pursue a degree from the School of Music, Theatre & Dance do not have to reapply for admission to the College of Engineering.

**College of Engineering and the Stamps School of Art & Design**

Students enrolled in an undergraduate degree in the College of Engineering (CoE) or School of Art & Design (A&D) may obtain degrees from both simultaneously by enrolling
in the Multiple Dependent Degree Program (MDDP) that has been established between the two. This program is designed to allow students to develop a course of study that offers broader academic opportunities than would normally be possible by enrolling in only one unit or the other.

Students are required to meet regularly with advisors in both A&D and CoE to review specific course requirements and to develop a plan of study. It is the student’s responsibility to develop a strategy for completing the degree requirements for both undergraduate degrees, as well as learn the academic policies for both units as described in the A&D Undergraduate Student Handbook and the CoE Bulletin. In order to remain in good academic standing in both A&D and CoE, MDDP students must maintain a minimum cumulative grade point average of 2.0, and must follow additional academic policies of both academic units.

Degree requirements must be met for both programs simultaneously to be eligible to receive the appropriate undergraduate degrees. Candidates must complete a Bachelor of Science in Engineering (B.S.E.) in the College of Engineering, and a Bachelor of Fine Art (B.F.A.) in the School of Art & Design. Upon completion of the requirements of both academic units, MDDP students are granted concurrent degrees. If a requirement for either degree is lacking, neither degree will be conferred. The student must submit a separate Diploma Application through Wolverine Access to each unit along with any additional required documents.

**College of Engineering and the Taubman College of Architecture and Urban Planning**

Students enrolled in an undergraduate degree in the College of Engineering (CoE) or Taubman may obtain degrees from both simultaneously by enrolling in the Multiple Dependent Degree Program (MDDP) that has been established between the two. This program is designed to allow students to develop a course of study that offers broader academic opportunities than would normally be possible by enrolling in only one unit or the other.

Students are required to meet regularly with advisors in both Taubman and CoE to review specific course requirements and to develop a plan of study. It is the student’s responsibility to develop a strategy for completing the degree requirements for both undergraduate degrees, as well as learn the academic policies for both units as described in the Taubman and CoE Bulletins. In order to remain in good academic standing in both Taubman and CoE, MDDP students must maintain a minimum cumulative grade point average of 2.0, and must follow additional academic policies of both academic units.

Degree requirements must be met for both programs simultaneously to be eligible to receive the appropriate undergraduate degrees. Candidates must complete a Bachelor of Science in Engineering (B.S.E.) in the College of Engineering, and a Bachelor of Science in Architecture (B.S.A.) in the Taubman College of Architecture and Urban Planning. Upon completion of the requirements of both academic units, MDDP students are granted concurrent degrees. If a requirement for either degree is lacking, neither degree will be conferred. The student
must submit a separate *Diploma Application* through Wolverine Access to each unit along with any additional required documents.

**Combined Bachelor’s/Master’s Programs**

*Please note that students earning more than one degree are not eligible for SUGS programs.*

In many fields, the master’s degree provides substantial benefits for engineering graduates seeking employment. The College of Engineering therefore offers two different options for those students who wish to obtain a combined bachelor’s and master’s degree. Both of these options are academically demanding and require recommendation from the student’s undergraduate program advisor. The combined programs in the College of Engineering include the Sequential Undergraduate/Graduate Studies Program (SUGS) and the Engineering Global Leadership Honors Program (EGL).

**Sequential Undergraduate/Graduate Study (SUGS)**

The five-year Sequential Undergraduate/Graduate Study (SUGS) Program permits students who enter the program in the first term of their senior year to receive the B.S.E. and M.S.E. degrees (or the B.S.E. and M.Eng. degrees) upon completion of a minimum of 149 credit hours (depending on program). The baccalaureate may be awarded upon completion of the undergraduate requirements or concurrently with the master’s degree. Students apply to the SUGS program at the end of their junior year or early in the first semester of their senior year. Consult with the appropriate graduate departmental coordinator for specific deadlines and restrictions. Recommendation from the appropriate Undergraduate Program Advisor is required, and the standard department graduate admission process is used. SUGS admissions requirements will vary and each program will have a minimum GPA for admission; interested students should contact the department in which they would like to pursue graduate study. For a list of SUGS programs by department, please refer to the degree program listings under the B.S.E. home department.

**Honors Program**

The College of Engineering Honors Program identifies highly talented students who demonstrate extraordinary academic ability, intellectual curiosity and clear potential to make a difference as a leader in their field. Honors Program students pursue challenging coursework and enrich their academics through significant engagement beyond the classroom. The program is intended to inspire and enable highly motivated students to reach beyond the traditional curriculum in both breadth and depth.

Students must choose a capstone experience area, such as research, entrepreneurship, design, global business/operations or public service, and are required to develop academic breadth and leadership experience:

**Core Academic Requirements**

- Maintain a **cumulative GPA of 3.6**.
• Complete 9 credits of advanced electives in an identified focus area, selected in consultation with the capstone supervisor.
• These credits cannot be required by the minor or specifically required by the major. They can include technical elective credit.
• Complete an honors capstone experience (e.g. a project, research experience, thesis, etc.)
• This capstone can draw on the major design experience, but must extend beyond that experience to demonstrate the student’s individual scholarly or professional work. Each student will identify a capstone supervisor to oversee this experience. See below for more details.

Academic Breadth and Leadership Requirements

• Participate in an honors seminar each year.
• The honors seminar will center on leadership development, community building and discussion related to the student’s focus area. Portions of the seminar will be required for all honors students, while other topics offered will be specific to a student’s focus area. Existing seminars and colloquia will also be leveraged.
• Develop academic breadth through the completion of a U-M minor.

Additional Rules

• Courses counting toward the Honors Program cannot be elected as pass/fail.
• Students must apply for the program at least a year and a half before they plan to graduate, so that they can participate in leadership seminars and community building experiences.
• The honors program faculty advisor may approve specialized curriculum plans in both the core and breadth components of the Honors Program.

Admission Criteria and Process

In order to be admitted, students must:

• Have completed two full-time terms at U-M (or, for transfer students, one term.)
• Have declared a major within the College of Engineering.
• Maintain a 3.6 minimum GPA.
• Submit a portfolio, including an individual development plan.
• Be interviewed and recommended for admission by an admission committee (comprising of the honors program faculty advisor, a representative of the Faculty Advisory Board, a staff advisor and a student representative.)

Honors Capstone Process and Completion

Each student will identify a capstone supervisor (a CoE faculty member) to oversee the honors capstone experience. Honors capstone proposals must be approved by the student's capstone supervisor, the Honors Program faculty advisor and the Honors Faculty Advisory Board; these parties will ensure that sufficient rigor is present in the proposed project. Students should meet regularly with their capstone supervisor to assess progress and establish goals throughout the duration of the project. The project will be considered complete once it has been publicly presented and the capstone supervisor and Honors Program faculty advisor have certified its completion. The Faculty Advisory Board will work with the Honors Program faculty advisor to establish criteria for
ensuring the quality of capstone projects. Students must display their capstone project during the Honors Capstone Showcase event, which includes a poster session and an interactive presentation forum, and the project must be published online in the Honors Capstone Library.

Program Completion
Students who complete the program will graduate "with honors" and will receive a notation on their transcript and diploma.

Engineering Global Leadership Honors Program
The Engineering Global Leadership (EGL) Honors Program is a specialization of the Honors Program. Employers tell us that the inability of many professionals to communicate across cultures and across the engineering and business boundary is one of the greatest barriers to global competitiveness. The EGL Honors Program prepares students to bridge these gaps. The business coursework offers a focus in operations management, along with the basics of marketing, accounting and finance. Completion of the International Minor for Engineers exposes students to the language, history and customs of another part of the world. The success of EGL graduates confirms that this preparation is in high demand. Students admitted to the CoE Honors Program who choose a global business/operations focus are eligible to apply to EGL.

The EGL Honors Program requires the completion of the following

- All requirements of the College of Engineering Honors Program.
- The International Minor for Engineers (simultaneously fulfills CoE Honors required minor).
- 9 credits of Technology and Operations coursework in the Ross School of Business, as required by the Tauber Institute for Global Operations (simultaneously fulfills CoE Honors required focus area).
- The Tauber Institute for Global Operations Team Project (simultaneously fulfills CoE Honors Capstone Experience).
- A U-M College of Engineering master’s degree.
- 6 credits of elective coursework in the Ross School of Business (typically completed during the Masters program.)

College of Engineering Honors Program
Email: coehonors@umich.edu
Website: honors.engin.umich.edu

Additional Opportunities

Cooperative Education
The Cooperative (co-op) Education Program assists students in pursuing an optional program of work while studying in the College of Engineering. Students can find co-op positions independently or by using ECRC resources such as Engineering Careers, by Symplicity, a web-based recruiting system. A co-op search is the same as any other job search—students apply to organizations and then may be invited to interview.
Students in the Co-op program are registered students at the University and will be enrolled in Engineering 400: Cooperative Education Engineering. The student’s co-op work semester(s) are entered on the transcript and becomes part of the student’s academic record. Co-op students do not receive credit – co-op is zero credit hours and you are not charged for credit hours, but will be charged a fee for enrollment. However, you are considered a full-time student, loans are deferred, email accounts remain open, etc.

Search for co-op opportunities by using the resources below:
Search Engineering Careers
Additional Job Search Links

Typical Co-op Assignments

A typical co-op assignment is eight months (May through December or January through August) of hands-on engineering experience that will allow you to use the skills you have learned in the classroom and apply those skills to actual engineering projects; you are part of an engineering team! It may only delay your graduation one or two semesters, and you will find the experience to be a wonderful asset when you start looking for full-time employment.

Eligibility

Students may enroll as early as the second semester of their first year. In order to enroll, students must have a GPA of 2.75 or higher. The co-op job duties must relate to the student’s major and students must work 30 to 40 hours per week for a minimum of 6 weeks. It is not available to students requiring CPT (please contact the ECRC for more details).

Work Assignment

While working a co-op assignment, students are subject to the rules and regulations of the employer. Work assignments must be at least 30 hours per week for a minimum of six weeks. The employer will evaluate the student’s performance at the end of the co-op work term and forward the evaluation to the Engineering Career Resource Center. Co-op students are also required to complete and return an evaluation report of their learning experience to the ECRC.

Getting Started

Students interested in the co-op programs should visit https://career.engin.umich.edu/career/co-ops/ or contact the Engineering Career Resource Center co-op coordinator at ecrc-coop@umich.edu. Co-op students are registered in ENGR 400 while on a co-op work assignment; registration is by permission only and must be completed through the ECRC.

Engineering Career Resource Center
230 Chrysler Center
Ann Arbor, Michigan 48109-2192
Phone: (734) 647-7160
Education Abroad

The International Programs in Engineering (IPE) office provides support for a variety of education abroad opportunities for CoE students. International experiences for CoE students can take many forms from traditional study abroad for academic credit to work/internship abroad, research, volunteer and co-curricular international projects in conjunction with CoE student organizations.

College of Engineering Study Abroad

IPE sponsors semester and summer study abroad programs for academic credit. CoE students may choose from programs taught in English or foreign languages, depending on their skill levels and prior experience. IPE staff members advise students about program options and provide assistance with applications and course approvals. Undergraduate students in good academic standing are eligible to apply for College of Engineering study abroad programs. Graduate students may apply for select programs with the approval of IPE and their respective CoE Academic Advisor. Additional requirements may apply; please see the IPE website, https://ipe.engin.umich.edu for program specific admission guidelines.

Most forms of student financial aid can be applied to College of Engineering study abroad programs. IPE offers walk-in advising Monday-Friday from 1:00pm to 4:00pm, no appointment needed.

International Programs in Engineering
245 Chrysler Center
Ann Arbor, MI, 48109-2092
Phone: (734) 647-7192
Email: ipe-office@umich.edu

Campus-Wide Study Abroad Programs

CoE students may also participate in study abroad programs sponsored by other U-M schools and colleges. The LS&A Center for Global & Intercultural Study (CGIS) offers a broad range of study abroad programs that are open to CoE students. Students considering a CGIS study abroad program must consult the International Programs in Engineering office to determine applicability of credit to Engineering degree requirements. For CoE students, grades for STDABRD credit programs will generally not be calculated into the cumulative GPA. Campus-wide study abroad programs can be found in M-Compass, https://mcompass.umich.edu.

Beyond U-M Study Abroad Programs

Students studying abroad on a program that is not sponsored by a U-M office may earn transfer credit if the program sponsor is a fully accredited institution of higher learning, an official transcript is furnished by that institution, and the course is evaluated for transfer credit. Students considering Beyond U-M study abroad must register their plans in the U-M travel registry prior to departure and consult with the IPE Office about course
approvals and transfer credit. U-M Travel Registry, https://www.ipe.engin.umich.edu/registry

Work/Internship Abroad

IPE in partnership with the Engineering Career Resource Center (ECRC) assist students pursuing a work or internship position abroad. Overseas work experience can enhance your future job prospects, provide exposure to foreign business environments and help you understand global trends in the engineering profession. Whether it’s an internship with a multinational corporation or a research position in a foreign laboratory, overseas employment presents unique opportunities for professional development.

Interested students should meet with a Career Counselor from ECRC or an International Programs Advisor/Coordinator from IPE to discuss work abroad and internship search strategies. The ECRC can also critique resumes and provide resources to help adapt application documents for a non-U.S. audience. More information can be found online at https://ipe.engin.umich.edu/work-internship-volunteer-research-abroad/ International Travel with CoE Student Organizations

International Travel with CoE Student Organizations

IPE in partnership with the CoE Office of Student Affairs provides support and assistance for student organizations that travel internationally. Beyond traditional study and work abroad opportunities, the College encourages student organizations to consider developing international experiences for their members. International travel can be a great way to maximize an organization’s impact and to build leadership skills for their members. Check the IPE website (link below) to see where CoE student organizations are currently engaged globally. There are many resources available to student organizations who want to travel internationally, please visit https://ipe.engin.umich.edu/student-organization-international-travel/ for more details.

Undergraduate Research Opportunity Program (UROP)

The UROP program enables students to work one-on-one or as part of a small group of students on research projects conducted by faculty and research scientists all across campus. Students will choose research projects by looking through a catalog of over 700 research projects and will then interview for the positions with the faculty researcher.

All students participating in the program are also required to attend a biweekly research seminar and a monthly meeting with a peer advisor, read research-related articles (e.g., research ethics, research in specific disciplines, research methods) and complete short journal assignments.

Students may participate in UROP for academic credit, or they may utilize their work study financial aid, if they are eligible to earn work study funding. ENGR students working on engineering projects will enroll in ENGR 280 and determine their workload with their research mentor by choosing from the following options:
2 credits = 6 hours of research/week
3 credits = 9 hours of research/week
4 credits = 12 hours of research/week

*** Students earning work study funding will earn 1 academic credit and be compensated monetarily for their research hours ***

Most projects in the engineering and health science disciplines are time-intensive, and many students work 10-12 hours per week.

For more information and to access the online application, please visit the UROP website at http://www.lsa.umich.edu/urop.

**College-Wide Offerings**

**Engineering Division**

Offering a broad range of topics, the Engineering Division encourages students to explore and refine their interests. Lower-level courses introduce new students to multiple facets of the engineering landscape, focusing on the diversity and practical application of new innovations. Higher-level courses cover broad research interests and facilitate a deeper understanding of specific areas of study.

[Learn More](#)

**Engineering Physics**

Basic physics is an integral part of every engineering curriculum. However, in many areas of engineering the sophistication of the field, coupled with the staggering rate of technological advance, has created a need for engineers with much stronger backgrounds in math and physics—people who can work in an engineering environment and who are capable of applying advanced physics concepts to bring innovations to the marketplace. Engineering Physics offers a thorough curriculum in basic and advanced engineering courses combined with sufficient physics and mathematics to be equivalent to a traditional degree in physics.

[Learn More](#)

**Entrepreneurship**

U-M offers unparalleled support for students looking to combine engineering expertise with real-world business skills. Collaborations with the Ross School of Business and facilities like the TechArb Accelerator enable students to explore this burgeoning,
important field. Pursue coursework in entrepreneurship, get involved in the MPowered community or work with the Center for Entrepreneurship to find the perfect path.

Learn More

International Opportunities

Gaining experience in a global market is imperative for today’s engineers. Engineering students are encouraged to take advantage of the College’s own International Programs in Engineering, or explore campus-wide programs through the Center for Global and Intercultural Studies. Students can also participate in international programs that are not sponsored by the University.

Learn More

Military Officer Education

In conjunction with the Reserve Officers’ Training Corps, students can enroll in the Military Officer Education Program to receive a commission from the Army, Navy, Air Force or Marine Corps. Through this program, students obtain special training and instruction and can receive stipends to aid with the cost of their education.

Learn More

Multidisciplinary Design

The Multidisciplinary Design Program (MDP) brings students together from across the University and provides them with a chance to develop their skills by working on real-world, multidisciplinary team-based design projects. Whether through participation in student competition teams, faculty research teams, student-led initiatives or partner-sponsored projects, MDP student teams function cohesively to develop professional and technical skills while creating value through innovative design.

Learn More

Technical Communications

The Technical Communications program offers undergraduate and graduate engineering students the skills to more effectively communicate technical information.

Learn More
**Military Officer Education Programs**

The University of Michigan, in cooperation with the armed services of the United States, provides an opportunity for eligible male and female students to earn a commission from the Army, Navy, Marine Corps and Air Force upon completion of the degree and commissioning requirements. This opportunity is available through enrollment in the Military Officer Education Program (MOEP), which is known nationally as the Reserve Officers Training Corps (ROTC).

All three officer education programs (Army, Navy, and Air Force) offer four- and two-year program options, financial benefits and scholarship opportunities. Minor variations, however, do exist among the programs and students should consult the specific information under the applicable program.

**Financial Benefits**

All students enrolled in advanced (junior and senior year) officer education courses, whether or not on scholarship, receive a monthly stipend for the academic year. Uniforms, required books and equipment are furnished to students. Additionally, pay and travel allowances are provided for attendance at summer field training courses.

**Scholarships**

In addition to the financial benefits provided for all students contracted in the advanced courses, two-, three- and four-year merit-based scholarships are awarded on a competitive basis by each of the Officer Education Programs. These scholarships provide tuition, laboratory fees, payment for required books and a monthly stipend.

**Course Election by Non-Program Students**

Officer education courses are also open to University students not enrolled in the program with the permission of the instructor.

---

**Air Force**

**Air Force Officer Education Program**

Students who enroll as cadets in the Air Force Officer Education Program, which is known nationally as the Air Force Reserve Officers Training Corps (AFROTC), and successfully complete the program receive a University degree and are commissioned as Second Lieutenants in the United States Air Force.

**Career Opportunities**
Men and women can serve in a wide range of technical fields such as meteorology, research and development, communications and electronics, engineering, transportation, logistics and intelligence as well as in numerous managerial and training fields such as administrative services, accounting and finance, personnel, statistics, manpower management, education and training, investigation and information services. There are also opportunities in the pilot, combat systems officer, space operations and missile career fields. Advanced education or technical training for these career areas may be obtained on active duty at Air Force expense.

Four-Year and Three-Year Programs

Students may choose one of two program options as described in the general introduction to Military Officer Education Programs. The four-year and three-year program options include a summer four-week field training course at Maxwell Air Force base between the sophomore and junior years. Students electing to take the three-year program will be required to take the basic course sequence in one year instead of two years. No military obligation is incurred during the freshman year for scholarship recipients and none during the freshman or sophomore years for non-scholarship recipients.

Financial Benefits and Scholarships

For a detailed description of the available financial benefits and scholarships, consult the appropriate sections in the general introduction to the Military Officer Education Programs.

Course of Study

Students enroll in one course in Aerospace Studies (AS) during each term of participation in the program for a total of 16 credit hours.

- Basic course sequence (first and second year): Aerospace Studies 101, 102, 201, 202 (4 hours).
- Advanced course sequence (third and fourth years): Aerospace Studies 310, 311, 410, 411 (12 hours).

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

Military Obligation

After being commissioned, graduates of the program will be called to active duty with the Air Force in a field usually related to their academic degree program. The period of service is four years for non-flying officers, six years for combat systems officers and air battle managers after completion of their training, and ten years for pilots after completion of flight training.
Air Force Officer Education Course Listings

(Subject = AERO)

Course descriptions are found on the College of Engineering web site at https://bulletin.engin.umich.edu/courses/aero/

Army

Army Officer Education Program

Graduates may request active duty in the Army as commissioned officers or choose reserve duty service in the Army National Guard or Army Reserve in order to pursue a civilian career or graduate schooling.

Active duty officers are available for worldwide assignment. Service in the Army’s 17 branches and the possibility for educational delay provides an opportunity to gain extensive leadership experience.

Four-Year, Three-Year, and Two-Year Programs

Students may choose one of three program options as described in the general introduction to the Military Officer Education Programs. All programs include a four-week advanced summer camp at an Army post, which is taken as part of the advanced course sequence normally between the junior and senior years. The first two years of the four-year program can be taken without an obligation to the Army.

Students who intend to enroll in the two-year program should contact the recruiting officer by February of their sophomore year to apply for attendance at a four-week summer leadership development camp before enrollment in the program the following fall term. Two-year candidates must have a total of two years of school remaining at the undergraduate and/or graduate level. Students with prior military service (or prior ROTC training) may enroll in the program with advanced standing.

Financial Benefits and Scholarships

Army ROTC scholarships are merit-based and provide full tuition plus books and fees. All students receive a monthly stipend to help cover additional expenses. The stipend is $420/month for all contracted Cadets. Engineering students may request an additional year of scholarship benefits if they are enrolled in a five-year program. Two-, three- and four-year scholarships are available.

Simultaneous Membership Program
Non-scholarship students can choose to join a Reserve or National Guard unit of their choice while enrolled at the University. The student trains as an officer trainee, gaining valuable leadership training as a member of the Reserve Forces and can collect over $1,000 a month.

Branch Assignments

In their last year, cadets are classified for branch assignments to one of the following 18 branches of the Army in accordance with their personal preference, aptitude, academic background, and the needs of the Army: Corps of Engineers, Signal Corps, Aviation, Armor, Field Artillery, Air Defense Artillery, Adjutant General’s Corps, Military Intelligence, Finance Corps, Infantry, Medical Service Corps, Military Police Corps, Ordnance Corps, Quartermaster Corps, Transportation Corps, Chemical Corps, and Cyber branch.

Course of Study

Students enroll in one course in Military Science (MS) during each term of participation in the program for a total of 12 credit hours distributed as follows:

- Basic Course sequence (first and second years): Military Science 101, 102, 201, 202
  (4 hours total).
- Advanced Course sequence (third and fourth years): Military Science 301, 302, 401, 402
  (8 hours total).

The complete course of instruction includes professional ethics, professional writing and briefing, principles of military leadership, staff management principles, military justice, and tactics. In addition to the classroom courses, students participate in Leadership Laboratories (one 90 minute period per week). Training includes orienteering, rappelling, marksmanship, land navigation and physical training. In addition, courses in effective writing and military history are required for completion of the program.

Military Obligation

Students may request active duty or non-active duty assignments in the Army Reserve or National Guard. All Advanced Course students are obligated to four years of service which may be served in an active or reserve status depending on individual preference and Army needs and an additional four years of IRR (on call) status. No obligation is incurred during the freshman and sophomore years, unless the student is on scholarship.

Note: A Leadership Laboratory (0 credit), meeting for one and one-half hours each week, accompanies each of the above listed MS courses.

Army Officer Education Course Listings

(Subject = MILSCI)
Course descriptions are found on the College of Engineering web site at
https://bulletin.engin.umich.edu/courses/

101. Introduction to Officership  
Prerequisite: none. (1 credit)

102. Introduction to Leadership  
Prerequisite: none. (1 credit)

103. Leadership Laboratory  
Prerequisite: none. (0 credit)

104. Innovative Tactical Leadership  
Prerequisite: none. (1 credit)

105. Leadership in Changing Environments  
Prerequisite: none. (1 credit)

106. Leading Small Organizations I  
Prerequisite: permission of Chairman. (2 credits)

107. Leading Small Organizations II  
Prerequisite: permission of Chairman. (2 credits)

108. Leadership and Management  
Prerequisite: permission of Chairman. (2 credits)

109. Military Professionalism and Professional Ethics  
Prerequisite: permission of Chairman. (2 credits)

Military Obligation

Newly commissioned officers incur a minimum of four years of active duty service obligation.

Chair: Lieutenant Colonel Jason R. Dye

Program Office  
930 N. University Ave, Room 1090  
Phones: (734) 764-2400  
Scholarships: (734) 936-2839  
www.army.rotc.umich.edu

Navy

Navy Officer Education Program

Students enrolled as Midshipmen in the Navy Officer Education Program who receive a scholarship or advanced standing placement and successfully complete required courses and receive a degree from either the University of Michigan (Ann Arbor) or Eastern Michigan University will be commissioned as officers in the United States Navy or Marine Corps.

Career Opportunities
Graduates of the program have a wide range of job and career opportunities. Navy officers may choose duty assignments in the surface, aviation, submarine, special warfare or nursing communities. Marine Corps officers may choose duty assignments in aviation, infantry, armor or artillery specialties. After graduation, all commissioned officers receive additional training in their prospective fields.

**Program Length**

The program normally includes eight terms of course work. A military obligation is incurred at the beginning of the sophomore year for scholarship students. Non-scholarship students may enroll in the College Program and take ROTC courses without incurring a military obligation. College Program students may be considered for scholarship in their first- or second-year in the program. Students must first be nominated by their respective N.R.O.T.C. advisor, endorsed by the Professor of Naval Science, and approved by Naval Service Training Command. All scholarships are funding-dependent, and are based upon academic and athletic performance, as well as military aptitude and the competition is with the other N.R.O.T.C. units nationwide. If not selected for a scholarship or advanced standing by the end of the second-year in the program, students must be disenrolled from the R.O.T.C. program.

**Financial Benefits and Scholarships**

Scholarships cover tuition, lab fees, books, uniforms, and provide a monthly stipend for a length of two- to five-years of study. For a more detailed description of the available financial benefits and scholarships consult the following websites: [http://navy.rotc.umich.edu](http://navy.rotc.umich.edu) and [http://www.nrotc.navy.mil/](http://www.nrotc.navy.mil/). Most students who enter the program as freshmen have received four-year scholarships based on national competition. As mentioned above, any other student may join the program through the College Program. These students will participate in the same way as the scholarship students. The only exception will be the absence of financial benefits. Additionally, the Navy offers several other scholarship opportunities. Immediate scholarships for up to 3.5 years may be awarded to students pursuing degrees in engineering and related fields. College program students may earn 3.5, 3 or 2 year scholarships through the Navy Officer Education Program at the University along with continuing to apply through the national selection board. Finally, students who wish to join the program for two years may apply for two-year scholarships during the winter of their sophomore year. Criteria for eligibility vary based upon program; details are available from the program chair.

**Course of Study**

Students enroll in Naval Science (NS) courses during each term of participation in the program. Additionally, all students are required to complete course work in calculus, calculus-based physics and other required courses. Students also participate in a four- to six-week summer training exercises during periods between academic years.

**Military Obligation**
Newly commissioned officers incur a minimum of five years of active duty service obligation. Aviation officers incur minimum active duty of up to 10 years.

**Navy Officer Education Course Listings**

(Subject = NAVSCI)

Course descriptions are found on the College of Engineering web site at https://bulletin.engin.umich.edu/courses/(Electrical Engineering), and at http://www.lsa.umich.edu/cg/default.aspx (NavSci)

**Per101. Introduction to Naval Science**  
Prerequisite: none. (2 credits)

**102. (UC 101). Seapower and Maritime Affairs**  
Prerequisite: none. (2 credits)

**201. (NAVARCH 102). Introduction to Ship Systems**  
Prerequisite: none. (3 credits)

**202. (EECS 250). Electronic Sensing Systems**  
Prerequisite: Prior or concurrent enrollment in Physics 240 (or 260) or EECS 230. (3 credits)

**203. (UC 205). Leadership and Management**  
Prerequisite: NavSci 101 & 102 or Permission of Instructor. (3 credits)

**301. (Astro 261). Navigation**  
Prerequisite: none. (3 credits)

**302. Naval Operations**  
Prerequisite: NavSci 301. (3 credits)

**310. (UC 310). Evolution of Warfare**  
Prerequisite: none (3 credits) (Offered Fall of even years)

**402. (UC 403). Leadership and Ethics**  
Prerequisite: NavSci 203 or Permission of Instructor II (2 credits)

**410. (UC 410). Amphibious Warfare**  
Prerequisite: none. (3 credits) (Offered Fall of odd years)

**Note:** The courses listed herein are offered primarily for the students participating in the program; however, they are open to, and may be taken by, any University – enrolled student. **Not all of them are accredited.**
Graduate Education
Mission Statement

Mission

Michigan Engineering aspires to create an educational experience for engineering graduate students that is among the finest in the world. We serve a diverse population of top students from around the globe by preparing them for successful careers in academia, industry, and the public sector through access to world-class facilities, cutting edge research, and innovations in graduate education.

We offer dozens of top-ranked Master’s and doctoral degree programs, along with a range of specialized graduate certificates, to help students meet their academic and professional goals. Several degrees are available entirely online by design, offering students the opportunity to pursue a high-quality graduate engineering education that is flexible and convenient. With over 600 faculty members who are leaders in their fields, Michigan Engineering provides an inclusive and collaborative environment that challenges its students to find innovative and impactful solutions to global problems.

Degrees by Discipline

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace Engineering</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Applied Climate</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Applied Physics</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Atmospheric &amp; Space Sciences</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automotive Engineering</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Engineering Field</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Biomedical Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Civil Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate &amp; Space Sciences &amp; Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Science &amp; Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction Engineering and Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical &amp; Computer Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Systems Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering Education Research</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Environmental Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Automotive &amp; Manufacturing Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial &amp; Operations Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macromolecular Science &amp; Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials Science &amp; Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naval Architecture &amp; Marine Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear Engineering &amp; Radiological Sciences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's Degree Programs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With nearly 40 Master’s degree programs, Michigan Engineering offers a multitude of opportunities for students to specialize, advance, lead, and make an impact in their chosen field. Explore Michigan Engineering Master’s degrees by clicking <a href="#">here</a>.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Dual Degrees

- [Construction Engineering & Management MSE / MBA](#)
- [Construction Engineering & Management MSE / MSE](#)
- [Construction Engineering & Management MEng / MArch](#)
- [Construction Engineering & Management MEng / MBA](#)
- [Civil Engineering MSE / Sustainable Systems MS](#)
- [Environmental Engineering MSE / Natural Resources and Environment MS](#)
- [Industrial Operations Engineering MS / MBA](#)
- [Manufacturing MEng / MBA](#)
- [Naval Architecture & Marine Engineering MSE / MBA](#)
Graduate Certificate Programs
The College of Engineering offers a number of graduate certificate programs, in the following disciplines:

- Augmented and Virtual Reality
- Computational Discovery and Engineering (CDE)
- Cellular Biotechnology
- Climate Change Solutions
- Computational Neuroscience
- Data Science
- Engineering Education Research
- Innovation & Entrepreneurship
- Medical Physics
- Microfluidics in Biomedical Sciences Training Program (MBSTP)
- Plasma Science & Engineering
- Urban Informatics

Additional graduate certificate programs can be found at the Rackham Graduate School and Nexus.

Graduate Admissions

For more information on admissions, please contact the graduate coordinator from the graduate program of interest here.

Graduate Student Resources

Academic Integrity

Academic Integrity is a critical aspect of scholarship within the College of Engineering. To learn more about the Honor Code in the College of Engineering, please see the Rules, Rights, and Responsibilities section of the Bulletin. To better educate students about standards for excellence, the College of Engineering’s Responsible Conduct of Research and Scholarship (RCRS) workshops are required for all Ph.D. students, as well as those master’s and undergraduate students participating in NSF or NIH funded research.

C.A.R.E. (Consultation, Assistance, and Resources in Engineering) Center

The Michigan Engineering C.A.R.E. Center is the central hub to assist engineering students by providing genuine and practical support, both inside and outside the classroom. The C.A.R.E. Center works with all College of Engineering students to assess individual support needs, help navigate problem-solving options, and connect them to relevant resources across the University. CRLT-Engin

The Center for Research on Learning & Teaching in Engineering (CRLT-Engin) promotes evidence-based practices in engineering education so that students and instructors from diverse backgrounds and social identities can learn and thrive. CRLT-Engin provides a number of resources, including programs and workshops, for student instructors.
Engineering Career Resource Center

The Engineering Career Resource Center offers comprehensive career development services to College of Engineering students to support a successful transition from campus to career, and to assist employers with developing and maintaining successful recruiting relationships with Michigan Engineering.

Graduate Student Organizations

The University of Michigan offers 135+ engineering affiliated student organizations, which provide opportunities for students to advance their leadership, team development, technical skills and engineering knowledge.

Graduate Student Professional Development

Many professional development opportunities exist within the College of Engineering (CoE) for Master’s and doctoral students. CoE’s Office of Student Affairs, Rackham Graduate School, Michigan Libraries, and Student Life also offer professional and personal development programs for graduate students.

International Center

The International Center serves the international student population, facilitates intercultural and international education, and fosters a global campus community at the University of Michigan and beyond.

Office of Student Affairs

The Office of Student Affairs provides support and opportunities for all Michigan Engineering students on a wide variety of topics including career services, advising, student organization policies, mental health, scholarships, tutoring, admissions, transfers and much more.

Teaching & Learning Resources

The College of Engineering provides a number of teaching & learning resources for graduate students. This includes the following:

- COVID-19 Faculty Resources
- COVID-19 Student Resources
- CRLT-E for Student Instructors
- Faculty Resources for Online & Hybrid Teaching
- Nexus Faculty Resources Blog
- Online Graduate Courses
- Online Registration FAQs
- Upcoming Remote Teaching Events

Funding and Fellowships for Graduate Students

Funding for Master’s Students

Funding opportunities for master’s students administered by Rackham Graduate School can be found here. Some College of Engineering departments also have fellowships or awards designated for master’s students, as well as Graduate Student Instructor (GSI) or Graduate Student Research Assistant (GSRA) appointments. Current master’s
students who have interest in a Ph.D. program may apply by the appropriate application deadline to receive consideration for Ph.D. admission and the full funding it provides.

**Bridge to the Doctorate Program**

The Bridge to the Doctorate program offers two terms of full funding (tuition, fees, University health insurance, and monthly stipend) for the first academic year, as well as direct guidance and preparation for a subsequent application to the Ph.D. program. For this fellowship, new full-time master’s students who are U.S. citizens or permanent residents are nominated by departments upon admission, based on the information in their graduate applications.

**Funding for Ph.D. Students**

The College of Engineering operates under a fully-funded model for all admitted Ph.D. students. Students admitted from a bachelor's degree program receive five years of full funding, while students admitted from a master's degree program receive four years of full funding. This funding commitment is guaranteed, provided the student meets all necessary milestones and fulfills program requirements, as stipulated by their individual faculty advisor and graduate program. A comprehensive funding package includes tuition, fees, University health insurance and monthly stipend. More information can be found by clicking [here](#).

**Graduate Student Emergency Fund**

The College of Engineering recognizes that some Engineering students find themselves facing emergency expenses in order to be able to continue with their studies. For this reason, the College of Engineering has a Graduate Student Emergency Fund intended to help meet the financial needs of any Michigan Engineering graduate student who encounters an emergency situation or one-time, unusual, or unforeseen expenses during their degree program when resources, such as a GSI appointment, from the student’s home program are unavailable or insufficient. Such situations may include family or medical emergencies, periods of transition between research advisors, and other financial emergencies. More information on this can be found [here](#).

**Further Resources for Funding include:**
- [CoE Funding and Fellowship Application Resources](#)
- [Rackham Graduate School Fellowship Office](#)
- [Other Funding for Engineering Graduate Students](#)
- [Careers.umich.edu](#)

**Online Graduate Degree Programs**

The College of Engineering currently offers 5 top-ranked online master’s degree programs:
- [Automotive Engineering MEng](#)
Nexus, the College’s home for online learning, offers valuable master’s degree programs, leading edge graduate engineering courses, and highly regarded professional education certificates available to learners around the globe. Through dynamic lecture capture, enhanced live classroom technology, and other innovative teaching methods, the College is changing what it means to be an online learner. Students will engage with U-M faculty and other learners in a way that’s both authentic and effective, offering an immersive learning experience from anywhere in the world.

Graduate Certificate

The Rackham Certificate in Engineering Education Research provides a way for engineering doctoral students with a formal program to learn and practice the skills needed to be proficient in the field. It requires 9 credit hours of coursework (with a B average) and a related engineering education research project. Engineering graduate students who have completed at least one term in a Rackham program and are in good academic standing are invited to apply at any time. Students should apply prior to completing the requirements to ensure the plan of study is approved. Effective Fall 2019, the requirements are as listed here:

- EER 601 Foundations of EER (3 credits)
- EER 602 Theoretical and Conceptual Frameworks in EER (3 credits)
- Either a course on quantitative methods for educational research (EDUC 795, EDUC 793, or approved equivalent) or
- a course on qualitative methods for educational research (EDUC 792 or approved equivalent);
- (3-4 credits)
- Completion of an approved engineering education research project (Approx 3 credits)
  - Students pursuing the certificate are encouraged to consult relevant resources about EER and to meet with EER faculty

Applications to the program can be submitted at this site https://eer.engin.umich.edu/graduate-certificate/ as they plan and conduct their research. Application materials and questions about certificate should be emailed to Dr. Cynthia Finelli.

College-Wide Offerings

Engineering Division

Offering a broad range of topics, the Engineering Division encourages students to explore and refine their interests. Lower-level courses introduce new students to multiple facets of the engineering landscape, focusing on the diversity and practical application of new innovations. Higher-level
courses cover broad research interests and facilitate a deeper understanding of specific areas of study.

Learn More

---

**Engineering Physics**

Basic physics is an integral part of every engineering curriculum. However, in many areas of engineering the sophistication of the field, coupled with the staggering rate of technological advance, has created a need for engineers with much stronger backgrounds in math and physics—people who can work in an engineering environment and who are capable of applying advanced physics concepts to bring innovations to the marketplace. Engineering Physics offers a thorough curriculum in basic and advanced engineering courses combined with sufficient physics and mathematics to be equivalent to a traditional degree in physics.

Learn More

---

**Entrepreneurship**

U-M offers unparalleled support for students looking to combine engineering expertise with real-world business skills. Collaborations with the Ross School of Business and facilities like the TechArb Accelerator enable students to explore this burgeoning, important field. Pursue coursework in entrepreneurship, get involved in the MPowered community or work with the Center for Entrepreneurship to find the perfect path.

Learn More

---

**International Opportunities**

Gaining experience in a global market is imperative for today’s engineers. Engineering students are encouraged to take advantage of the College’s own International Programs in Engineering, or explore campus-wide programs through the Center for Global and Intercultural Studies. Students can also participate in international programs that are not sponsored by the University.

Learn More

---

**Military Officer Education**

In conjunction with the Reserve Officers’ Training Corps, students can enroll in the Military Officer Education Program to receive a commission from the Army, Navy, Air Force or Marine Corps. Through this program, students obtain special training and instruction and can receive stipends to aid with the cost of their education.

Learn More
Multidisciplinary Design

The Multidisciplinary Design Program (MDP) brings students together from across the University and provides them with a chance to develop their skills by working on real-world, multidisciplinary team-based design projects. Whether through participation in student competition teams, faculty research teams, student-led initiatives or partner-sponsored projects, MDP student teams function cohesively to develop professional and technical skills while creating value through innovative design.

Learn More

Technical Communications

The Technical Communications program offers undergraduate and graduate engineering students the skills to more effectively communicate technical information.

Learn More

Additional Opportunities

Cooperative Education

The Cooperative (co-op) Education Program assists students in pursuing an optional program of work while studying in the College of Engineering. Students can find co-op positions independently or by using ECRC resources such as Engineering Careers, by Symplicity, a web-based recruiting system. A co-op search is the same as any other job search—students apply to organizations and then may be invited to interview.

Students in the Co-op program are registered students at the University and will be enrolled in Engineering 400: Cooperative Education Engineering. The student’s co-op work semester(s) are entered on the transcript and becomes part of the student’s academic record. Co-op students do not receive credit – co-op is zero credit hours and you are not charged for credit hours, but will be charged a fee for enrollment. However, you are considered a full-time student, loans are deferred, email accounts remain open, etc.

Search for co-op opportunities by using the resources below:
Search Engineering Careers
Additional Job Search Links

Typical Co-op Assignments

A typical co-op assignment is eight months (May through December or January through August) of hands-on engineering experience that will allow you to use the skills you have learned in the classroom and apply those skills
to actual engineering projects; you are part of an engineering team! It may only delay your graduation one or two semesters, and you will find the experience to be a wonderful asset when you start looking for full-time employment.

Eligibility

Students may enroll as early as the second semester of their first year. In order to enroll, students must have a GPA of 2.75 or higher. The co-op job duties must relate to the student’s major and students must work 30 to 40 hours per week for a minimum of 6 weeks. It is not available to students requiring CPT (please contact the ECRC for more details).

Work Assignment

While working a co-op assignment, students are subject to the rules and regulations of the employer. Work assignments must be at least 30 hours per week for a minimum of six weeks. The employer will evaluate the student’s performance at the end of the co-op work term and forward the evaluation to the Engineering Career Resource Center. Co-op students are also required to complete and return an evaluation report of their learning experience to the ECRC.

Getting Started

Students interested in the co-op programs should visit https://career.engin.umich.edu/career/co-ops/ or contact the Engineering Career Resource Center co-op coordinator at ecrc-coop@umich.edu. Co-op students are registered in ENGR 400 while on a co-op work assignment; registration is by permission only and must be completed through the ECRC.

Engineering Career Resource Center
230 Chrysler Center
Ann Arbor, Michigan 48109-2192
Phone: (734) 647-7160

Education Abroad

The International Programs in Engineering (IPE) office provides support for a variety of education abroad opportunities for CoE students. International experiences for CoE students can take many forms from traditional study abroad for academic credit to work/internship abroad, research, volunteer and co-curricular international projects in conjunction with CoE student organizations.

College of Engineering Study Abroad

IPE sponsors semester and summer study abroad programs for academic credit. CoE students may choose from programs taught in English or foreign languages, depending on their skill levels and prior experience. IPE staff members advise students about program options and provide assistance with applications and course approvals. Undergraduate students in good academic standing are eligible to apply for College of Engineering study abroad programs. Graduate students may apply for select programs with the approval of IPE and their respective CoE Academic Advisor. Additional requirements may apply; please see the IPE website, https://ipe.engin.umich.edu for program specific admission guidelines.

Most forms of student financial aid can be applied to College of Engineering study abroad programs.

International Programs in Engineering
245 Chrysler Center
CoE students may also participate in study abroad programs sponsored by other U-M schools and colleges. The Center for Global & Intercultural Study (CGIS) offers a broad range of study abroad programs that are open to CoE students. Students considering a CGIS study abroad program must consult the International Programs in Engineering office to determine applicability of credit to Engineering degree requirements. For CoE students, grades for STDABRD credit programs will generally not be calculated into the cumulative GPA. Campus-wide study abroad programs can be found in M-Compass, [https://mcompass.umich.edu](https://mcompass.umich.edu).

### Beyond U-M Study Abroad Programs

Students studying abroad on a program that is not sponsored by a U-M office may earn transfer credit if the program sponsor is a fully accredited institution of higher learning, an official transcript is furnished by that institution, and the course is evaluated for transfer credit. Students considering Beyond U-M study abroad must register their plans in the U-M travel registry prior to departure and consult with the IPE Office about course approvals and transfer credit. U-M Travel Registry, [https://www.ipe.engin.umich.edu/registry](https://www.ipe.engin.umich.edu/registry).

### Work/Internship Abroad

IPE in partnership with the Engineering Career Resource Center (ECRC) assist students pursuing a work or internship position abroad. Overseas work experience can enhance your future job prospects, provide exposure to foreign business environments and help you understand global trends in the engineering profession. Whether it's an internship with a multinational corporation or a research position in a foreign laboratory, overseas employment presents unique opportunities for professional development.

Interested students should meet with a Career Counselor from ECRC or an International Programs Advisor/Coordinator from IPE to discuss work abroad and internship search strategies. The ECRC can also critique resumes and provide resources to help adapt application documents for a non-U.S. audience. More information can be found online at [https://ipe.engin.umich.edu/work-internship-volunteer-research-abroad/](https://ipe.engin.umich.edu/work-internship-volunteer-research-abroad/) International Travel with CoE Student Organizations

### International Travel with CoE Student Organizations

IPE in partnership with the CoE Office of Student Affairs provides support and assistance for student organizations that travel internationally. Beyond traditional study and work abroad opportunities, the College encourages student organizations to consider developing international experiences for their members. International travel can be a great way to maximize an organization's impact and to build leadership skills for their members. Check the IPE website (link below) to see where CoE student organizations are currently engaged globally. There are many resources available to student organizations who want to travel internationally, please visit [https://ipe.engin.umich.edu/student-organization-international-travel/](https://ipe.engin.umich.edu/student-organization-international-travel/) for more details.
Undergraduate Research Opportunity Program (UROP)

The UROP program enables students to work one-on-one or as part of a small group of students on research projects conducted by faculty and research scientists all across campus. Students will choose research projects by looking through a catalog of over 700 research projects and will then interview for the positions with the faculty researcher.

All students participating in the program are also required to attend a biweekly research seminar and a monthly meeting with a peer advisor, read research-related articles (e.g., research ethics, research in specific disciplines, research methods) and complete short journal assignments.

Students may participate in UROP for academic credit, or they may utilize their work study financial aid, if they are eligible to earn work study funding. ENGR students working on engineering projects will enroll in ENGR 280 and determine their workload with their research mentor by choosing from the following options

2 credits = 6 hours of research/week
3 credits = 9 hours of research/week
4 credits = 12 hours of research/week

*** Students earning work study funding will earn 1 academic credit and be compensated monetarily for their research hours ***

Most projects in the engineering and health science disciplines are time-intensive, and many students work 10-12 hours per week.

For more information and to access the online application, please visit the UROP website at [http://www.lsa.umich.edu/urop](http://www.lsa.umich.edu/urop).

Engineering Academic Minors and Supplemental Studies

College of Engineering Policy for Engineering Minors

Undergraduate students enrolled in a College of Engineering degree program can often benefit from study and practice at some depth outside of their major. An Engineering minor is a coherent program of study, but with requirements far less comprehensive than those of a BS or BSE degree. Engineering minors can be sponsored by CoE departments, programs, or, for the purpose of supporting cross-departmental programs, sponsored by the Office of the Associate Dean for Undergraduate Education. An Engineering minor is not intended to provide specialization within a student’s major field.

Rules:
1. Completion of an academic minor is optional; no student can be required to complete an Engineering minor.
2. A student can complete one or more Engineering minors, along with one or more LSA minors. However, a minor is not intended to provide specialization within a student’s major field. Therefore, the posted rules for each minor will outline any restrictions on the availability of a minor for students in particular program, e.g. “A student seeking a BSE in NERS cannot earn the minor in NERS.”
3. Advanced Placement credits may not be used to meet the requirements of an academic minor, but may be used to meet the prerequisites to a minor.
4. Transfer credit may not be used to fulfill the requirements of a minor unless specifically stated in the minor.
5. Courses taken to satisfy the requirements of a minor must be taken for a grade, unless the course was specifically approved as Pass/Fail within the requirements of that minor.
6. A student must earn an overall GPA of at least 2.0 in courses taken to meet the requirements of an academic minor.
7. Students are responsible for notifying both the sponsoring program and their major department of their intention to pursue a minor. Such notification should take place prior to enrollment in the upper-division courses for the minor.
8. The advisor for each minor is responsible for approving any variance in course requirements for a minor.
9. Responsibility for auditing completion of requirements for a minor lies within the sponsoring unit.
10. Students will always be allowed to count courses towards an approved minor retroactively, as long as the minor is approved before the date of their graduation.
11. Engineering minors will be noted on a student’s academic transcript, but not on their diploma.

Other Approved Academic Minors

Engineering students have considerable flexibility in electing courses from other colleges through their Intellectual Breadth courses and general electives. In the interest of helping students make coherent choices in selecting these courses, we allow and encourage our students to pursue minors offered in LSA, Art & Design and the School of Social Work.

Minors also serve as recognition, via a transcript notation, of the completion of these more in-depth course sequences. Electing to earn an academic minor is optional and there is no limit on the number of academic minors a student may elect.

In practice, a student will meet with an advisor in the minor discipline and together map out the minor courses. The certification that the appropriate courses have been completed will be communicated from the offering department to a student’s undergraduate program advisor in CoE as well as the College of Engineering Student Records Office. The student will be responsible for making sure this paperwork arrives at the appropriate offices.

Minors Approved by the College of Engineering

The list below shows the minors approved for students in the College of Engineering.

Minors Offered Through LSA (list subject to change)
• Afro American and African Studies
• American Culture
• Anthropology
• Applied Statistics
• Arab and Muslim American Studies
• Asian Languages and Cultures
• Asian Studies
• Asian/Pacific Islander American Studies
• Astronomy and Astrophysics
• Biochemistry
• Biological Anthropology
• Biology
• Biophysics
• Bosnian/Croatian/Serbian Literature and Culture
• Central Eurasian Studies
• Chemical Measurement Science
• Chemical Physics
• Chemistry
• Classical Archaeology
• Classical Civilization
• Complex Systems
• Computer Science
• Creative Writing
• Cultures and Literature of Eastern Europe
• Crime and Justice
• Czech Language, Literature, and Culture
• Digital Studies
• Drama: Text to Performance
• Early Christian Studies
• Earth Sciences
• East European Studies
• Ecology and Evolutionary Biology
• Economics
• English
• Energy and Science Policy
• Entrepreneurship
• Environment
• Environmental Geology
• Epistemology and Philosophy of Science
• Food and the Environment
• French and Francophone Studies
• Gender and Health
• Gender, Race, and Nation
• General Philosophy
• Geology
• German Studies
• Global History
• Global Media Studies
• Greek (Ancient) Language and Literature
• Greek (Modern) Language and Literature
• History
• History of Art
• History of Law and Policy
• History of Medicine and Health
• History of Philosophy
• Interdisciplinary Astronomy
• Intergroup Relations Education
• International Studies
• Islamic Studies
• Italian
• Judaic Studies
• Latin American and Caribbean Studies
• Latin Language and Literature
• Latina/o Studies
• Law, Justice and Social Change
• Lesbian, Gay, Bisexual, Transgender, Queer (LGBTQ) and Sexuality Studies
• Linguistics
• Mathematics
• Medical Anthropology
• Medieval and Early Modern Studies
• Middle Eastern Studies
• Modern European Studies
• Modern Greek Studies
• Modern Middle Eastern and North African Studies
• Moral and Political Philosophy
• Museum Studies
• Music
• Native American Studies
• Oceanography
• Paleontology
• Peace and Social Justice
• Physics
• Plant Biology
• Polish Language, Literature, and Culture
• Political Science
• Polymer Chemistry
• Portuguese
• Religion
• Russian Language, Literature, and Culture
• Russian Studies
• Scandinavian Studies
• Science, Technology, and Society
• Sociology of Health and Medicine
• Spanish Language, Literature, and Culture
• Statistics
• Sustainability
• Translation Studies
• Ukrainian Language, Literature and Culture
• Urban Studies
• Water and the Environment
• Writing
• Yiddish Studies
Policies and Procedures for Declaring and Completing LSA Academic Minors

The following describes the policies and procedures to be followed for declaring and completing LSA minors:

1. Each B.S.E. student who wishes to complete an approved academic minor must develop a plan for the minor in consultation with the designated LSA advisor, who must also approve it. The faculty and staff advisors in the LSA units will advise Engineering students on course selection and complete the minor declaration form and confirm completion of the minor. No prior approval is required from an Engineering advisor.
2. Students may not elect two academic minors offered by the same department or program.
3. The minor declaration form must be received by the College of Engineering Student Records Office. Upon receipt of the declaration form, the staff member will enter the minor in the M-Pathways database. The form will be available through all Engineering academic departments, the Engineering Advising Center and all relevant LSA departments.
4. Student Transcripts:
   • The unofficial transcript for an Engineering student who has declared a minor will show the minor in the program action history section.
   • The Official Transcript issued by the Registrar’s Office will show the minor at the beginning of the transcript when the student has completed the degree.
5. Minors cannot be completed and added to the transcript after a student has graduated.

More information on LSA minors can be found in the LSA Bulletin.

Minor in Computer Science

A Minor in Computer Science (CS), offered through LSA and administered by the EECS Department, is open to undergraduate students. Students wishing to pursue this minor should meet with a faculty advisor for the LSA Computer Science major.

Students must satisfy two prerequisites before declaring the minor:

MATH 115, and one of the following programming courses: EECS 183 or ENGR 101, or their equivalent. Students must also be currently enrolled in and pursuing one of the minor Core Courses to be eligible to declare.

Requirements for the Minor (16 credits total):

- Three Core Courses (4 credits each; must complete all three):
  - EECS 203: Discrete Mathematics
  - EECS 280: Programming and Introductory Data Structures
  - EECS 281: Data Structures and Algorithms
- Elective Course: One 4-credit elective selected from EECS 388, 482, 483, 485, 487, 490, 492, or 493.

Note: EECS 281 has both EECS 203 and 280 as prerequisites. All of the electives have EECS 281 as a prerequisite. Thus, completing the minor requires a minimum of three academic terms.

Grades of C or better must be achieved in all courses taken to satisfy Computer Science requirements.
Minor in Art & Design

Undergraduate engineering students can complete an academic Minor in Art & Design in consultation with an advisor in the Stamps School of Art & Design. Appointments may be scheduled by visiting or calling the Smucker-Wagstaff Academic Programs Center, Art & Architecture Building, room 2038, or (734) 764-0397. The requirements for the minor are maintained by the School.

Students must secure written approval from their home school/college to pursue an A&D minor and must develop a plan for the minor in consultation with an A&D advisor.

Minors in Other Schools/Colleges

- Minor in Business (Ross School of Business), [https://www2.bus.umich.edu/MyiM pact/academics/businessminor](https://www2.bus.umich.edu/MyiM pact/academics/businessminor)
- Minor in Community Action and Social Change (School of Social Work), [http://ssw.umich.edu/offices/casc-undergraduate-minor](http://ssw.umich.edu/offices/casc-undergraduate-minor)
- Minor in Education for Empowerment (School of Education), [http://soe.umich.edu/academics/minor/](http://soe.umich.edu/academics/minor/)
- Minor in Public Policy (Ford School of Public Policy), [http://fordschool.umich.edu/ba/minor](http://fordschool.umich.edu/ba/minor)
- Minor in Real Estate Development (Taubman College of Architecture and Urban Planning in cooperative effort with the School of Kinesiology and Ross School of Business), [https://studyrealestate.umich.edu/real-estate-development-minor/](https://studyrealestate.umich.edu/real-estate-development-minor/)
- Minor in School of Music, Theatre & Dance
  - Minor in Music, [https://www.music.umich.edu/current_students/student_resources/Academic Minors.htm](https://www.music.umich.edu/current_students/student_resources/Academic Minors.htm)
  - Minor in Design and Production, [https://www.music.umich.edu/current_students/student_resources/AcademicMinors.htm](https://www.music.umich.edu/current_students/student_resources/AcademicMinors.htm)
  - Minor in Playwriting, [https://www.music.umich.edu/current_students/student_resources/AcademicMinors.htm](https://www.music.umich.edu/current_students/student_resources/AcademicMinors.htm)

Non-CoE Minor Release

For non-College of Engineering minors/supplemental studies, including LSA, many schools and colleges around campus use the LSA Advising System to process their minor/supplemental studies program declarations and to create the corresponding releases. The deadline for the receipt of the LSA Advising System Minor/Supplemental Studies Release is no later than the last day of classes in the graduation term.

Please do not wait until the last minute to contact the appropriate non-College of Engineering program advisor to ask for a release because some require appointments. Remember, no release = removal of the minor/supplemental studies during the degree audit and no posting on the transcript. Incomplete minors/supplemental studies cannot be finished after graduation!
Sample Schedules & Course Descriptions
Sample Schedules

The information in this Bulletin for a number of the degree programs includes a schedule that is an example of one leading to graduation in eight terms. This sample schedule is for informational purposes only and should not be construed to mean that students are required to follow the schedule exactly.

A transfer student attending a community or liberal arts college and pursuing a pre-engineering degree program may not be able to follow a similar schedule because of a lack of certain offerings. Departmental program advisors should always be consulted when planning course selections.

### Aerospace Engineering

<table>
<thead>
<tr>
<th>Subjects Required by all Programs (55 hours)</th>
<th>Credit Hours</th>
<th>Term:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, 215, and 216</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ENGR 100, Introduction to Engineering</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ENGR 101, Introduction to Computers</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CHEM 125/126, 130 or 210, 2111</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Physics 140 with Lab 1412</td>
<td>5</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Physics 240 with Lab 2412</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Related Technical Core Subjects (12 hours)</th>
<th>Credit Hours</th>
<th>Term:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MECHE 240, Intro to Dynamics and Vibrations</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engineering Distribution 13</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engineering Distribution 23</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aerospace Science Subjects (26 hours)</th>
<th>Credit Hours</th>
<th>Term:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AEROSP 201, Introduction to Aerospace Engine</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AEROSP 215, Introduction to Solid Mechanics and Aerospace Structures</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AEROSP 225, Introduction to Gas Dynamics</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AEROSP 315, Aircraft and Spacecraft Structures</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AEROSP 325, Aerodynamics</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AEROSP 335, Aircraft and Spacecraft Propulsion</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Candidates for the Bachelor of Science degree in Engineering (Aerospace Engineering) - B.S.E. (Aerospace E.) - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

**Notes:**

1. If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for the College of Engineering.

2. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and 240/241 you will have met the Physics Core Requirement for the College of Engineering.


4. Technical electives must total at least 7 credits of approved upper division courses (that is, 300 level or above). At least 3 credits must be approved mathematics or science courses, a maximum of 3 credits is allowed for directed study and a maximum of 2 credits is allowed for seminar courses. Recommended courses that satisfy the mathematics or science technical electives are described in a document that can be obtained from the Department or on the Department website.
### Chemical Engineering Sample Schedule

<table>
<thead>
<tr>
<th>Subjects Required by all Programs (53 Hours)</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115+, 116+, 215+, 216+</td>
<td>16</td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering +</td>
<td>4</td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers +</td>
<td>4</td>
</tr>
<tr>
<td>Chemistry 130¹</td>
<td>3</td>
</tr>
<tr>
<td>Physics 140 with Lab 141+; Physics 240 with Lab 241²+</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual Breadth (to include a course in micro or macro economics)</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Advanced Chemistry (11 Hours)</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry 210/211, Structure and Reactivity I and Lab +</td>
<td>5</td>
</tr>
<tr>
<td>Chemistry 215/216, Structure and Reactivity II and Lab +</td>
<td>5</td>
</tr>
</tbody>
</table>

Notes:
- ¹If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for the College of Engineering.
- ²If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and 240/241 you will have met the Physics Core Requirement for the College of Engineering.
- ³If you have a satisfactory score or grade in Biology AP, A-Level, IB Exams or transfer credit from another institution for Biology 172/174 you will have met the Biology Core Requirement for the College of Engineering.
- ⁴Depth requirements: A list of depth requirements and optional tracks is available on the department website and in 1111 Gerstacker.

Revised: April 2021
Candidates for the Bachelor of Science in Engineering in Biomedical Engineering - B.S.E. in Biomed E. - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

<table>
<thead>
<tr>
<th>Total</th>
<th>Term:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit Hours</td>
<td>1</td>
</tr>
<tr>
<td>128</td>
<td>17</td>
</tr>
</tbody>
</table>
Candidates for the Bachelor of Science in Engineering in Chemical Engineering - B.S.E. in Chem E. - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

**Notes:**

1. If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core
Requirement for the College of Engineering. Chemical Engineering only requires Chemistry 130 because Chem 211 fulfills the lab portion of the requirement.

2. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and 240/241 you will have met the Physics Core Requirement for the College of Engineering.

3. Either Physics 390 or Materials Science 242 or Chemistry 370 can be taken to fulfill the Chemistry 261 requirement.

4. See department list for other courses that satisfy the Biology/Life Science elective requirement for students with BIO100x AP credit.

5. Engineering courses are to be at the 200 or higher level and cannot include seminar courses. Engineering research hours at the 400 level or higher may be used to satisfy this requirement. Up to 8 hours of ChE 490 or ChE 695 research may be taken for a grade. Beyond that, ChE 490 or 695 hours must be taken pass/fail.

(+) Students must earn a "C-" or better in prerequisite courses indicated by the "+".

---

### Matriculation Fall 2017 and later

#### Sample Schedule 2020-2021

<table>
<thead>
<tr>
<th>Civil Engineering</th>
<th>Total Credit Hours</th>
<th>Terms: 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>revised: October 2020 7 8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subjects Required by all Programs (55 hours)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics 115, 116, 215, 216</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chemistry 130 and 125/126 or Chemistry 210 and 2111</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Physics 140 with Lab 1412</td>
<td>5</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Physics 240 with Lab 2412</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intellectual Breadth (includes Economics 101 or 102)</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><strong>Mathematical Methods (7 hours)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 303, Computational Methods</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CEE 373, Statistical Methods</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Required Program Subjects (22 hours)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 200, Intro to Civil and Environmental Engineering</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CEE 211, Statics and Dynamics</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CEE 212, Solid and Structural Mechanics</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CEE 230, Thermodynamics and the Environment or CEE 375, Sensors and Circuits</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3 or 3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CEE 265, Sustainable Engineering Principles</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3 or 3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CEE 325, Fluid Mechanics</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CEE 402, Professional Issues &amp; Design</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td><strong>Science Elective (3 hours)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology 171, 172, or 174</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Earth &amp; Environmental Sciences 119, 201, 222, 284, or 320</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

*Matriculation Fall 2017 and later*
Candidates for the Bachelor of Science degree in Engineering (Civil Engineering) - B.S.E. (C.E.) - must complete the program listed above.
This sample schedule is an example of one leading to graduation in eight terms.

Notes:

1. Civil Engineering students must earn a C- or better in all courses whose categories are marked with a plus.
2. If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams, or transfer credit from another institution for Chemistry 130/125/126, you will have met the Chemistry Core Requirement for the College of Engineering.
3. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams, or transfer credit from another institution for Physics 140/141 and 240/241, you will have met the Physics Core Requirement for the College of Engineering.
4. CEE may accept equivalent courses offered by other departments in the College of Engineering. Please see program advisor.
5. At least six of the seven program electives are required.

<table>
<thead>
<tr>
<th>Subject Requirements</th>
<th>Prerequisite(s)</th>
<th>Must Be Taken Before</th>
<th>Semester(s) Offered</th>
</tr>
</thead>
<tbody>
<tr>
<td>College Requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math 115</td>
<td>Math 116</td>
<td></td>
<td>Fall, Winter, Spring, Summer</td>
</tr>
<tr>
<td>Math 116</td>
<td>Math 115</td>
<td>Math 215, CEE 230, CEE 265</td>
<td>Fall, Winter, Spring, Summer</td>
</tr>
<tr>
<td>Math 215</td>
<td>Math 116</td>
<td>Math 216</td>
<td>Fall, Winter, Spring, Summer</td>
</tr>
<tr>
<td>Math 216</td>
<td>Math 116</td>
<td>CEE 303</td>
<td>Fall, Winter, Spring, Summer</td>
</tr>
<tr>
<td>Engr 100</td>
<td>Math 115</td>
<td></td>
<td>Fall, Winter</td>
</tr>
<tr>
<td>Chem 130</td>
<td>CEE 230, CEE 265</td>
<td></td>
<td>Fall, Winter, Spring</td>
</tr>
<tr>
<td>Chem 125/126</td>
<td>CEE 581</td>
<td></td>
<td>Fall, Winter, Spring</td>
</tr>
<tr>
<td>Phys 140/141</td>
<td>Math 115</td>
<td>CEE 211</td>
<td>Fall, Winter, Spring</td>
</tr>
<tr>
<td>Phys 240/241</td>
<td>Phys 140, Math 116</td>
<td></td>
<td>Fall, Winter, Spring</td>
</tr>
<tr>
<td>Mathematical Methods</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 303</td>
<td>Math 216, Engr 101</td>
<td>CEE 421</td>
<td>Winter</td>
</tr>
<tr>
<td>CEE 373</td>
<td>Math 215, Math 216</td>
<td></td>
<td>Fall</td>
</tr>
<tr>
<td>Required Program Subjects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>CEE 200</td>
<td>Fall, Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE211 Phys 140</td>
<td>CEE 212, CEE 325 Fall, Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 212 CEE 211</td>
<td>CEE 312, CEE 345, CEE 351 Fall, Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 230 Math 116, Chem 130 &amp; 125/126</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 265 Math 116, Chem 130</td>
<td>CEE 365 Fall, Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 325 CEE 211</td>
<td>CEE 421 Fall, Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 345 Phys 140</td>
<td>CEE 540, CEE 545, CEE 546, CEE 549 Fall, Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 375 Phys 240</td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 402 Senior standing</td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program Electives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 312 CEE 212</td>
<td>CEE 413, CEE 415, CEE 512 Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 351 CEE 212</td>
<td>CEE 537 Fall, Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 365 Chem 130, Math 116</td>
<td>CEE 485 Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 421 CEE 303, CEE 325</td>
<td>CEE 521 Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 431 Senior standing</td>
<td>Fall, Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical Electives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 534</td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 536</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 537 CEE 351</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 539 Senior standing</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 413 CEE 312</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 415 CEE 312</td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 412 CEE 312, Math 216</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 547 CEE 345</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 574 CEE 212</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geotechnical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 540 CEE 345</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 545 CEE 345</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 546 CEE 345</td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 549 CEE 345</td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulics/ Hydrology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 526 CEE 325</td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 428 CEE 325</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 521 CEE 325</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 522 CEE 325</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 465 CEE 325, CEE 365</td>
<td>CEE 480 Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 480 CEE 465</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 481/581 Chem 130</td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 482/582 Chem 130</td>
<td>Fall</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Computer Engineering Sample Schedule

<table>
<thead>
<tr>
<th>Subjects Required by all Programs (55 hours)</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, 215 and 216</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td></td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering</td>
<td>4</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemistry 125/126 and 130 or Chemistry 210 and 2111</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics 140 with Lab 141; Physics 240 with Lab 2412</td>
<td>10</td>
<td></td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td></td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Program Subjects (32 hours)

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>EECS 203, Discrete Mathematics</td>
<td>4</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECS 215, Introduction to Circuits3</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECS 216, Introduction to Signals and Systems</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECS 270, Introduction to Logic Design</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECS 280, Programming and Elementary Data Structures</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECS 370, Introduction to Computer Organization</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECS 301, MATH 425, or STATS 412</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCHNCLCM 3004</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCHNCLCM 496 and EECS 4965</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Technical Electives (28 hours) 6, 11

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible Technical Electives7</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>EECS Electives8</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core Electives9</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Level CE Electives10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Electives (13-16 hours)</td>
<td>13-16</td>
<td></td>
<td>3</td>
<td></td>
<td>3</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total** 128 17 17 16 16 16 16 15 15

Candidates for the Bachelor of Science in Engineering in Computer Engineering - B.S.E. in Compt. E. must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

**Notes:**

1. C- Rule: Among science, engineering and mathematics courses, a grade of C- or below is considered unsatisfactory.
2. If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for the College of Engineering.
3. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and 240/241 you will have met the Physics Core Requirement for the College of Engineering.
4. EECS 215 must be preceded or accompanied by Physics 240.
5. TCHNCLCM 300 can be taken independently of any EECS course, but it is a prerequisite for TCHNCLCM 496.
6. TCHNCLCM 496 must be taken in the same or later semester as the Major Design Experience (preferably the same semester).
7. Technical Electives: At least one of these classes must be an approved Major Design Experience Course.
8. Unused credits from Upper Level CE Electives or EECS Elective courses may be used to satisfy this requirement.
9. Unused credits from Upper Level CE Elective courses may be used to satisfy this requirement.
10. Technical Electives: At least 10 hours Contact the EECS Undergraduate Advising Office for the current list.
11. A maximum of 4 hours of EECS 499 may be applied to Technical Elective requirements and only in the area of Flexible Technical Electives.
Subjects Required by all Programs (55 hours)

<table>
<thead>
<tr>
<th>Subjects Required by all Programs (55 hours)</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, and 2143</td>
<td>12 4 4 - - 4 - - -</td>
</tr>
<tr>
<td>Mathematics 215 or 2164</td>
<td>4 - - - 4 - - -</td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering</td>
<td>4 - 4 - - - - -</td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers</td>
<td>4 4 - - - - - -</td>
</tr>
<tr>
<td>Chemistry 125/126 and 130 or Chemistry 210 and 2111</td>
<td>5 5 - - - - - -</td>
</tr>
<tr>
<td>Physics 140 with Lab 141; Physics 240 with Lab 2412</td>
<td>10 - 5 5 - - - -</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16 3 3 - 4 4 - - 2</td>
</tr>
</tbody>
</table>

Program Subjects (26 hours)

<table>
<thead>
<tr>
<th>Program Subjects (26 hours)</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EECS 203 Discrete Mathematics5</td>
<td>4 - - - 4 - - -</td>
</tr>
<tr>
<td>EECS 280, Programming and Elementary Data Structures</td>
<td>4 - - 4 - - - -</td>
</tr>
<tr>
<td>EECS 281, Data Structures and Algorithms</td>
<td>4 - - - - 4 - - -</td>
</tr>
<tr>
<td>EECS 370, Introduction to Computer Architecture</td>
<td>4 - - - - 4 - - -</td>
</tr>
<tr>
<td>STATS 250 or STATS 412 or STATS 426 or EECS 301/401 or IOE 2656</td>
<td>3 - - 3 - - - -</td>
</tr>
<tr>
<td>EECS 376, Foundations of Computer Science</td>
<td>4 - - - - - - -</td>
</tr>
<tr>
<td>TCHNCLCM 300</td>
<td>1 - - 1 - - -</td>
</tr>
<tr>
<td>EECS 496 Major Design Experience Professionalism</td>
<td>2 - - - - - - 2</td>
</tr>
</tbody>
</table>

Major Design Experience (6 hours)

<table>
<thead>
<tr>
<th>Major Design Experience (6 hours)</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved CS MDE course7</td>
<td>4 - - - - - 4 -</td>
</tr>
<tr>
<td>TCHNCLCM 497 or TCHNCLCM 496</td>
<td>2 - - - - - 2 -</td>
</tr>
</tbody>
</table>

Technical Electives (26 hours)

<table>
<thead>
<tr>
<th>Technical Electives (26 hours)</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Level CS Technical Electives8</td>
<td>16 - - - 4 4 4 4</td>
</tr>
<tr>
<td>Flexible Technical Electives9,10</td>
<td>10 - - - - - 4 6</td>
</tr>
<tr>
<td>General Electives (15 hours)</td>
<td>15 - - 3 - 4 4 4</td>
</tr>
</tbody>
</table>

Total

Revised: March-2020

Candidates for the Bachelor of Science in Engineering in Computer Science - B.S.E. in C.S. - must complete the program listed above. This sample schedule is an

Notes:

- C- Rule: Among science, engineering and mathematics courses, a grade of C- or below is considered unsatisfactory.
- Credits from a course may only be used to fulfill a single requirement (no double counting).
- If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for the College of Engineering.
- If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and 240/241 you will have met the Physics Core Requirement for the College of Engineering.
- The requirements for Math 214 can be satisfied by Math 217, 417, or 419.
- If both Math 215 and Math 216 are taken, Math 216 will be counted as a Flexible Technical Elective.
- Math 465 can be used to satisfy this requirement.
- Stats 250, EECS 301, and IOE 265 are 4 hour courses; if this is elected, the extra hour is counted toward General Electives.
- An approved Computer Science (CS) Major Design Experience (MDE) course; see the appropriate CS Program Guide for the current list. Must be taken in the same term as EECS 496 and TCHNCLCM 497. A 3-credit CS MDE course can be used if a total of 27 credits of Technical Electives are elected.
- Upper Level CS Technical Electives (ULCS): approved Computer Science courses at the 300-level or higher. See the appropriate CS Program Guide for the current list.
- Flexible Technical Electives (FTEs): Approved courses at the 200 or higher level. See the appropriate CS Program Guide for the current list.
- A maximum of 4 hours of EECS 499 (or other upper-level directed/independent study) may be applied to Flexible Technical Electives. Anything beyond 4 hours

<table>
<thead>
<tr>
<th>Data Science in Engineering</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects Required by all Programs (55 credits)</td>
<td>Credit Hours</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Mathematics 115, 116, and (214 or 217)</td>
<td>12 4 4 - - 4 - - -</td>
</tr>
<tr>
<td>Mathematics 215</td>
<td>4 - - - 4 - - -</td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering</td>
<td>4 - 4 - - - - -</td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers</td>
<td>4 4 - - - - - -</td>
</tr>
<tr>
<td>Chemistry 125/126 and 130, or Chemistry 210 and 2111</td>
<td>5 5 - - - - - -</td>
</tr>
<tr>
<td>Physics 140 and Lab 141</td>
<td>5 - 5 - - - - -</td>
</tr>
<tr>
<td>Physics 240 and Lab 241</td>
<td>5 - - 5 - - - -</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16 4 4 - 4 4 - - -</td>
</tr>
</tbody>
</table>

Program Core (30 credits)

<table>
<thead>
<tr>
<th>Program Core (30 credits)</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects Required by all programs (55 hrs.)</td>
<td>Credit Hours</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Mathematics 115, 116, 215, 216</td>
<td>12</td>
</tr>
<tr>
<td>ENGR 100</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 101</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 125/126/130 or CHEM 210/211</td>
<td>5</td>
</tr>
<tr>
<td>PHYSICS 140/141; PHYSICS 240/241</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
</tr>
<tr>
<td>Subjects Required by all programs (55 hrs.)</td>
<td></td>
</tr>
<tr>
<td>Mathematics 115, 116, 215, 216</td>
<td>12</td>
</tr>
<tr>
<td>ENGR 100</td>
<td>4</td>
</tr>
<tr>
<td>ENGR 101</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 125/126/130 or CHEM 210/211</td>
<td>5</td>
</tr>
<tr>
<td>PHYSICS 140/141; PHYSICS 240/241</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
</tr>
<tr>
<td>Program Subjects (30 hrs.)</td>
<td></td>
</tr>
<tr>
<td>EECS 200, Electrical Engineering Systems Design I</td>
<td>2</td>
</tr>
<tr>
<td>EECS 215, Introduction to Circuits</td>
<td>4</td>
</tr>
<tr>
<td>EECS 216, Signals and Systems</td>
<td>4</td>
</tr>
</tbody>
</table>

Candidates for the Bachelor of Science in Engineering in Data Science - B.S.E. in Data Science - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:

1. The requirements for Math 214 can be satisfied by Math 217 as an alternative.
2. List of approved courses for this requirement can be found through the DS Eng section of the EECS website.
3. Advanced DS Technical Electives: 300-level or higher from a pre-approved list of courses found through the DS-Eng section of the EECS website, or with Chief Program Advisor approval prior to taking the course.
4. Flexible Technical Electives (FTEs): Approved courses at the 200+ level; list can be found through the DS-Eng section of the EECS website.
5. A maximum of 4 hours of EECS 499 (or other upper-level directed/independent study) may be applied to Flexible Technical Electives. Anything beyond 4 hours will be applied toward the General Electives.
6. Another approved 400-level technical communications course may be used with Chief Program Advisor approval prior to taking the course.
### Subjects required by all programs (55 hours)

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, 215, and 216</td>
<td>16</td>
</tr>
<tr>
<td>Engr 100, Intro to Engr</td>
<td>4</td>
</tr>
<tr>
<td>Engr 101, Intro to Computers</td>
<td>4</td>
</tr>
<tr>
<td>Chemistry 125/126 and 130 or Chemistry 210 and 211</td>
<td>5</td>
</tr>
<tr>
<td>Physics 140 with Lab 141; Physics 240 with Lab 241</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
</tr>
<tr>
<td>Advanced Mathematics (3 hours)</td>
<td>3</td>
</tr>
<tr>
<td>Mathematics Electives (3 hours)</td>
<td></td>
</tr>
<tr>
<td>Related Technical Subjects (8 hours)</td>
<td></td>
</tr>
<tr>
<td>MATSCIE 250, Princ of Eng Materials or MATSCIE 220, Intr</td>
<td>4</td>
</tr>
<tr>
<td>EECS 314, Elect Cir, Sys, and Appl or EECS 215, Intro to Cir</td>
<td>4</td>
</tr>
<tr>
<td>Physics Technical Subjects (23 hours)</td>
<td></td>
</tr>
<tr>
<td>Physics 340, Waves, Heat and Light</td>
<td>3</td>
</tr>
<tr>
<td>Physics 351, Methods of Theoretical Physics 14</td>
<td>3</td>
</tr>
<tr>
<td>Physics 390, Intro to Modern Physics or NERS 311, Ele of N</td>
<td>3</td>
</tr>
<tr>
<td>Physics 401, Int Mech6</td>
<td>3</td>
</tr>
<tr>
<td>Physics 405, Int Elect and Mag</td>
<td>3</td>
</tr>
<tr>
<td>Physics 406, Static/Thermal Physics</td>
<td>3</td>
</tr>
<tr>
<td>Physics Lab Elective or Directed Study with Research Lab C</td>
<td>2</td>
</tr>
<tr>
<td>Physics Elective (300-level or higher)</td>
<td>3</td>
</tr>
<tr>
<td>Engr Technical Electives (20 hours)</td>
<td>16</td>
</tr>
<tr>
<td>Engineering Electives</td>
<td></td>
</tr>
<tr>
<td>Engineering Laboratory Elective (400-level or higher)</td>
<td>4</td>
</tr>
<tr>
<td>Technical Electives (7 hours)?</td>
<td></td>
</tr>
<tr>
<td>Mathematics, Physics or Engr Courses (300-level or higher)</td>
<td>7</td>
</tr>
<tr>
<td>General Electives (12 hours)</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>128</td>
</tr>
</tbody>
</table>

### General Electives (11 hrs.)

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics Electives (3 hours)</td>
<td></td>
</tr>
<tr>
<td>Related Technical Subjects (8 hours)</td>
<td></td>
</tr>
<tr>
<td>MATSCIE 250, Princ of Eng Materials or MATSCIE 220, Intr</td>
<td>4</td>
</tr>
<tr>
<td>EECS 314, Elect Cir, Sys, and Appl or EECS 215, Intro to Cir</td>
<td>4</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
</tr>
<tr>
<td>Advanced Mathematics (3 hours)</td>
<td>3</td>
</tr>
<tr>
<td>Related Technical Subjects (8 hours)</td>
<td></td>
</tr>
<tr>
<td>MATSCIE 250, Princ of Eng Materials or MATSCIE 220, Intr</td>
<td>4</td>
</tr>
<tr>
<td>EECS 314, Elect Cir, Sys, and Appl or EECS 215, Intro to Cir</td>
<td>4</td>
</tr>
<tr>
<td>Physics Technical Subjects (23 hours)</td>
<td></td>
</tr>
<tr>
<td>Physics 340, Waves, Heat and Light</td>
<td>3</td>
</tr>
<tr>
<td>Physics 351, Methods of Theoretical Physics 14</td>
<td>3</td>
</tr>
<tr>
<td>Physics 390, Intro to Modern Physics or NERS 311, Ele of N</td>
<td>3</td>
</tr>
<tr>
<td>Physics 401, Int Mech6</td>
<td>3</td>
</tr>
<tr>
<td>Physics 405, Int Elect and Mag</td>
<td>3</td>
</tr>
<tr>
<td>Physics 406, Static/Thermal Physics</td>
<td>3</td>
</tr>
<tr>
<td>Physics Lab Elective or Directed Study with Research Lab C</td>
<td>2</td>
</tr>
<tr>
<td>Physics Elective (300-level or higher)</td>
<td>3</td>
</tr>
<tr>
<td>Engr Technical Electives (20 hours)</td>
<td>16</td>
</tr>
<tr>
<td>Engineering Electives</td>
<td></td>
</tr>
<tr>
<td>Engineering Laboratory Elective (400-level or higher)</td>
<td>4</td>
</tr>
<tr>
<td>Technical Electives (7 hours)?</td>
<td></td>
</tr>
<tr>
<td>Mathematics, Physics or Engr Courses (300-level or higher)</td>
<td>7</td>
</tr>
<tr>
<td>General Electives (12 hours)</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>128</td>
</tr>
</tbody>
</table>

- EE students are advised to take MATH 216 before MATH 215 as EECS 216 is to be preceded or accompanied by MATH 216.
- EE students are advised to take EECS 230 no later than the fifth semester.
- EE students are advised to take EECS 301 no later than the sixth semester. EE students may select only EECS 301 to fulfill this requirement. At most 4 credits of undergraduate probability may be applied towards the BSEE-EE degree requirements. MATH 425 will not suffice as a pre-requisite for any class that requires EECS 301.
- EE students are advised to take EECS 230 no later than the fifth semester.
- EE students are advised to take MATH 216 before MATH 215 as EECS 216 is to be preceded or accompanied by MATH 216.
- EE students are advised to take EECS 230 no later than the fifth semester.
- EE students are advised to take EECS 301 no later than the sixth semester. EE students may select only EECS 301 to fulfill this requirement. At most 4 credits of undergraduate probability may be applied towards the BSEE-EE degree requirements. MATH 425 will not suffice as a pre-requisite for any class that requires EECS 301.
- EE students are advised to take EECS 230 no later than the fifth semester.
- EE students are advised to take MATH 216 before MATH 215 as EECS 216 is to be preceded or accompanied by MATH 216.
- EE students are advised to take EECS 301 no later than the sixth semester. EE students may select only EECS 301 to fulfill this requirement. At most 4 credits of undergraduate probability may be applied towards the BSEE-EE degree requirements. MATH 425 will not suffice as a pre-requisite for any class that requires EECS 301.
- EE students are advised to take EECS 230 no later than the fifth semester.
- EE students are advised to take MATH 216 before MATH 215 as EECS 216 is to be preceded or accompanied by MATH 216.
Candidates for the Bachelor of Science in Engineering in Engineering Physics - B.S.E. in Eng Physics - must complete the program listed above. This sample Notes:
1. If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.
2. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and 240/241 you will have met the Physics Core Requirement for CoE.
3. Math Electives must be 300-level or higher.
4. For students pursuing ME in Engr Technical Electives, CEE 211 or ME 240 will be advised as a substitute for Physics 401. MECHENG 440 or MECHENG 540 can be substituted with faculty program advisor approval.
5. For students pursuing ME in Engr Tech Elective, students may be advised to take ME 235 and ME 320 as Flexible Tech Electives. For students pursuing Aero in Engr Tech Electives, students may be advised to take Aero 225 and Aero 325 as Flexible Tech Electives.
6. Students contemplating graduate studies in Physics should elect Physics 453, Quantum Mech and Physics 463, Solid State for a complete background.

<table>
<thead>
<tr>
<th>Sample Schedule 2018-2019</th>
<th>Total</th>
<th>Terms:</th>
<th>revised: 8-Jan-2019</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Engineering</strong></td>
<td></td>
<td>1 2 3 4 5 6</td>
<td>7 8</td>
</tr>
<tr>
<td><strong>Subjects Required by all Programs (55 hours)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics 115, 116, 215, 216</td>
<td>16</td>
<td>4 4 4 4 4 - - - -</td>
<td></td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering</td>
<td>4</td>
<td>4 - - - - - - -</td>
<td></td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers</td>
<td>4</td>
<td>- 4 - - - - - -</td>
<td></td>
</tr>
<tr>
<td>Chemistry 130 and 125/126</td>
<td>5</td>
<td>5 - - - - - - -</td>
<td></td>
</tr>
<tr>
<td>Physics 140 with Lab 1412</td>
<td>5</td>
<td>- 5 - - - - - -</td>
<td></td>
</tr>
<tr>
<td>Physics 240 with Lab 2412</td>
<td>5</td>
<td>- - 5 - - - - -</td>
<td></td>
</tr>
<tr>
<td>Intellectual Breadth (includes Economics 101 or 102)</td>
<td>16</td>
<td>4 4 - - 4 4 -</td>
<td></td>
</tr>
<tr>
<td><strong>Mathematical Methods (7 hours)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 303, Computational Methods</td>
<td>4</td>
<td>- - - - - 4 -</td>
<td></td>
</tr>
<tr>
<td>CEE 373, Statistical Methods</td>
<td>3</td>
<td>- - - - 3 - -</td>
<td></td>
</tr>
<tr>
<td><strong>Technical Core Subjects (32 hours)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemistry 210, Structure &amp; Reactivity I</td>
<td>4</td>
<td>- - - 4 - - -</td>
<td></td>
</tr>
<tr>
<td>CEE 200, Intro to Civil &amp; Environmental Engineering</td>
<td>1</td>
<td>- - - 1 - - -</td>
<td></td>
</tr>
<tr>
<td>CEE 211, Statics and Dynamics</td>
<td>4</td>
<td>- - 4 - - - -</td>
<td></td>
</tr>
<tr>
<td>CEE 230, Thermodynamics and the Environment</td>
<td>3</td>
<td>- - 3 - - - -</td>
<td></td>
</tr>
<tr>
<td>CEE 265, Sustainable Engineering Principles</td>
<td>3</td>
<td>- - - 3 - - -</td>
<td></td>
</tr>
<tr>
<td>CEE 325, Fluid Mechanics</td>
<td>4</td>
<td>- - - 4 - - -</td>
<td></td>
</tr>
<tr>
<td>CEE 365, Environmental Engineering Principles</td>
<td>4</td>
<td>- - - - 4 - -</td>
<td></td>
</tr>
<tr>
<td>CEE 366, Environmental Engineering Laboratory</td>
<td>2</td>
<td>- - - - 4 - -</td>
<td></td>
</tr>
<tr>
<td>CEE 421, Hydrology and Floodplain Hydraulics</td>
<td>4</td>
<td>- - - - - 4 -</td>
<td></td>
</tr>
<tr>
<td>CEE 465, Environmental Process Engineering</td>
<td>3</td>
<td>- - - - - 3 -</td>
<td></td>
</tr>
<tr>
<td><strong>Environmental Sciences (9 hours)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earth Science Elective: CLIMATE 320, 410, 463 or 475; EARTH 305, 315, 321, 323, 442, 451 or 477</td>
<td>3</td>
<td>- - - 3 - -</td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td>Prerequisite(s)</td>
<td>Must Be Taken Before</td>
<td>Semester(s) Offered</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>----------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>College Requirements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math 115</td>
<td>Math 116</td>
<td></td>
<td>Fall, Winter, Spring, Summer</td>
</tr>
<tr>
<td>Math 116</td>
<td>Math 115</td>
<td>Math 215, CEE 230, CEE 265</td>
<td>Fall, Winter, Spring, Summer</td>
</tr>
<tr>
<td>Math 215</td>
<td>Math 116</td>
<td>Math 216</td>
<td>Fall, Winter, Spring, Summer</td>
</tr>
<tr>
<td>Math 216</td>
<td>Math 116</td>
<td>CEE 303</td>
<td>Fall, Winter, Spring, Summer</td>
</tr>
<tr>
<td>Engr 100</td>
<td></td>
<td></td>
<td>Fall, Winter</td>
</tr>
<tr>
<td>Engr 101</td>
<td>Math 115 (or concurrent)</td>
<td>CEE 303, CEE 373</td>
<td>Fall, Winter</td>
</tr>
<tr>
<td>Chem 130</td>
<td></td>
<td>CEE 230, CEE 265</td>
<td>Fall, Winter, Spring</td>
</tr>
<tr>
<td>Chem 125/126</td>
<td></td>
<td>CEE 581</td>
<td>Fall, Winter, Spring</td>
</tr>
<tr>
<td>Phys 140/141</td>
<td>Math 115</td>
<td>CEE 211</td>
<td>Fall, Winter, Spring</td>
</tr>
<tr>
<td>Phys 240/241</td>
<td>Phys 140, Math 116</td>
<td></td>
<td>Fall, Winter, Spring</td>
</tr>
<tr>
<td><strong>Mathematical Methods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEE 303</td>
<td>Math 216, Engr 101</td>
<td>CEE 421</td>
<td>Winter</td>
</tr>
<tr>
<td>CEE 373</td>
<td>Math 215, Math 216</td>
<td></td>
<td>Fall</td>
</tr>
<tr>
<td><strong>Technical Core Subjects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course</td>
<td>Prerequisites</td>
<td>Term(s)</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>Chem 210</td>
<td>CHEM 130</td>
<td>Fall, Winter, Spring, Summer</td>
<td></td>
</tr>
<tr>
<td>CEE 200</td>
<td></td>
<td>Fall, Winter</td>
<td></td>
</tr>
<tr>
<td>CEE 211</td>
<td>Physics 140</td>
<td>Fall, Winter</td>
<td></td>
</tr>
<tr>
<td>CEE 230</td>
<td>Math 116, Chem 130 &amp; 125/126</td>
<td>Fall</td>
<td></td>
</tr>
<tr>
<td>CEE 265</td>
<td>Math 116, Chem 130</td>
<td>Fall, Winter</td>
<td></td>
</tr>
<tr>
<td>CEE 325</td>
<td>CEE 211</td>
<td>Fall, Winter</td>
<td></td>
</tr>
<tr>
<td>CEE 365</td>
<td>Chem 130, Math 116</td>
<td>Fall</td>
<td></td>
</tr>
<tr>
<td>CEE 366</td>
<td>CEE 365 (or concurrent)</td>
<td>Winter</td>
<td></td>
</tr>
<tr>
<td>CEE 421</td>
<td>CEE 303, CEE 325</td>
<td>Fall</td>
<td></td>
</tr>
<tr>
<td>CEE 465</td>
<td>CEE 325, CEE 365</td>
<td>CEE 480</td>
<td>Winter</td>
</tr>
</tbody>
</table>

**Environmental Sciences**

<table>
<thead>
<tr>
<th>Course</th>
<th>Prerequisites</th>
<th>Term(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLIMATE 320</td>
<td>Math 116</td>
<td></td>
</tr>
<tr>
<td>CLIMATE 410</td>
<td>Climate 320, 321</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Advised</td>
<td></td>
</tr>
<tr>
<td>CLIMATE 475</td>
<td>Senior standing</td>
<td></td>
</tr>
<tr>
<td>EARTH 305</td>
<td>Introductory geology</td>
<td>Fall</td>
</tr>
<tr>
<td></td>
<td>lab</td>
<td></td>
</tr>
<tr>
<td>EARTH 315</td>
<td>CHEM 130</td>
<td>Fall</td>
</tr>
<tr>
<td>EARTH 321</td>
<td>MATH 215, MATH 216</td>
<td>Winter</td>
</tr>
<tr>
<td>EARTH 323</td>
<td></td>
<td>Winter</td>
</tr>
<tr>
<td>EARTH 442</td>
<td>Math 115, Chem 130</td>
<td>Fall</td>
</tr>
<tr>
<td>EARTH 451</td>
<td></td>
<td>Winter</td>
</tr>
<tr>
<td>EARTH 477</td>
<td>Math 115</td>
<td>Fall</td>
</tr>
<tr>
<td>CEE 481/581</td>
<td>Chem 130</td>
<td>Winter</td>
</tr>
<tr>
<td>CEE 482/582</td>
<td>Chem 130</td>
<td>Fall</td>
</tr>
</tbody>
</table>

**Environmental Engr Design**

<table>
<thead>
<tr>
<th>Course</th>
<th>Prerequisites</th>
<th>Term(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE 402</td>
<td>Senior Standing</td>
<td>Winter</td>
</tr>
</tbody>
</table>

**Technical Electives**

**Water Quality and Health**

<table>
<thead>
<tr>
<th>Course</th>
<th>Prerequisites</th>
<th>Term(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE 428</td>
<td>CEE 325, CEE 345 or 366</td>
<td>Fall</td>
</tr>
<tr>
<td>CEE 480</td>
<td>CEE 465</td>
<td>Fall</td>
</tr>
<tr>
<td>CHE 342</td>
<td>CHE 230, CHE 341, Math 216</td>
<td>Fall</td>
</tr>
<tr>
<td>EHS 500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Atmospheric and Earth Systems**

<table>
<thead>
<tr>
<th>Course</th>
<th>Prerequisites</th>
<th>Term(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE 549</td>
<td>CHE 345</td>
<td>Winter</td>
</tr>
<tr>
<td>CEE 563</td>
<td>CEE 230 and CEE 325 or equiv.</td>
<td>Winter</td>
</tr>
<tr>
<td>CLIMATE 463</td>
<td>Math 215</td>
<td></td>
</tr>
<tr>
<td>CLIMATE 467</td>
<td>Math 116, Chem 210, Physics 240</td>
<td></td>
</tr>
<tr>
<td>EARTH 413</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Environmental Fluid Dynamics**

<table>
<thead>
<tr>
<th>Course</th>
<th>Prerequisites</th>
<th>Term(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEE 428</td>
<td>CEE 325, CEE 345 or 366</td>
<td>Fall</td>
</tr>
<tr>
<td>CEE 521</td>
<td>CEE 325</td>
<td>Fall</td>
</tr>
<tr>
<td>CEE 522</td>
<td>CEE 325</td>
<td>Fall</td>
</tr>
<tr>
<td>CEE 526</td>
<td>CEE 325</td>
<td>Winter</td>
</tr>
</tbody>
</table>
## Energy & Sustainable Infrastructure

<table>
<thead>
<tr>
<th>CEE 567</th>
<th>CEE 230 recommended</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>URP 423</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EARTH 344</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Environ Policy &amp; Entrepreneurship</td>
<td></td>
</tr>
<tr>
<td>ENGR 520</td>
<td>Senior Standing</td>
<td></td>
</tr>
<tr>
<td>EAS 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLIMATE 480</td>
<td>Senior Standing, Math 216</td>
<td></td>
</tr>
</tbody>
</table>

### Sample Schedule

#### Industrial Operations Engineering

<table>
<thead>
<tr>
<th>Subjects required by all programs (55 hours)</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, 215, and 214</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engr 100, Intro to Engr</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engr 101, Intro to Computers</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chemistry 125/126 and 130 or Chemistry 210 and 211¹</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Physics 140 with Lab 141; Physics 240 with Lab 241²</td>
<td>10</td>
<td>-</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Related Engineering Subjects (11-12 hours)

| Non-IOE Engineering Courses (11-12 hours)² | 12 | - | - | - | 4 | 4 | - | - | 4 |

#### Required Program Subjects (34)

| IOE 201, Industrial, Operations Modeling | 2 | - | - | 2 | - | - | - | - | - |
| IOE 202, Operations Modeling | 2 | - | - | 2 | - | - | - | - | - |
| IOE 265, Engr Probability and Statistics | 3 | - | - | - | 3 | - | - | - | - |
| IOE 310, Intro to Optim Methods | 3 | - | - | - | - | 3 | - | - | - |
| IOE 333, Ergonomics | 3 | - | - | - | 3 | - | - | - | - |
| IOE 334, Ergonomics Lab | 1 | - | - | - | 1 | - | - | - | - |
| IOE 316, Intro to Markov Processes | 3 | - | - | - | - | 3 | - | - | - |
| IOE 366, Linear Statistical Models | 3 | - | - | - | - | 3 | - | - | - |
| IOE 373, Data Processing | 4 | - | - | - | - | - | 4 | - | - |
| IOE 474, Simulation | 4 | - | - | - | - | - | - | 4 | - |
| IOE Senior Design Course IOE 424, 481, 499* | 4 | - | - | - | - | - | - | - | 4 |
| TC 380, Technical Communication in IOE | 2 | - | - | - | - | - | 2 | - | - |
| Technical Electives (18)³ | 18 | - | - | - | - | 3 | 6 | 6 | 3 |
| General Electives (9-12 hours) | 9-12 | - | - | - | - | - | 6 | 6 | 3 |

#### Total Term:

| Total | 128 | 17 | 17 | 17 | 15 | 16 | 16 | 16 | 14 |
Revised: March 2020

Candidates for the Bachelor of Science in Engineering in Industrial and Operations Engineering - B.S.E. I.O.E - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:
1. If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 you will have met the Chemistry Core Requirement for CoE.
2. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and 240/241 you will have met the Physics Core Requirement for CoE.
3. Non-IOE Engineering Courses - Select 11-12 hours; one course from any three different groups:
   - MECHENG 211 or CEE 211 or MECHENG 240
   - MECHENG 235 or CHE 230
   - MATSCIE 220 or MECHENG 382
   - BIOMEDE 458 or EECS 270 or EECS 314
   - CEE 265 or NERS 211

4. IOE Senior Design courses are restricted to IOE undergraduate students only.

5. Technical Electives - Select 12 hours from the following four groups; at least one course each from three of the following four groups:
   - A. IOE 410, 413, 419, 440, 441, 447, 449
   - B. IOE 416, 460, 461*, 465*, 466*
   - C. IOE 430, 432, 434, 436, 437, 438, 463
   - D. IOE 421, 422, 425, 430, 452, 453

The remaining 6 hours may be selected from any 400-level IOE courses (except IOE 490, IOE 499, IOE 424, and IOE 481) and/or from the approved list of non-IOE courses.

*Maximum of 6 hours allowed from IOE 461, 465, 466.

**Consult IOE academic advisor for requirements based on term of admission.

### Materials Science and Engineering Sample Schedule

<table>
<thead>
<tr>
<th>Subjects Required by all Programs (55 hours)</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, 215, and 216</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chemistry 125/126 and 130 or Chemistry 210 and 2111</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Physics 140 with Lab 141; Physics 240 with Lab 24</td>
<td>10</td>
<td>-</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science and Technical Subjects (14 hours)</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME 211, Introduction to Solid Mechanics</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Science and Technical Electives (must include a program-approved Math course)</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Program Subjects (47 hours)</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSE 250, Principles of Engineering Materials or MSE 220, Introduction to Materials and</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MSE 242, Physics of Materials</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MSE 330, Thermodynamics of Materials</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MSE 335, Kinetics and Transport in Materials Engineering</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MSE 350, Structure of Materials</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MSE 360, Materials Lab I</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MSE 365, Materials Lab II</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MSE 420, Mechanical Behavior of Materials</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MSE 481, Designing Sustainable Products and Processes</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>MSE 482, Product Design and Manufacturing</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Choose four MSE courses 400 level or above</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electives</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Electives</td>
<td>12</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Total** 128 17 17 16 16 14 17 16 15

Revised: March 2021

Candidates for the Bachelor of Science Degree in Engineering in Materials Science and Engineering - B.S.E. in Matl. Sci. & E. - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.
## Intellectual Breadth
- Physics 240 with Lab 241
- Chemistry 210 and 211
- Chemistry 125/126 and 130
- Introduction to Computers
- Engineering 101, Introduction to Engineering
- Mathematics 115, 116, 215, and 216

### College of Engineering 300-Level or Higher Prerequisites

<table>
<thead>
<tr>
<th>Subject</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME 240, Introduction to Dynamics and Vibrations</td>
<td>4</td>
</tr>
<tr>
<td>ME 250, Design and Manufacturing I</td>
<td>4</td>
</tr>
<tr>
<td>ME 320, Fluids II</td>
<td>3</td>
</tr>
<tr>
<td>ME 350, Heat Transfer</td>
<td>3</td>
</tr>
<tr>
<td>ME 390, Design and Manufacturing II</td>
<td>4</td>
</tr>
<tr>
<td>ME 391, Introduction to Engineering</td>
<td>4</td>
</tr>
<tr>
<td>ME 393, Introduction to Engineering</td>
<td>4</td>
</tr>
<tr>
<td>ME 395, Laboratory II</td>
<td>4</td>
</tr>
</tbody>
</table>

### Electives (21 to 24 hours)

<table>
<thead>
<tr>
<th>Elective</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Electives #3</td>
<td>9</td>
</tr>
<tr>
<td>Specialization Elective #5</td>
<td>3</td>
</tr>
<tr>
<td>General Electives #3</td>
<td>9</td>
</tr>
</tbody>
</table>

### Total Credit Hours
- 128
- 76
- 76
- 76
- 76
- 76
- 76
- 16

---

### Mechanical Engineering Sample Schedule

<table>
<thead>
<tr>
<th>Subjects Required by All Programs (55 hours)</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, 215, and 216</td>
<td>16</td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering</td>
<td>4</td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers</td>
<td>4</td>
</tr>
<tr>
<td>Chemistry 125/126 and 130 or Chemistry 210 and 211</td>
<td>5</td>
</tr>
<tr>
<td>Physics 140 with Lab 141; Physics 240 with Lab 2412</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
</tr>
</tbody>
</table>

### Program Subjects (55 hours)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME 211, Introduction to Solid Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>ME 230, Thermodynamics I+</td>
<td>4</td>
</tr>
<tr>
<td>ME 240, Introduction to Dynamics and Vibrations+</td>
<td>4</td>
</tr>
<tr>
<td>ME 250, Design and Manufacturing I+</td>
<td>4</td>
</tr>
<tr>
<td>ME 320, Fluids II+</td>
<td>3</td>
</tr>
<tr>
<td>ME 355, Heat Transfer</td>
<td>3</td>
</tr>
<tr>
<td>ME 350, Design and Manufacturing II</td>
<td>4</td>
</tr>
<tr>
<td>ME 390, Systems and Controls</td>
<td>4</td>
</tr>
<tr>
<td>ME 392, Engineering Materials</td>
<td>4</td>
</tr>
<tr>
<td>ME 395, Laboratory I+</td>
<td>4</td>
</tr>
<tr>
<td>ME 400, Design and Manufacturing III+</td>
<td>4</td>
</tr>
<tr>
<td>ME 495, Laboratory II</td>
<td>4</td>
</tr>
</tbody>
</table>

### Naval Architecture & Marine Engineering

<table>
<thead>
<tr>
<th>Subject</th>
<th>Credit Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, 215, and 216</td>
<td>16</td>
</tr>
<tr>
<td>Engineering 100, Introduction to Engineering</td>
<td>4</td>
</tr>
<tr>
<td>Engineering 101, Introduction to Computers</td>
<td>4</td>
</tr>
<tr>
<td>Chemistry 125/126 and 130 or Chemistry 210 and 211</td>
<td>5</td>
</tr>
<tr>
<td>Physics 140 with Lab 141; Physics 240 with Lab 2412</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
</tr>
</tbody>
</table>

### Notes:
1. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and/or Physics 240/241 you will have met the Physics Core Requirement for the College of Engineering.
2. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 130/125/126 or Chemistry 210/211, you will have met the Chemistry Core Requirement for the College of Engineering.
4. The ME department requires each student to take at least 3 credit hours economic or financial course as part of their Intellectual Breadth requirements. Any course on the supplied list within LSA fulfills the Intellectual Breadth as a LAC. Any 2 electives are required.
5. A specialization elective is any three hour credit course that meets the requirement of either 1) have a 300 level or higher prerequisite or 2) be any 300 level or higher ME course.

* Students must earn a "C" or better in prerequisite courses indicated by the (+) symbol;
* Students must earn a "D" or better in pre-requisite design/manufacturing or lab course indicated by (D); students must earn a "D" or better in advanced courses indicated by the (D) symbol;
* Any grade less than indicated means this class must be repeated prior to taking a subsequent class for which this class is required.

Students are limited to two "attempts" without permission from the ME Associate Chair for undergraduate education.

"D" Rule: No grade less than a "D" shall be earned in any course used for degree credit.

Candidates for the B.S.E. (ME) must complete the program listed above. This is just a sample of a schedule that will lead to graduation in eight terms.
<table>
<thead>
<tr>
<th>Related Technical Core Subjects (10 hours)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NA 210, Intro to Marine Structures (or ME 211)</td>
<td>3</td>
<td>- - - 3 - - - -</td>
</tr>
<tr>
<td>ME 240, Introduction to Dynamics</td>
<td>4</td>
<td>- - - 4 - - - -</td>
</tr>
<tr>
<td>NA 235, Marine Thermodynamics (or ME 235)</td>
<td>3</td>
<td>- - 3 - - - -</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Program Subjects (45 hours)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NA 270, Vessel/Platform Design</td>
<td>4</td>
<td>- - 4 - - - -</td>
</tr>
<tr>
<td>NA 280, Probability for Marine Engineers</td>
<td>3</td>
<td>- - - 3 - - -</td>
</tr>
<tr>
<td>NA 310, Marine Structures I</td>
<td>4</td>
<td>- - - - 4 - -</td>
</tr>
<tr>
<td>NA 320, Marine Hydrodynamics I</td>
<td>4</td>
<td>- - - - 4 - -</td>
</tr>
<tr>
<td>NA 321, Marine Hydrodynamics II</td>
<td>4</td>
<td>- - - - 4 - -</td>
</tr>
<tr>
<td>NA 331, Marine Engineering I</td>
<td>3</td>
<td>- - - - 3 - -</td>
</tr>
<tr>
<td>NA 332, Marine Electrical Engineering</td>
<td>3</td>
<td>- - - - 3 - -</td>
</tr>
<tr>
<td>NA 340, Marine Dynamics I</td>
<td>4</td>
<td>- - - - 4 - -</td>
</tr>
<tr>
<td>NA 370 Conceptual Vessel/Platform Design</td>
<td>3</td>
<td>- - - - 3 - -</td>
</tr>
<tr>
<td>NA 461, Marine Structures Construction</td>
<td>3</td>
<td>- - - - - - 3</td>
</tr>
<tr>
<td>NA 470, Foundations of Ship Design</td>
<td>4</td>
<td>- - - - - - 4</td>
</tr>
<tr>
<td>NA 475, Marine Design Team Project</td>
<td>4</td>
<td>- - - - - - 4</td>
</tr>
<tr>
<td>NA 492, Marine Engineering Laboratory II</td>
<td>3</td>
<td>- - - - - - 3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electives (18 hours)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Electives3</td>
<td>7</td>
<td>- - - - - - - - 4 3</td>
</tr>
<tr>
<td>General Electives</td>
<td>10</td>
<td>- - - 2 4 2 1 1</td>
</tr>
</tbody>
</table>

| Total | 128 | 17 17 16 16 15 16 16 15 |

Candidates for the Bachelor of Science Degree in Engineering in Naval Architecture and Marine Engineering - B.S.E. in N.A.M.E. - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

**Notes:**

1. If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 125/126/130 you will have met the Chemistry Core Requirement for the College of Engineering.
2. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and Physics 240/241 you will have met the Physics Core Requirement for the College of Engineering.

3. Technical Electives - Choose 2 from the following lists. At least one must come from Group 1:

**Group 1**
- NA 410, Marine Structure II
- NA 423, Introduction to Numerical Hydrodynamics
- NA 431, Marine Engineering II
- NA 440, Marine Dynamics II

**Group 2**
- NA 401, Small Craft Design
- NA 403, Sailing Craft Design Principles
- NA 416, Theory of Plates and Shells
- NA 483 Marine Control Systems
- NA 525 Drag Reduction Techniques
- NA 562, Marine Systems Production Strategy Operations Management

Advanced Mathematics: Math 450, Math 454, or Math 471

Other courses as approved by the department.

---

**Nuclear Engineering and Radiological Sciences**

<table>
<thead>
<tr>
<th>Subjects required by all programs (55 hours)</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics 115, 116, 215, and 216</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engr 100, Intro to Engr</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Engr 101, Intro to Computers</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chemistry 125/126 and 130 or Chemistry 210 and 2111</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Physics 140 with Lab 141; Physics 240 with Lab 2412</td>
<td>10</td>
<td>-</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Related Technical Subjects (11 hours)**

| MATSCIE 250, Princ of Eng Materials or MSE 220, Intro to Materials and Manf | 4 | - | - | 4 | - | - | - | - |
| EECS 215, Intro to Circuits or EECS 314,Electrical Circuits, Systems, and Applications | 4 | - | - | - | 4 | - | - | - |
| MECHENG 235, Thermodynamics I             | 3 | - | - | - | 3 | - | - | - | - |

**Program Subjects (45 hours)**

| NERS 250, Fundamentals of Nuclear Eng and Rad Sci | 4 | - | - | 4 | - | - | - | - |
| NERS 311, Ele of Nuc Eng & Rad Sci I            | 3 | - | - | - | 3 | - | - | - |
| NERS 312, Ele of Nuc Eng & Rad Sci II           | 3 | - | - | - | - | 3 | - | - | - |
| NERS 315, Nuclear Instr Lab                    | 4 | - | - | - | - | 4 | - | - | - |
| NERS 320, Prob in nucl Engr & Rad Sci          | 4 | - | - | - | 4 | - | - | - | - |
| NERS 344, Fluid Mech Nucl Eng                  | 3 | - | - | - | - | 3 | - | - | - |
| NERS 441, Nuclear Reactor Theory I             | 4 | - | - | - | - | 4 | - | - | - |
| NERS 444, Therm-hyd Nucl Sys                  | 3 | - | - | - | - | 3 | - | - | - |
Candidates for the Bachelor of Science Degree in Engineering in Nuclear Engineering and Radiological Sciences - B.S.E. in N.E.R.S. - must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:
1. If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams or transfer credit from another institution for Chemistry 125/126/130 you will have met the Chemistry Core Requirement for the College of Engineering.
2. If you have a satisfactory score or grade in Physics AP, A-Level, IB Exams or transfer credit from another institution for Physics 140/141 and Physics 240/241 you will have met the Physics Core Requirement for the College of Engineering.
3. Laboratory Course, (above NERS 315) select one from the following: NERS 425, 535, 575, 586. (NERS 535 and 575 require program advisor's consent.)
4. One course must be selected from the following: NERS 421, NERS 471 and NERS 484. A maximum of 3 credit hours of independent study (NERS 499) can count as a NERS elective. All additional NERS 499 credits beyond those 3 can only be counted as a general elective.
5. Technical electives are defined as: 300-level and above Mathematics, Physics or non-NERS Engineering courses. Course content must be technical. All substitutions must be approved by the faculty advisor.

### Space Sciences and Engineering Sample Schedule

<table>
<thead>
<tr>
<th>Subject Required by all Programs (55 hours)</th>
<th>Credit Hours</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics (15, 16, 215, and 216)</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering 385 Introduction to Engineering</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering 391, Introduction to Computers</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemistry 125/126 and 140 or Chemistry 210 and 2111</td>
<td>5</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics 140 with Lab, Physics 240 with Lab 315</td>
<td>16</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intellectual Breadth</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required Core Subjects (50 hrs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 385, Earth and Space Systems Evolution</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 361, Earth and Space System Dynamics</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 322, Earth System Analysis</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 324, Instrumentation for Atmos &amp; Space Science</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 391, Space Visualization</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 423, Data Analysis and Visualization(Note 1)</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 476, Space Environment</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 485/585/685 (Note 2)</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>55</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentration: (select one)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Science (9 hrs total)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYSICS 245 Quantum Mechanics</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYSICS 291, Introduction to Radiation</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYSICS 325, Interfacial Electrode Theory and Electrons (Note 4)</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYSICS 391, Nuclear Physics (Note 6)</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYSICS 390, Lab</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NERS 411, Introduction to Climate</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NERS 469/569/669 Marine/Space (Note 2) or SPACE 384</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical Electives (11 hours)</td>
<td>11</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Electives (3/4 credit)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>136</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Instrumentation (21/30) (Note 3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering/Breadth (programming or EECS 215/150 Intro to Electronic Circuits) (Note 2)</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 311 Small Satellite Design</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 311/312 Marine Engineering (Note 1)  SPACE 315 Radiation/Propagation (Note 6)</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensors/Remote Sensing/Space/Measurements (Note 6)</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 411, Space Sciences Instrumentation (Note 3)</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 411, Space Science Modeling</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical Electives (10/11 hours)</td>
<td></td>
<td>4</td>
<td>5</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Electives (3/4 credit)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>153</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Revised: 19-Sep**

1. Students should take one of these courses (each offered every other year).
2. New Course: Students may take either year-long (2 CR each term) SPACE 499 Directed Study as a Senior Thesis option or SPACE 455 Senior Capstone Design.
3. Recommended students minor in another Engineering Discipline. If not, an Intro CS, ME, EECS, MATSCI course. Call NCES describing minors: https://bulletin.engin.umich.edu/ugcommunications/minors/
4. Students need to request waiver to Physics 351 for 455 or take 351 as a Tech Elective.
5. The instrumentation course is also useful for our PhD students to learn about techniques and is a "theory" course.
6. GEOS 501 for Coaster Marine/Space (3 CR) and GEOS 410 Introduction to Probability and Statistics (3 CR) or AGRO 305 Aero Engineering Lab (1 CR). If AGRO 305 is taken reduce unrestricted Elective from 12 to 11 credits. Have discussed AGRO 305 option with instructor.
7. SPACE 371 and 401 are every other year courses. If 401 is taken, reduce restricted Elective requirement from 11 to 10 credits.

Candidate for the Bachelor of Science in Engineering in Space Sciences and Engineering must complete the program listed above. This sample schedule is an example of one leading to graduation in eight terms.

Notes:
1. Students should take one of these courses (each offered every other year).
2. New Course: Students may take either year-long (2 CR each term) SPACE 499 Directed Study as a Senior Thesis option or SPACE 455 Senior Capstone Design.
3. Recommended students minor in another Engineering Discipline. If not, an Intro CS, ME, EECS, MATSCI course. Call NCES describing minors: https://bulletin.engin.umich.edu/ugcommunications/minors/
4. Students need to request waiver to Physics 351 for 455 or take 351 as a Tech Elective.
5. The instrumentation course is also useful for our PhD students to learn about techniques and is a "theory" course.
6. GEOS 501 for Coaster Marine/Space (3 CR) and GEOS 410 Introduction to Probability and Statistics (3 CR) or AGRO 305 Aero Engineering Lab (1 CR). If AGRO 305 is taken reduce unrestricted Elective from 12 to 11 credits. Have discussed AGRO 305 option with instructor.
7. SPACE 371 and 401 are every other year courses. If 401 is taken, reduce restricted Elective requirement from 11 to 10 credits.
Aerospace Engineering
Undergraduate Sample Schedule
B.S.E. in Aerospace Engineering

The Aerospace Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. Please see the PDF version of the sample schedule. Additional information can be found on the department advising website, https://aero.engin.umich.edu/academics/undergrad/.

Focus of Study
The Aerospace Engineering department offers a variety of areas of focus for students to consider. Specific information about the requirements can be found on the department advising website.

- Propulsion, Aerodynamics and Combustion
  - Air-Breathing Propulsion and Combustion Science
  - Space Propulsion
  - Aerodynamics and Turbulence
  - Computational Fluid Dynamics of Transonic and Hypersonic Vehicles
- Structural Mechanics
  - Advanced Materials for Airframe Applications
  - Adaptive Materials and Constitutive Modeling for Aerospace Structures
  - Modeling for Airframe Applications
  - Aeroelasticity, Structural Dynamics, Optimal Design of Structures
- Flight Dynamics and Control
  - Dynamics and Control of Aircraft
  - Dynamics and Control of Spacecraft
  - Astrodynamics
- Aerospace Software
  - Computer Science Fundamentals
  - Computational Science for Aerospace Analysis and Design
  - Embedded Systems
- Aerospace Vehicles

Mission Statement
Mission
To provide internationally recognized leadership in aerospace engineering education, through a continuously improving educational program that graduates students with strong engineering science fundamentals while incorporating applied engineering aspects.
Goals

- Educate students who are widely known for exceptional strength in technical fundamentals across all aerospace disciplines, who are cognizant of modern aerospace technologies and who are sought after by top graduate schools and by aerospace and related industries worldwide.
- Support vibrant and highly recognized research programs that serve the educational goals of the undergraduate and graduate degree programs, that make major contributions to the knowledge base in aerospace sciences and technology and that are turned to by industry and government for solutions.
- Create a diverse, equitable and inclusive environment that is supportive, intellectually challenging and conducive to higher learning.
- Take full advantage of knowledge, technology, facilities and resources at the University of Michigan.

Objectives

The Undergraduate Program Educational Objectives are that, within 3-5 years after graduation:

- Alumni of the program will use their breadth and depth of knowledge and skills in the fundamental disciplines of aerospace engineering to pursue successful professional careers
- Alumni will feel that they received outstanding preparation for the next step in their careers, whether it be graduate school or work in industry, government or academia
- Alumni of the program will be emerging leaders in engineering, science, academia, business and public service
- Alumni of the program will be productive citizens with high professional and ethical standards.

The above program educational objectives are accomplished by a rigorous curriculum that emphasizes fundamentals in basic sciences, mathematics and the humanities and integrates classroom and laboratory experiences in the fundamental disciplines of Aerospace Engineering.

More specifically our curricular goals are to:

- Educate students in the following fundamental disciplines of Aerospace Engineering: aerodynamics, materials, structures, propulsion, flight mechanics, orbital mechanics, software, and dynamics and control
- Educate students in the methodology and tools of design and the synthesis of fundamental aerospace disciplines necessary to carry out the design of an aerospace vehicle or system
- Educate students in the basics of instrumentation and measurement, laboratory techniques, and how to design and conduct experiments
- Develop students’ ability to function on multi-disciplinary teams and provide them with teamwork experiences throughout their curriculum
- Develop students’ ability to communicate effectively
- Expose students to environmental, ethical and contemporary issues in Aerospace Engineering
- Expose students to other disciplines of engineering beyond the aerospace field.
Outcomes

Program Student Outcomes are that U-M Aerospace Engineering graduates demonstrate:

- An ability to apply knowledge of mathematics, science and engineering;
- An ability to design and conduct experiments as well as to analyze and interpret data;
- An ability to design a system, component or process to meet desired needs;
- An ability to function on multi-disciplinary teams;
- An ability to identify, formulate and solve engineering problems;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively;
- The broad education necessary to understand the impact of engineering solutions in a global and societal context;
- A recognition of the need for, and an ability to engage in life-long learning;
- A knowledge of contemporary issues;
- An ability to use the techniques, skills and modern engineering tools necessary for engineering practice;
- A knowledge of aerodynamics, aerospace materials, structures, propulsion, flight mechanics, orbital mechanics, software, and stability and control; and
- Competence in the integration of aerospace science and engineering topics and their application in aerospace vehicle design.

Enrollment and Graduation Data

In Winter 2021, 389 students enrolled in the program. In 2020, 137 degrees were awarded. For other terms, the University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

Contacts

Departmental Website: https://aero.engin.umich.edu/

Aerospace Engineering Department
3000 Francois-Xavier Bagnoud Building (FXB)
1320 Beal Ave
Ann Arbor, MI 48109-2140
Phone: (734) 764-3310

Graduate

Graduate Degrees

- Master of Science in Engineering (M.S.E.) in Aerospace Engineering
- Master of Engineering (M.Eng.) in Space Engineering
M.S.E. in Aerospace Engineering

This degree is designed for students who desire a curriculum focused on the scientific aspects of Aerospace Engineering. A total of 30 credit hours is required including 500-level classes in Aerospace Engineering, and approved courses in mathematics. Students are encouraged to take advantage of directed study and become involved in research as part of their M.S.E. experience. The M.S.E. program does not include an option for a thesis per se; however, through AEROSP 590, students can perform research work in close supervision of a faculty member and investigate a problem of common interest.

Admission requirements include a strong performance in an undergraduate program in engineering or science, and competitive Graduate Record Exam (GRE) scores. Learn more about the Academic Background of Applicants.

Details of the M.S.E. degree requirements may be found at: https://aero.engin.umich.edu/academics/graduate/mse/

M.Eng in Space Engineering

The M.Eng. in Space Engineering degree provides a comprehensive set of courses and training in space-related science and engineering, and the systems approach to design and management of complex space systems. It develops both the theoretical and applied aspects of space engineering. The M.Eng. in Space Engineering is a professional program managed by the Climate and Space Sciences and Engineering (CLaSP) department.

Details of the M.Eng. degree requirements may be found at: http://clasp.engin.umich.edu/academics/graduate/meng

Doctor of Philosophy (Ph.D.) in Aerospace Engineering

The Ph.D. degree requires a strong academic foundation and an ability to carry out independent research. Students must complete:

1. Coursework & Training
2. Preliminary Examinations

Research and the Dissertation

1. Coursework & Training

A student must take five core doctoral courses selected by the student and approved by the student’s research advisor. In addition, a student must take graduate coursework outside the student’s field of study, but related or connected with an aspect of their field.

A student must complete training for the College of Engineering’s Responsible Conduct of Research and Scholarship (RCRS) program. Training consists of four workshops which engage students to be
able to recognize, address, and resolve ethical issues in classroom, professional and research settings.

2. Preliminary Examination

The preliminary examinations are oral examinations covering material taught in the five selected core courses administered by the preliminary examination committee. This examination is offered twice a year. A student must pass the prelimination examination.

3. Research and the Dissertation

The student must initiate research activity with their advisor in the first year of graduate study. To demonstrate their ability to pursue and solve an original research problem the student must present the research results in a written dissertation and defend the dissertation at a final oral defense. The research is done under the supervision of a faculty advisor in the Aerospace Engineering department and a dissertation committee.

The Ph.D. degree is awarded upon successful completion of a Ph.D. dissertation, a Ph.D. defense, and other academic credit requirements.

Details of the Ph.D. degree requirements may be found at: https://aero.engin.umich.edu/academics/graduate/phd

Overview

Aerospace technology has grown out of the problems of design, construction and operation of vehicles that move above the Earth’s surface; vehicles ranging from airplanes and helicopters to rockets and spacecraft. Design of such vehicles has always been challenging, not only because of the high premium placed on lightweight vehicles performing efficiently and with high reliability, but also because they must sometimes operate in hostile environments. These same requirements exist not only for future spacecraft and high-performance transport aircraft, but also for the next generation of ground transportation, such as high-speed trains, over-water transportation and automated motor vehicles. In addition to working on vehicle-oriented design problems, aerospace engineering graduates are often involved in systems management in the broadest sense. Because of the anticipated life mission of the aerospace student, the undergraduate curriculum at the University of Michigan is designed to convey a clear understanding of the fundamental aspects of the fields most pertinent to aerospace engineering. Real-life problems in aerospace and related areas are emphasized in the applications of theory. In their senior year, students select a design course in which they are given an appreciation of the interrelation of the various areas of study in the design of a whole system.
Department Administration

Department Chair
Anthony Waas, Felix Pawlowski Collegiate Professor of Aerospace Engineering, 3064 FXB.

For more specific information on contacting people, go to our Contacts page.

Mission

To provide internationally recognized leadership in aerospace engineering education, through a continuously improving educational program that graduates students with strong engineering science fundamentals while incorporating applied engineering aspects.

Goals

- Educate students who are widely known for exceptional strength in technical fundamentals across all aerospace disciplines, who are cognizant of modern aerospace technologies and who are sought after by top graduate schools and by aerospace and related industries worldwide.
- Support vibrant and highly recognized research programs that serve the educational goals of the undergraduate and graduate degree programs, that make major contributions to the knowledge base in aerospace sciences and technology and that are turned to by industry and government for solutions.
- Create a diverse, equitable and inclusive environment that is supportive, intellectually challenging and conducive to higher learning.
- Take full advantage of knowledge, technology, facilities and resources at the University of Michigan.

Objectives

The Undergraduate Program Educational Objectives are that, within 3-5 years after graduation:

- Alumni of the program will use their breadth and depth of knowledge and skills in the fundamental disciplines of aerospace engineering to pursue successful professional careers
- Alumni will feel that they received outstanding preparation for the next step in their careers, whether it be graduate school or work in industry, government or academia
- Alumni of the program will be emerging leaders in engineering, science, academia, business and public service
- Alumni of the program will be productive citizens with high professional and ethical standards.

The above program educational objectives are accomplished by a rigorous curriculum that emphasizes fundamentals in basic sciences, mathematics and the humanities and
integrates classroom and laboratory experiences in the fundamental disciplines of Aerospace Engineering. More specifically our curricular goals are to:

- Educate students in the following fundamental disciplines of Aerospace Engineering: aerodynamics, materials, structures, propulsion, flight mechanics, orbital mechanics, software, and dynamics and control
- Educate students in the methodology and tools of design and the synthesis of fundamental aerospace disciplines necessary to carry out the design of an aerospace vehicle or system
- Educate students in the basics of instrumentation and measurement, laboratory techniques, and how to design and conduct experiments
- Develop students’ ability to function on multi-disciplinary teams and provide them with teamwork experiences throughout their curriculum
- Develop students ability to communicate effectively
- Expose students to environmental, ethical and contemporary issues in Aerospace Engineering
- Expose students to other disciplines of engineering beyond the aerospace field.

Outcomes

Program Student Outcomes are that U-M Aerospace Engineering graduates demonstrate:

- An ability to apply knowledge of mathematics, science and engineering;
- An ability to design and conduct experiments as well as to analyze and interpret data;
- An ability to design a system, component or process to meet desired needs;
- An ability to function on multi-disciplinary teams;
- An ability to identify, formulate and solve engineering problems;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively;
- The broad education necessary to understand the impact of engineering solutions in a global and societal context;
- A recognition of the need for, and an ability to engage in life-long learning;
- A knowledge of contemporary issues;
- An ability to use the techniques, skills and modern engineering tools necessary for engineering practice;
- A knowledge of aerodynamics, aerospace materials, structures, propulsion, flight mechanics, orbital mechanics, software, and stability and control; and
- Competence in the integration of aerospace science and engineering topics and their application in aerospace vehicle design.

Enrollment and Graduation Data

In Winter 2021, 389 students enrolled in the program. In 2020, 137 degrees were awarded. For other terms, the University Registrar publishes the number of students.
enrolled annually in this program, and the number of degrees granted each term by this program.
Undergraduate Degree Program

The degree program gives the student a broad education in engineering by requiring basic courses in aerodynamics and propulsion (collectively referred to as “gas dynamics”), structural mechanics, flight dynamics and control systems, and aerospace software. These courses cover fundamentals and their application to the analysis, design and construction of aircraft, spacecraft and other vehicular systems and subsystems. Courses in gas dynamics treat fluid and gas flow around bodies and through turbojet engines and rocket nozzles. In courses on structural mechanics, lightweight structures are studied from their strength, elastic, stiffness, stability and dynamic behavior. Flight dynamics and control systems courses deal with the dynamical behavior of vehicles and systems as a whole, their stability and controllability both by human pilots and as autonomous systems. Aerospace software deals with fundamentals of computer science, development and use of software for simulating aerospace analysis, and embedded sensors and software systems. Integration of all these subjects takes place in the capstone aircraft design course or space system design course that is chosen by students. The aerospace engineering program offers considerable flexibility through technical and general electives, in which students have an opportunity to study in greater depth any of the areas mentioned above. In addition, other technical elective areas are available to aerospace engineering students, including aerophysical sciences, environmental studies, computers, person-machine systems and transportation. Elective courses in each technical elective area include courses taught both inside and outside the aerospace engineering department.

Sample Schedule

B.S.E. in Aerospace Engineering

The Aerospace Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. Please see the PDF version of the sample schedule. Additional information can be found on the department advising website, https://aero.engin.umich.edu/academics/undergrad/

Focus of Study

The Aerospace Engineering department offers a variety of areas of focus for students to consider. Specific information about the requirements can be found on the department advising website.

- Propulsion, Aerodynamics and Combustion
  - Air-Breathing Propulsion and Combustion Science
  - Space Propulsion
  - Aerodynamics and Turbulence
  - Computational Fluid Dynamics of Transonic and Hypersonic Vehicles
- Structural Mechanics
• Advanced Materials for Airframe Applications
• Adaptive Materials and Constitutive Modeling for Aerospace Structures
• Modeling for Airframe Applications
• Aeroelasticity, Structural Dynamics, Optimal Design of Structures
• Flight Dynamics and Control
  • Dynamics and Control of Aircraft
  • Dynamics and Control of Spacecraft
  • Astrodynamics
• Aerospace Software
  • Computer Science Fundamentals
  • Computational Science for Aerospace Analysis and Design
  • Embedded Systems
• Aerospace Vehicles

Sequential Undergraduate/Graduate Study (SUGS)

The five-year Sequential Undergraduate/Graduate Study (SUGS) Program permits students to receive the B.S.E. and M.S.E. degrees (or the B.S.E. and M.Eng. degrees) upon completion of a minimum of 149 credit hours: up to 9 credit hours can be double-counted between the undergraduate and Master’s degrees. Eligible students typically apply to the Aerospace Engineering SUGS program in their senior year and are required to have a minimum graduating GPA of 3.5. Students should speak with the Aerospace Engineering Graduate Student Coordinator, at the start of their senior year to learn more about the SUGS application process and procedures.

Details of the SUGS program may be found at: Aerospace Engineering Sequential Undergraduate/ Graduate Studies Program.

Available programs include:

• S.E. in Aerospace Engineering/M.S.E. in Aerospace Engineering
• S.E. in Aerospace Engineering/M.Eng. in Space Engineering

Graduate

Graduate Degrees

• Master of Science in Engineering (M.S.E.) in Aerospace Engineering
• Master of Engineering (M.Eng.) in Space Engineering
• Doctor of Philosophy (Ph.D.) in Aerospace Engineering

M.S.E. in Aerospace Engineering

This degree is designed for students who desire a curriculum focused on the scientific aspects of Aerospace Engineering. A total of 30 credit hours is required including 500-
level classes in Aerospace Engineering, and approved courses in mathematics. Students are encouraged to take advantage of directed study and become involved in research as part of their M.S.E. experience. The M.S.E. program does not include an option for a thesis per se; however, through AEROSP 590, students can perform research work in close supervision of a faculty member and investigate a problem of common interest.

Admission requirements include a strong performance in an undergraduate program in engineering or science, and competitive Graduate Record Exam (GRE) scores. Learn more about the Academic Background of Applicants.

Details of the M.S.E. degree requirements may be found at: https://aero.engin.umich.edu/academics/graduate/mse/

**M.Eng in Space Engineering**

The M.Eng. in Space Engineering degree provides a comprehensive set of courses and training in space-related science and engineering, and the systems approach to design and management of complex space systems. It develops both the theoretical and applied aspects of space engineering. The M.Eng. in Space Engineering is a professional program managed by the Climate and Space Sciences and Engineering (CLaSP) department.

Details of the M.Eng. degree requirements may be found at: http://clasp.engin.umich.edu/academics/graduate/meng

**Doctor of Philosophy (Ph.D.) in Aerospace Engineering**

The Ph.D. degree requires a strong academic foundation and an ability to carry out independent research. Students must complete:

1. Coursework & Training
2. Preliminary Examinations

**Research and the Dissertation**

1. **Coursework & Training**

A student must take five core doctoral courses selected by the student and approved by the student’s research advisor. In addition, a student must take graduate coursework outside the student’s field of study, but related or connected with an aspect of their field.

A student must complete training for the College of Engineering’s Responsible Conduct of Research and Scholarship (RCRS) program. Training consists of four workshops which engage students to be able to recognize, address, and resolve ethical issues in classroom, professional and research settings.

2. **Preliminary Examination**
The preliminary examinations are oral examinations covering material taught in the five selected core courses administered by the preliminary examination committee. This examination is offered twice a year. A student must pass the prelimination examination.

3. Research and the Dissertation

The student must initiate research activity with his/her advisor in the first year of graduate study.

To demonstrate his/her ability to pursue and solve an original research problem the student must present the research results in a written dissertation and defend the dissertation at a final oral defense. The research is done under the supervision of a faculty advisor in the Aerospace Engineering department and a dissertation committee.

The Ph.D. degree is awarded upon successful completion of a Ph.D. dissertation, a Ph.D. defense, and other academic credit requirements.

Details of the Ph.D. degree requirements may be found at: https://aero.engin.umich.edu/academics/graduate/phd

Contacts

Departmental Website: https://aero.engin.umich.edu/

Aerospace Engineering Department
3000 Francois-Xavier Bagnoud Building (FXB)
1320 Beal Ave
Ann Arbor, MI 48109-2140
Phone: (734) 764-3310

Aerospace Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under “How to Read a Course Description”, in the CoE Bulletin

Website: https://bulletin.engin.umich.edu/courses/course-info/

200 Level Courses

AEROSP 200. Introduction to the Aerospace Enterprise
Prerequisite: None (2 credits)
An introduction to leadership, culture, and wide variety of technical fields that are part of the design, construction, and operations of Aeronautical and Astronautical vehicles. The course includes numerous seminars by notable practitioners. CourseProfile (ATLAS)

AEROSP 201. Introduction to Aerospace Engineering
Prerequisite: ENGR 100 (or equivalent) and 101 or 151 and PHYSICS 140 and 141 and MATH 116 or equivalent. Minimum grade of a “C-” for enforced prerequisites. (2 credits)
Introduction to Aerospace Engineering. Flight vehicles in the atmosphere and in space. Flight technologies, including structures, materials, propulsion, aerodynamics, vehicle dynamics, flight
control, flight information systems and systems integration. An overview of aeronautics. Steady aircraft flight and performance. An overview of astronautics. CourseProfile (ATLAS)

AEROSP 205. Introduction to Aerospace Engineering Systems
Prerequisites: PHYS 140, 141, MATH 116, ENGR 100, ENGR 101 or 151. (3 credits)
A Systems Engineering Experience: Introduces engineering processes by means of design, build, test and operation of flight vehicles. Exposure to technologies including: computer aided design, manufacturing, simulation, composites, mechanisms, instrumentation and basic electronics. Embedded software development for data acquisition and processing, control and communications. Individual and team projects. CourseProfile (ATLAS)

AEROSP 215. Introduction to Solid Mechanics and Aerospace Structures
Advisory Prerequisite: Preceded or accompanied by MATH 216 and AEROSP 201. (3 credits)
An introduction to the fundamental phenomena of solid and structural mechanics in Aerospace systems. Includes analysis and numerical methods of solutions used for design of thin-walled Aerospace structures. Emphasis is placed on understanding behavior particular to thin-walled structures. CourseProfile (ATLAS)

AEROSP 225. Introduction to Gas Dynamics
Prerequisite: (MATH 215 or 255 or 285) and (CHEM 125 and130) and (PHYSICS 140 or 160) and PHYSICS 141. Minimum grade of a “C-” for enforced prerequisites. (3 credits)
This course covers fundamental concepts in thermodynamics and fluid dynamics. Topics include molecular and continuum concepts for fluids, first and second laws of thermodynamics, conservation laws for moving fluids, one-dimensional compressible flows, shocks and expansion waves, flows in nozzles, and two- and three-dimensional compressible flows. CourseProfile (ATLAS)

AEROSP 290. Directed Study
Prerequisite: permission of instructor (1-3 credits)
Study aspects of aerospace engineering that are not suitable for technical elective credit. May be used for student team projects, pilot ground school, UROP or other academic studies that are directed by an Aerospace Engineering faculty member. CourseProfile (ATLAS)

300 Level Courses

AEROSP 305. Aerospace Engineering Laboratory I
Advisory Prerequisite: Preceded by AEROSP 205, AEROSP 215, AEROSP 225, and PHYSICS 240 or PHYSICS 260. (4 credits)
First course of a two-semester sequence covering fundamentals of instrumentation and measurement and their application in engineering testing and experimentation. Includes principles of analog and digital data acquisition, analysis of discrete measurement data, statistical assessment of hypotheses, design of experiments and similarity scaling of data. Emphasized development of skills for written communication and for working effectively in a team environment. CourseProfile (ATLAS)

AEROSP 315. Aircraft and Spacecraft Structures
Advisory Prerequisite: AEROSP 215 and MATH 216. (3 credits)
An introduction to the fundamental phenomena of solid and structural mechanics in aerospace systems. Includes analysis and numerical methods of solution that are used for design of aerospace structures. CourseProfile (ATLAS)

AEROSP 325. Aerodynamics
Advisory Prerequisite: preceded by MATH 216 and AEROSP 225. (3 credits)
Fundamental concepts in aerodynamics. Students learn how airfoils produce lift and how the pressure distribution about an airfoil can be calculated. Introduces the boundary-layer concept, how
boundary layers lead to drag and what makes them prone to instability and turbulence or separation.  

AEROSP 335. Aircraft and Spacecraft Propulsion  
Advisory Prerequisite: preceded by AEROSP 225 and MATH 216. (3 credits)  
Airbreathing propulsion, rocket propulsion and an introduction to modern advanced propulsion concepts. Includes thermodynamic cycles as related to propulsion and the chemistry and thermodynamics of combustion. Students analyze turbojets, turbofans and other air-breathing propulsion systems. Introduces liquid- and solid-propellant rockets and advanced propulsion concepts such as Hall thrusters and pulsed plasma thrusters. Students also learn about the environmental impact of propulsion systems and work in teams to design a jet engine.  

AEROSP 341. Aircraft Dynamics  
Prerequisite: MECHENG 240, MATH 216 and AEROSP 201. Minimum grade of a “C-” for enforced prerequisites. (3 credits)  

AEROSP 343. Spacecraft Dynamics  
Prerequisite: MECHENG 240, MATH 216 and AEROSP 201. Minimum grade of a “C-” for enforced prerequisites. (3 credits)  

AEROSP 350. Fundamentals of Aerospace Computing  
Advisory Prerequisite: Math 216 and ENG 101. (3 credits)  
Fundamentals of computer science, computational science, and embedded systems, with applications from aerospace engineering. Topics include: pointers; data structures; algorithms; computational complexity; signal decomposition; numerical linear algebra; numerical integration; and modeling, design, analysis and verification of sensors, actuators, and embedded processors.  

AEROSP 384. Introduction to Solid Modeling and CAD  
Prerequisite: preceded or accompanied by AEROSP 201 and AEROSP 215. (3 credits)  
Design process including specifications, configurations, trades and design drivers. Introduction to solid visualization and modeling through an integrated CAD/CAE/CAM/PDM software package in the context of the design process. The role of CAD in analysis, manufacturing and product management. Flight vehicle related projects.  

AEROSP 390. Directed Study  
Prerequisite: permission of instructor (1-3 credits)  
Study specialized aspects of aerospace engineering. May be used for student team projects, pilot certification or other academic studies that are directed by an Aerospace Engineering faculty member. The student will submit a final report.
400 Level Courses

AEROSP 405. Aerospace Laboratory II
Prerequisite: preceded by AEROSP 305. Preceded or accompanied by AEROSP 315 and AEROSP 325. (4 credits)
Second course of a two-semester sequence covering fundamentals of instrumentation and measurement and their application in engineering testing and experimentation. Focuses primarily on application of the fundamental principles learned in Aero 305 to more advanced test and measurement applications. Involves instructor-designed experiments and one major project conceived, designed, conducted, analyzed and reported by student teams. Emphasizes development of skills for written communication and for working effectively in a team environment. CourseProfile (ATLAS)

AEROSP 416 (NAVARCH 416). Theory of Plates and Shells
Prerequisite: AEROSP 315. (3 credits)

AEROSP 421. Engineering Aerodynamics
Prerequisite: AEROSP 325. (3 credits)
This course teaches contemporary aerodynamic analysis and design of aerospace vehicles and other systems. Topics include: review of theoretical concepts and methods, computer-based CFD tools, experimental methods and wind tunnel testing. Case studies are discussed to illustrate the combined use of advanced aerodynamic design methods. A team project is required. CourseProfile (ATLAS)

AEROSP 423. Computational Methods for Aerospace Engineering
Prerequisite: ENGR 101 or ENGR 151, MATH 216, and AEROSP 350 w/ minimum grade of C-. (3 credits)
This course covers computational methods used in Aerospace engineering, including time integration techniques for ordinary differential equations, finite differences, finite volumes, finite elements, and probabilistic methods. Emphasis is placed on analysis and implementation of the underlying numerical methods. Computer programming in Matlab or a similar language is required. CourseProfile (ATLAS)

AEROSP 445. Flight Dynamics of Aerospace Vehicles
Prerequisite: AEROSP 470 (Advisory). (3 credits)
Flight-oriented models of aerospace vehicles. Analytical modeling principles for analysis and control. Computer-based simulation, performance evaluation and model validation. Flight properties of various aerospace vehicles, such as fixed-wing aircraft, rotorcraft, launch and reentry vehicles, orbiters and interplanetary vehicles. CourseProfile (ATLAS)

AEROSP 447. Flight Testing
Prerequisite: AEROSP 305 and AEROSP 341 (Advisory). (3 credits)
Theory and practice of obtaining flight-test data on performance and stability of airplanes from actual flight tests. Modern electronic flight test instrumentation, collection of flight test data, calibration procedures for air data sensors, estimation of stability derivatives from flight test data. CourseProfile (ATLAS)
AEROSP 450. Flight Software Systems  
Prerequisite: ENGR 101 and AEROSP 201, or graduate standing. (3 credits)  
Theory and practice of embedded flight software systems. Computational theory topics include  
discrete mathematics, finite automata, computational complexity and model checking. Software  
development concepts include object oriented programming, networks, multi-threaded software,  
real-time scheduling and sensor/actuator interface protocols. Emphasis placed on C/C++  
development in Linux with guidance, navigational control applications.  
CourseProfile (ATLAS)

AEROSP 470. Control of Aerospace Vehicles  
Advisory Prerequisite: AEROSP 341 or AEROSP 343. (3 credits)  
Foundations of classical control theory; introduction to observers and state space control theory;  
effect of nonlinearities; application to aircraft and spacecraft; simulation of control systems using  
relevant software.  
CourseProfile (ATLAS)

AEROSP 481. Aircraft Design  
Prerequisite: Preceded by AEROSP 325. Preceded or accompanied by AEROSP 315, AEROSP 335  
and AEROSP 348 (Advisory). (4 credits)  
Multidisciplinary integration of aerodynamics, performance, stability and control, propulsion,  
structures and aeroelasticity in a systems approach aimed at designing an aircraft for a set of  
specifications. Includes weight estimates, configuration and power plant selection, tail-sizing,  
maneuver and gust diagrams, wing loading, structural and aeroelastic analysis. Students work in  
teams on the design project.  
CourseProfile (ATLAS)

AEROSP 483. Space System Design  
Prerequisite: preceded by AEROSP 343. Preceded or accompanied by AEROSP 315, 325, and 335  
(Advisory). (4 credits)  
Introduction to the engineering design process for space systems. Includes a lecture phase that  
covers mission planning, launch vehicle integration, propulsion, power systems, communications,  
budgeting and reliability. Subsequently, students experience the latest practices in space-systems  
engineering by forming into mission-component teams and collectively designing a space mission.  
Effective team and communication skills are emphasized. Report writing and presentations are  
required throughout, culminating in the final report and public presentation.  
CourseProfile (ATLAS)

AEROSP 484. Computer Aided Design  
Prerequisite: preceded by AEROSP 315, AEROSP 325, AEROSP 335, and AEROSP 341 or 343  
(Advisory). (4 credits)  
Advanced computer-aided design. Students learn about computer generation of geometric models,  
calculation of design parameters, trade-off diagrams and finite-element modeling and analysis. Each  
student carries out a structural component design using industry-standard software. The course  
includes individual and team assignments.  
CourseProfile (ATLAS)

AEROSP 490. Directed Study  
Prerequisite: permission of instructor (1-3 credits)  
Study of advanced aspects of aerospace engineering directed by an Aerospace faculty member.  
The student will submit a final report.  
CourseProfile (ATLAS)

AEROSP 495. Special Topics in Aerospace Engineering  
Prerequisite: permission of instructor. (1-4 credits)  
Specific aerospace engineering topics that are not treated in the regular Aerospace Engineering  
undergraduate curriculum.  
CourseProfile (ATLAS)
500 Level Courses

AEROSP 500. Aerospace Enterprise Leadership  
(1.5 credits)  
Leadership an business skills essential to leading and managing large technical teams and operations, with a focus on the Aerospace Enterprise. Numerous seminars and invited speakers include senior leaders and notable practitioners from industry, government, and academia. CourseProfile (ATLAS)

AEROSP 510. Finite Elements in Mechanical and Structural Analysis I  
Prerequisite: AEROSP 315. (3 credits)  

AEROSP 511. Finite Elements in Mechanical and Structural Analysis II  
Prerequisite: AEROSP 510 or MECHENG 505. (3 credits)  
Introduction to fundamental principles and latest developments in aerosol science. The dependence of aerosol composition and size distributions on the underlying atmospheric thermodynamics, dynamics, chemistry, and physics will be presented. Recent observations and theoretical treatments are used to illustrate aspects of aerosol science that are poorly quantified at present. CourseProfile (ATLAS)

AEROSP 512. Experimental Solid Mechanics  
Prerequisite: AEROSP 305, AEROSP 315 or equivalents. (3 credits)  
Lectures and experiments that demonstrate historical and contemporary methods of measurement in solid mechanics. A review of classical experiments that substantiate many typical assumptions (e.g., material linearity or Hooke’s Law) concerning the response of solids. An introduction to contemporary techniques of process measurement involving piezoresistivity. CourseProfile (ATLAS)

AEROSP 513. Foundations of Solid and Structural Mechanics I  
Prerequisite: AEROSP 315, MECHENG 311 or equivalent. (3 credits)  
Introduction to linear continuum and structural mechanics. Three-dimensional analysis of stress and infinitesimal strain, including transformation of tensors, equations of motion, and kinematic compatibility. Boundary value problem formation. Constitutive relations for isotropic and anisotropic linear elastic materials. Introduction to variational calculus and energy methods. Applications to thin-walled and slender aerospace structures. CourseProfile (ATLAS)

AEROSP 514. Foundations of Solid and Structural Mechanics II  
Prerequisite: AEROSP 315 or equivalent. (3 credits)  
Introduction to nonlinear continuum and structural mechanics. Elements of tensor calculus, basic kinematics, conservation laws (mass, linear and angular momentum, energy, etc.), constitutive equations in continual applications in hyperelastic solids, numerical (f.e.m.) methods for the corresponding nonlinear boundary value problems, derivation of nonlinear shell theories from 3-D considerations. CourseProfile (ATLAS)

AEROSP 515. Mechanics of Composite and Microstructured Media  
Prerequisite: AEROSP 514 or equivalent. (3 credits)  
An introduction to the mechanics of composite (more than one phase) solids with an emphasis on the derivation of macroscopical constitutive laws based on the microstructure. Eshelby transformation theory, self consistent methods, homogenization theory for periodic media, bounding properties for effective moduli of composites. Applications of aerospace interest. CourseProfile (ATLAS)
AEROSP 516. Mechanics of Fibrous Composites
*Prerequisite: AEROSP 315 or MECHENG 412. (3 credits)*

AEROSP 518. Theory of Elastic Stability I
*Prerequisite: AEROSP 315 or MECHENG 412 or the equivalent. (3 credits)*
Concepts of stability and bifurcation. Simple examples to illustrate buckling and instability mechanisms in structures. Both equilibrium and time dependent problems discussed. General theory for stability in continuum, conservative elastic solids. Applications to bars, rings, plates and shells. [CourseProfile (ATLAS)]

AEROSP 520. Compressible Flow I
*Prerequisite: AEROSP 325. (3 credits)*
Elements of inviscid compressible-flow theory: review of thermodynamics; equations of frictionless flow; analysis of unsteady one-dimensional and steady supersonic two-dimensional flows; including the method of characteristics; small-disturbance theory with applications to supersonic thin-airfoil theory. [CourseProfile (ATLAS)]

AEROSP 521. Experimental Methods in Fluid Mechanics
*Prerequisite: AEROSP 405 or Grad standing. (3 credits)*
Fundamentals principles and practice of non-intrusive measurement techniques for compressible and incompressible flows. REVIEW of geometric and Gaussian beam optics; Laser Doppler Velocimetry; quantitative flow field measurement techniques including interferometry, Laser Induced Fluorescence and Particle Image Velocimetry. Advanced data processing techniques for turbulent flow. Error estimation. [CourseProfile (ATLAS)]

AEROSP 522. Viscous Flow
*Prerequisite: AEROSP 325. (3 credits)*
The Navier-Stokes equations, including elementary discussion of tensors, exact solutions. Laminar boundary-layer theory; three-dimensional and compressible boundary layers. Laminar-flow instability theory; transition. Introduction to the mechanics of turbulence; turbulent free shear flows and boundary layers. [CourseProfile (ATLAS)]

AEROSP 523 (MECHENG 523). Computational Fluid Dynamics I
*Prerequisite: AEROSP 325 or preceded or accompanied by MECHENG 520. (3 credits)*
Physical and mathematical foundations of computational fluid mechanics with emphasis on applications. Solution methods for model equations and the Euler and the Navier-Stokes equations. The finite volume formulation of the equations. Classification of partial differential equations and solution techniques. Truncation errors, stability, conservation, and monotonicity. [CourseProfile (ATLAS)]

AEROSP 524. Aerodynamics II
*Prerequisite: AEROSP 325. (3 credits)*
Two- and three-dimensional potential flow about wings and bodies; complex-variable methods; singularity distributions; numerical solution using panel methods. Unsteady aerodynamics; slender-body theory. Viscous effects: airfoil stall, high-lift systems, boundary-layer control. Wings and bodies at transonic and supersonic speeds; numerical methods. [CourseProfile (ATLAS)]

AEROSP 525. Introduction to Turbulent Flows
*Prerequisite: AEROSP 522. (3 credits)*
Mathematical description of turbulent flow phenomena. Flow equations, vorticity dynamics, Reynolds-averaged equations, engineering turbulence models. Theory of homogeneous turbulence,
spectral dynamics. Shear flow turbulence, mean and fluctuating structure of free and wall-bounded turbulent flows. CourseProfile (ATLAS)

AEROSP 526. Hypersonic Aerothermodynamics  
*Prerequisite: Graduate standing or AEROSP 225 and AEROSP 325. (3 credits)*  
Hypersonic vehicles offer rapid air transportation and access to space. This course provides an introduction to the aerothermodynamics of hypersonic vehicles. Topics covered include: vehicle types (missiles, space planes, air-breathers); flight dynamics (trajectory, range, stability); aerothermodynamics (fluid dynamics, thermodynamics, aerodynamics, heating); and propulsion systems (scramjets, combined cycles). CourseProfile (ATLAS)

AEROSP 527. Unsteady Aerodynamics and Aeroacoustics  
*Prerequisite: AEROSP 325 or equivalent or permission of instructor. (3 credits)*  
Theoretical and numerical aspects of unsteady aerodynamics and aerodynamically-generated noise. Topics include vortex dynamics, steady and unsteady airfoil theory, indicial methods, unsteady compressible flow, basics of physical acoustics, sound generation by moving bodies and turbulence, combustion noise. CourseProfile (ATLAS)

AEROSP 530. Gas-Turbine Propulsion  
*Prerequisite: AEROSP 335. (3 credits)*  
Advanced analysis of turbojet engines: effect of altitude parameters on engine performance; off-design equilibrium running of a turbojet engine; dynamics of engine considered as a quasi-static system; fluid mechanics of a rotating axial blade row; centrifugal compressors; transonic flow problems. CourseProfile (ATLAS)

AEROSP 532. Molecular Gas Dynamics  
*Prerequisite: permission of instructor. (3 credits)*  
Analysis of basic gas properties at the molecular level. Kinetic theory: molecular collisions, the Boltzmann equation. Maxwellian distribution function. Quantum mechanics: the Schrodinger equation, quantum energy states for translation, rotation, vibration, and electronic models of atoms and molecules. Statistical mechanics: the Boltzmann relation, the Boltzmann energy distribution, partition functions. These ideas are combined for the analysis of a chemically reacting gas at the molecular level. CourseProfile (ATLAS)

AEROSP 533 (ENSCEN 533). Combustion Processes  
*Prerequisite: AEROSP 225. (3 credits)*  
This course covers the fundamentals of combustion systems and fire and explosion phenomena. Topics covered include thermochemistry, chemical kinetics, laminar flame propagation, detonations and explosions, flammability and ignition, spray combustion and the use of computer techniques in combustion problems. CourseProfile (ATLAS)

AEROSP 535. Rocket Propulsion  
*Prerequisite: AEROSP 335. (3 credits)*  
Analysis of liquid and solid propellant rocket power plants; propellant thermochemistry, heat transfer, system considerations. Low-thrust rockets, multi-stage rockets, trajectories in powered flight, electric propulsion. CourseProfile (ATLAS)

AEROSP 536. Electric Propulsion  
*Prerequisite: AEROSP 335, senior standing. (3 credits)*  
Introduction to electric propulsion with an overview of electricity and magnetism, atomic physics, non-equilibrium flows and electrothermal, electromagnetic and electrostatic electric propulsion systems. CourseProfile (ATLAS)

AEROSP 540 (MECHENG 540). Intermediate Dynamics  
*Prerequisite: MECHENG 240. (3 credits)*  
Newton/Euler and Lagrangian formulations for three dimensional motion of particles and rigid
bodies. Principles of dynamics applied to various rigid-body and multi-body dynamics problems that arise in aerospace and mechanical engineering. CourseProfile (ATLAS)

AEROSP 543. Structural Dynamics  
Prerequisite: AEROSP 315 or AEROSP 540. (3 credits)  

AEROSP 544. Aeroelasticity  
Prerequisite: AEROSP 315 or AEROSP 540. (3 credits)  
Vibration and flutter of elastic bodies exposed to fluid flow. Static divergence and flutter of airplane wings. Flutter of flat plates and thin walled cylinders at supersonic speeds. Oscillations of structures due to vortex shedding. CourseProfile (ATLAS)

AEROSP 545. Aeromechanics of Rotary Wing Vehicles  
Prerequisite: preceded by AEROSP 315 and 325. (3 credits)  
This course deals with fundamental aspects of helicopter aerodynamics, performance, dynamics, stability and control, aeroelastic stability in flap-pitch, flap-lag and coupled flap-lag-torsion. Aeroelastic response in forward flight or the vibration problem is also considered. CourseProfile (ATLAS)

AEROSP 548. Astrodynamics  
Prerequisite: AEROSP 343 or graduate standing (Advisory). (3 credits)  
Review of two-body problem for spacecraft: orbital trajectories, transfers, targeting and time of flight. Orbit perturbation formulations and analysis. Restricted 3-body problem and applications. CourseProfile (ATLAS)

AEROSP 549. Orbital Analysis and Determination  
Prerequisite: Either AEROSP 548, AEROSP 540, or AEROSP 573 – Permission of Instructor. (3 credits)  
The analysis, characterization and determination of space trajectories from a dynamical systems viewpoint. The general formulation and solution of the spacecraft trajectory design and navigation problems. Computation of periodic orbits and their stability. Estimation of model parameters from spacecraft tracking data (e.g., gravity field estimation). Elements of precision modeling and precision orbit determination. CourseProfile (ATLAS)

AEROSP 550 (CEE 571) (EECS 560) (MECHENG 564). Linear Systems Theory  
Prerequisite: graduate standing. (4 credits)  

AEROSP 551 (EECS 562). Nonlinear Systems and Control  
Prerequisite: graduate standing. (3 credits)  
Introduction to the analysis and design of nonlinear systems and nonlinear control systems. Stability analysis using Liapunov, input-output and asymptotic methods. Design of stabilizing controllers using a variety of methods: linearization, absolute stability theory, vibrational control, sliding modes and feedback linearization. CourseProfile (ATLAS)

AEROSP 552. Aerospace Information Systems  
Prerequisite: AEROSP 350  
Advised Prerequisite: ENGR 101 and MATH 216 or graduate standing. (3 credits) Minimum grade of a “C-” for enforced
prerequisite.

AEROSP 566. Data Analysis and System Identification
*Prerequisite: Graduate standing (3 credits)*

AEROSP 567. Inference, Estimation, and Learning
*Prerequisite: None. (3 credits)*
Theory and algorithms for synthesizing models and data for general applications across science and engineering. Topics include algorithms for maximum likelihood estimation, Bayesian inference, and regression for static inference problems and for estimation in dynamical systems. Theoretical foundations of the algorithms and projects that focus on implementation. 

AEROSP 573. Dynamics and Control of Spacecraft
*Prerequisite: AEROSP 470 or graduate standing (Advisory). (3 credits)*
Introduction to spacecraft dynamics and control. Spacecraft orbit and attitude representations, kinematics, dynamics. Perturbation equations for near circular orbits. Spacecraft maneuvers formulated and solved as control problems. 

AEROSP 574 (SPACE 574). Introduction to Space Physics
*Prerequisite: Senior or Graduate Standing. (4 credits)*
A graduate level introduction to physical and aeronomical processes in the space environment. Discussion of theoretical tools, the Sun, solar wind, heliosphere, magnetosphere, ionosphere and the upper atmosphere. Spacecraft interaction with radiation, spacecraft-plasma interactions. 

AEROSP 575. Flight and Trajectory Optimization
*Prerequisite: AEROSP 470 or graduate standing (Advisory). (3 credits)*
Formulation and solution of optimization problems for atmospheric flight vehicles and space flight vehicles. Optimality criteria, constraints, vehicle dynamics. Flight and trajectory optimization as problems of nonlinear programming, calculus of variations and optimal control. Algorithms and software for solution of flight and trajectory optimization problems. 

AEROSP 577. Data-driven & Reduced Complexity Modeling
*Advisory Prerequisite: Good background in Linear Algebra, Probability and Statistics. (3 credits)*
Review of Linear Algebra and Probability; Linear and Kernel Regression; Discovery of dynamical systems and PDEs from data; Statistical Learning Theory; Dimensionality reduction & Manifold Learning; Variational Inference & Variational Autoencoders; Compression/Sensing/Reconstruction; Projection-based Reduced Order Modeling. 

AEROSP 579. Control of Structures and Fluids
*Prerequisite: AEROSP 470 or graduate standing. (3 credits)*
Control-oriented modeling of structural and fluid-structure systems. Fixed-gain and adaptive disturbance rejection for vibration suppression. Application to aeroelastic flutter, limit-cycle oscillations, and gust alleviation. 

CourseProfile (ATLAS)
AEROSP 580. Linear Feedback Control Systems
Advised Prerequisite: AEROSP 550. (3 credits) (Credit for both AEROSP 580 and EECS 565 not allowed.)

AEROSP 581 (SPACE 581). Space System Management
Prerequisite: graduate standing. (3 credits)
The first part of the course will provide detailed information on how space policy is developed in the United States and the international space community, and how these policies result in specific missions. The second part will provide detailed information on modern management techniques and processes. Project managers from NASA centers and industry will lecture on the detailed management techniques and processes. CourseProfile (ATLAS)

AEROSP 582 (SPACE 582). Spacecraft Technology
Prerequisite: Graduate standing. (4 credits)
Systematic and comprehensive review of spacecraft and space mission design and key technologies for space missions. Discussions on project management and the economic and political factors that affect space missions. Specific space mission designs are developed in teams. Students of AERO 483/583 choose their projects based on these designs. CourseProfile (ATLAS)

AEROSP 583. Management of Space Systems Design
Prerequisite: preceded by AEROSP 582. (4 credits)
Meets with Aero. Eng. 483 (Space System Design), or other senior design course when appropriate topic is chosen. Students in this course lead teams in high level project design of a space system. Modern methods of concurrent engineering manufacturing, marketing and finance, etc., are incorporated. CourseProfile (ATLAS)

AEROSP 584. Avionics, Navigation and Guidance of Aerospace Vehicles
Prerequisite: AEROSP 470 or graduate standing (Advisory). (3 credits)

AEROSP 585. Aerospace Engineering Seminar
Prerequisite: AEROSP 285 or senior standing. (1 credit)
A series of seminars by noted speakers designed to acquaint graduate and undergraduate students with contemporary research and technological issues in the aerospace industry. Involves a short term paper pertinent to one of the seminar topics. CourseProfile (ATLAS)

AEROSP 588. Multidisciplinary Design Optimization
Prerequisite: MATH 419 or equivalent, MATH 371 or equivalent, graduate standing. (3 credits)
Introduction to numerical optimization and its application to the design of aerospace systems, including: mathematical formulation of multidisciplinary design problems, overview of gradient-based and gradient-free algorithms, optimality conditions (unconstrained and constrained, Pareto optimality), sensitivity analysis and multidisciplinary problem decomposition. No background in aerospace is required. CourseProfile (ATLAS)

AEROSP 590. Directed Study
Prerequisite: graduate standing and permission of instructor. (1-6 credits)
Study of advanced aspects of aerospace engineering directed by an Aerospace faculty member. Primarily for graduates. The student will submit a final report. CourseProfile (ATLAS)
AEROSP 597 (SPACE 597). Fundamentals of Space Plasma Physics
Prerequisite: senior-level statistical physics course. (3 credits)
Basic plasma concepts, Boltzmann equation, higher order moments equations, MHD equations, double adiabatic theory. Plasma expansion to vacuum, transonic flows, solar wind, polar wind. Collisionless shocks, propagating and planetary shocks. Fokker-Planck equation, quasilinear theory, velocity diffusion, cosmic ray transport, shock acceleration. Spacecraft charging, mass loading. CourseProfile (ATLAS)

600 Level Courses

AEROSP 611. Advanced Topics in Finite Element Structural Analysis
Prerequisite: AEROSP 511 or MECHENG 605. (3 credits)
Cyclic symmetry, design sensitivities and optimization. Applications to stress analysis, vibration, heat conduction, centrifugal effects, buckling. Introduction to high-level matrix-oriented programming languages (e.g., Direct Matrix Abstraction Program). Use of a large, general purpose finite element code as a research tool. CourseProfile (ATLAS)

AEROSP 614. Advanced Theory of Plates and Shells
Prerequisite: AEROSP 416. (3 credits)
Differential geometry of surfaces. Linear and nonlinear plate and shell theories in curvilinear coordinates. Anisotropic and laminated shells. Stability and post-buckling behavior. Finite element techniques, including special considerations for collapse analysis. CourseProfile (ATLAS)

AEROSP 615 (CEE 617) (MECHENG 649). Random Vibrations
Prerequisite: MATH 425 or equivalent, CEE 513 or MECHENG 541 or AEROSP 543 or equivalent. (3 credits)
Introduction to concepts of random vibration with applications in civil, mechanical and aerospace engineering. Topics include: characterization of random processes and random fields, calculus of random processes, applications of random vibrations to linear dynamical systems, brief discussion on applications to nonlinear dynamical systems. CourseProfile (ATLAS)

AEROSP 618. Theory of Elastic Stability II
Prerequisite: AEROSP 518 or equivalent and graduate standing. (3 credits)
Koiter’s theory for buckling, post-buckling, mode interaction and imperfection sensitivity behavior in nonlinear solids. Applications to thin-walled beams, cylindrical and spherical shells as well as to 3-D hyperelastic solids. Loss of ellipticity in finitely strained solids. Hill’s theory on bifurcation, uniqueness and post-bifurcation analysis in elastic-plastic solids with applications. CourseProfile (ATLAS)

AEROSP 623. Computational Fluid Dynamics II
Prerequisite: AEROSP 523 or equivalent, substantial computer programming experience, and AEROSP 520. (3 credits)
Advanced mathematical and physical concepts in computational fluid dynamics, with applications to one- and two-dimensional compressible flow. Euler and Navier-Stokes equations, numerical flux functions, boundary conditions, monotonicity, marching in time, marching to a steady state, grid generation. CourseProfile (ATLAS)

AEROSP 625. Advanced Topics in Turbulent Flow
Prerequisite: AEROSP 525. (3 credits)
Fundamentals of turbulent shear flows, with emphasis on dimensional reasoning and similarity scaling. Development of laminar shear flows, instability and transition to turbulent flow, kinetic and scalar energy transport mechanisms in turbulent shear flows, critical examination of numerical methods for turbulent flows, comparisons with experiments. CourseProfile (ATLAS)
AEROSP 627. Advanced Gas Dynamics  
Prerequisite: AEROSP 520, AEROSP 522. (3 credits) 
Linear and nonlinear surface waves. Flow instabilities; nonlinear stability analysis. Vorticity dynamics: vortex motions, instabilities and breakdown. Boundary layers: steady and unsteady interactions; nonlinear instability. CourseProfile (ATLAS)

AEROSP 633. Advanced Combustion  
Prerequisite: AEROSP 533. (3 credits) 
Thermodynamics of gas mixtures, chemical kinetics, conservation equations for multi-component reacting gas mixtures, deflagration and detonation waves. Nozzle flows and boundary layers with reaction and diffusion. CourseProfile (ATLAS)

700 Level Courses

AEROSP 714. Special Topics in Structural Mechanics  
Prerequisite: permission of instructor. Term offered depends on special topic (to be arranged) CourseProfile (ATLAS)

AEROSP 729. Special Topics in Gas Dynamics  
Prerequisite: permission of instructor (to be arranged) 
Advanced topics of current interest. CourseProfile (ATLAS)

AEROSP 740. Special Topics in Flight Dynamics and Control Systems  
(to be arranged) CourseProfile (ATLAS)

800 Level Courses

AEROSP 800. Seminar

AEROSP 820. Seminar in Aerodynamics  
(to be arranged)

AEROSP 830. Seminar in Propulsion  
(to be arranged)

AEROSP 840. Dynamics and Control Systems  
(to be arranged)

900 Level Courses

AEROSP 990. Dissertation/Pre-Candidate  
(2-8 credits); (1-4 credits) 
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

AEROSP 995. Dissertation/Candidate  
Prerequisite: Graduate School authorization for admission as a doctoral candidate. (8 credits); (4 credits) 
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)
Applied Physics
Overview

The quickening pace of development at the frontier between physics and engineering creates a need for interdisciplinary training and research which is not readily accommodated by traditional single-focus graduate programs. The University of Michigan Applied Physics Program is designed to fill this gap, providing students with the opportunity to gain a solid base in the fundamentals of modern physics while exploring applications in the context of various branches of engineering.

The program, which spans the Physical Science Division of the College of Literature, Science and the Arts and the College of Engineering, offers graduate studies leading to the Doctor of Philosophy (Ph.D.) degree in Applied Physics. Coursework and research are structured to meet individual goals so that the program is appropriate for students intending to pursue careers in industry, academia or government service.

From nonlinear optics to the latest developments in ultramicroscopy, Michigan has a distinguished record of innovation in applied physics. With a broad range of multidisciplinary research and access to the most advanced facilities, the program offers a dynamic environment for graduate training. The opportunities and challenges for bridging science and technology have never been more exciting, nor the potential impact on our society’s needs greater. The University of Michigan Applied Physics Program is committed to a leading role in this endeavor.

Enrollment and Graduation Data

The University Registrar publishes the number of student enrolled annually in this program, and the number of degrees granted each term by this program.

Graduate

Admission Criteria for the Applied Physics Ph.D. Degree

The Applied Physics Program is designed for students intending to pursue coursework and research leading to the Ph.D. degree. Accordingly, students are not admitted as candidates for the Master of Science degree. However, our students are usually eligible to receive a Masters degree in Applied Physics or Electrical Engineering at the time they become candidates for the Ph.D. degree.

A completed application and transcripts of all previous academic records must be on file.

The admission committee will take into account the applicant's background in the physical sciences, engineering physics and related disciplines. A good grounding in basic physics is expected with at least 15 hours of introductory and intermediate coursework in classical mechanics, statistical physics, electricity and magnetism and quantum physics. Graduate Record Examination general scores are required and the GRE Subject Test in Physics is recommended. Three letters of recommendation must be submitted. At least two of the letters must be from an academic institution. Students
from non-English-speaking countries are required to demonstrate proficiency in English via the TOEFL examination. The minimum score for admission is 560.

Applications will be processed for Fall term admission. The deadline for applications for financial aid consideration is February 1.

**Requirements for the Applied Physics Ph.D. Degree**

The curriculum leading to the Ph.D. degree in Applied Physics combines coursework in the fundamentals of physical theory, its applications to modern technology and practical “hands-on” training in the research laboratories.

Applied Physics is administered as an intercollegiate degree program with participating faculty in the College of Literature, Science, and the Arts and the College of Engineering. General admission and degree requirements are administered by the Horace Rackham Graduate School.

The program is normally four to five years with an emphasis on coursework during the first two years. Students are encouraged to become involved in research at the earliest opportunity and are required to complete a supervised research project in their first year. When students complete the basic academic core, have satisfied the qualification procedure (see below), have formed a Dissertation Committee and have obtained approval for their Dissertation Prospectus, they are eligible for admission to Candidacy for the Ph.D. Candidacy is normally achieved after four or five semesters of graduate work.

**Candidacy**

In order to achieve candidacy and form a dissertation committee, seven prescribed 500 level courses must be passed with a grade B or better. In addition, four elective courses (chosen in consultation with the program advisor according to the student’s research needs) must be completed satisfactorily. Satisfactory completion of one four-credit hour course on non-thesis research is also required, under the supervision of a faculty member. Prior approval by the program committee must be obtained before beginning this supervised research course. All first, second and third year students are required to enroll in the weekly seminar course (AP 514).

**Qualifying Procedure**

The decision to qualify a student for Ph.D. study is based on the student’s academic record, performance in a four-credit hour supervised research project and the results of a two-part qualifying examination. The first part of the qualifying examination consists of a written examination on basic undergraduate-level physics. The second part of the qualifying examination is an oral examination, beginning with a brief presentation of the student’s supervised research followed by questions on standard undergraduate-level physics. The student is expected to qualify within two years of entering the graduate program.

**Preliminary Examination**
A preliminary examination of the plans for dissertation research will be made by the student’s Dissertation Committee. The preliminary examination will take the form of a presentation to the committee of a Dissertation Prospectus stating the objectives and proposed methods of investigation. Over the signatures of the Dissertation Committee, the program committee will authorize the student to proceed with the thesis research. Students normally will have formed their Dissertation Committee by the end of their fifth term in graduate school. Approval of the Dissertation Prospectus is a program requirement prior to Candidacy.

Applied Physics Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin
Website: https://bulletin.engin.umich.edu/courses/course-info/

500 Level Courses

APPPHYS 514. Applied Physics Seminar
Prerequisite: graduate studies. (1 or 2 credits)
Graduate seminars are required each term to familiarize students with current research and problems. Given by a mix of faculty, external lecturers and the students themselves to acquaint students with the scope of research activity and opportunities, the goal of the seminar structure is to promote a strong interaction among the interdisciplinary work being done in applied physics. CourseProfile (ATLAS)

APPPHYS 530 (EECS 530). Electromagnetic Theory I
Prerequisite: EECS 330 or Physics 438. (3 credits)
Maxwell’s equations, constitutive relations and boundary conditions. Potentials and the representation of electromagnetic fields. Uniqueness, duality, equivalence, reciprocity and Babinet’s theorems. Plane, cylindrical and spherical waves. Waveguides and elementary antennas. The limiting case of electro- and magneto-statics. CourseProfile (ATLAS)

APPPHYS 537 (EECS 537). Classical Optics
Prerequisite: EECS 330 and EECS 334. (3 credits)

APPPHYS 540 (EECS 540). Applied Quantum Mechanics I
Prerequisite: permission of instructor. (3 credits)
Introduction to nonrelativistic quantum mechanics. Summary of classical mechanics, postulates of quantum mechanics and operator formalism, stationary state problems (including quantum wells, harmonic oscillator, angular momentum theory and spin, atoms and molecules, band theory in solids), time evolution, approximation methods for time independent and time dependent interactions including electromagnetic interactions, scattering. CourseProfile (ATLAS)

APPPHYS 541 (EECS 541). Applied Quantum Mechanics II
Prerequisite: APPPHYSICS 540 or EECS 540. (3 credits)
Continuation of nonrelativistic quantum mechanics. Advanced angular momentum theory, second quantization, non-relativistic quantum electrodynamics, advanced scattering theory, density matrix formalism, reservoir theory. CourseProfile (ATLAS)

APPPHYS 546 (EECS 546). Ultrafast Optics
Prerequisite: EECS 537. (3 credits)

APPPHYS 550 (EECS 538) (Physics 650). Optical Waves in Crystals
Prerequisite: EECS 434. (3 credits)
Propagation of laser beam: Gaussian wave optics and the ABCD law. Crystal properties and the dielectric tensor; electro-optic effects and devices; acousto-optic diffraction and devices. Introduction to nonlinear optics: coupled mode theory and second harmonic generation; phase matching. CourseProfile (ATLAS)

APPPHYS 551 (EECS 539) (Physics 651). Lasers
Prerequisite: EECS 537 and EECS 538. (3 credits)
Complete study of laser operation: the atom-field interaction; homogeneous and inhomogeneous broadening mechanisms; atomic rate equations; gain, amplification and saturation; laser oscillation; laser resonators, modes, and cavity equations; cavity modes; laser dynamics, Q-switching and modelocking. Special topics such as femto-second lasers and ultrahigh power lasers. CourseProfile (ATLAS)

APPPHYS 552 (EECS 552). Fiber Optical Communications
Prerequisite: EECS 434 or EECS 538 or permission of instructor. (3 credits)
This course covers the basics of fibers and applications in fields as diverse as high power and broadband lasers, biomedical diagnostics and therapeutics, telecommunications, and internet communications. Propagation, optical amplification, and nonlinearities in fibers are discussed, and examples include transmission systems and lasers. Biomedical applications include dermatology, cardiology, and ophthalmology. CourseProfile (ATLAS)

600 Level Courses

APPPHYS 601 (Physics 540). Advanced Condensed Matter
(3 credits)
A unified description of equilibrium condensed matter theory (using Green’s functions); critical phenomena, Anderson localization and correlated electron theory. CourseProfile (ATLAS)

APPPHYS 609 (EECS 638) (Physics 542). Quantum Theory of Light
Prerequisite: quantum mechanics electrodynamics and atom physics. I even years. (3 credits)
The atom-field interaction; density matrix; quantum theory of radiation including spontaneous emission; optical Bloch equations and theory of resonance fluorescence; coherent pulse propagation; dressed atoms and squeezed states; special topics in nonlinear optics. CourseProfile (ATLAS)

APPPHYS 611 (EECS 634) (Physics 611). Nonlinear Optics
Prerequisite: EECS 537 or EECS 538 or EECS 530. (3 credits)
Formalism of wave propagation in nonlinear media; susceptibility tensor; second harmonic generation and three-wave mixing; phase matching; third order nonlinearities and four-wave mixing processes; stimulated Raman and Brillouin scattering. Special topics: nonlinear optics in fibers, including solitons and self-phase modulation. CourseProfile (ATLAS)
APPPHYS 619 (Physics 619). Advanced Solid State Physics  
Prerequisite: APPPHYS 520 (or 463), Physics 511, Physics 510 or permission of instructor. (3 credits)  
Photon, neutron and electron scattering in condensed matter: elastic and inelastic scattering in condensed matter. The theory of neutron, electron and photon (Rayleigh, Brillouin, Raman, and x-ray) scattering will be presented with an overview of the corresponding experimental techniques; linear response theory, fluctuation-dissipation theorem, elementary excitations in condensed matter, hydrodynamics and symmetry analysis using group theory. AP 633 (Physics 633). Fluid Dynamics CourseProfile (ATLAS)

APPPHYS 633 (Physics 633). Fluid Dynamics  
(3 credits)  
The course begins with a derivation of the hydrodynamical equations as prototypical phenomenological equations, based on general conservation laws and the second law of thermodynamics; two dimensional ideal fluid flow, the Joukowsky theory of the airfoil, gravity waves and the theory of tides, solitary waves, incompressible viscous flow and the Stokes formula, Sommerfeld’s theory of lubrication, the turbulent wake, Prandtl’s theory of the boundary layer, shock waves, relativistic hydrodynamics, fluctuations in hydrodynamics, etc. CourseProfile (ATLAS)

APPPHYS 644 (Physics 644). Advanced Atomic Physics  
(3 credits)  
Laser atom interactions: Absorption, emission, and saturation, theory of line width, multiphoton absorption, stimulated and spontaneous Raman scattering; single photon, multiphoton and above-threshold ionization; Rydberg physics; AC stark shifts and ponderomotive effects; multichannel quantum defect theory; Floquet theory; Mechanical effects of light on atoms (atom traps, molasses), atom interferometry. CourseProfile (ATLAS)

APPPHYS 669 (Chem 669). Physics of Extended Surfaces  
Prerequisite: quantum mechanics or solid state physics, or permission of instructor. (3 credits)  
Chemical physics of extended surfaces: basic surface phenomena which control the physical and chemical properties of extended surfaces. A wide range of surface methods and issues regarding metal, semiconductor and insulator surfaces will be discussed. Fundamental principles regarding the geometric and electronic structure of surfaces, adsorption-desorption processes, surface reactions, and ion-surface interactions will be discussed. CourseProfile (ATLAS)

APPPHYS 672 (NERS 572). Intermediate Plasma Physics II  
Prerequisite: NERS 571. (3 credits)  
Waves in non-uniform plasmas, magnetic shear; absorption, reflection and tunneling gradient-driven microinstabilities; BGK mode and nonlinear Landau damping; macroscopic instabilities and their stabilization; non-ideal MHD effects. CourseProfile (ATLAS)

APPPHYS 674 (NERS 674). High-Intensity Laser Plasma Interactions  
Prerequisite: NERS 471, NERS 571 or permission of instructor. (3 credits)  
Coupling of intense electromagnetic radiation to electrons and collective modes in time-dependent and equilibrium plasmas, ranging from underdense to solid-density. Theory, numerical modes and experiments in laser fusion, x-ray lasers, novel electron accelerators and nonlinear optics. CourseProfile (ATLAS)
Mission Statement

Mission

The mission of the Department of Biomedical Engineering is to provide leadership in education, training and cutting-edge research by translating science and engineering to solve important challenges in medicine and life sciences to the benefit of humanity.

Goals

To provide students with the education needed for a rewarding career.

Objectives

The Accreditation Board for Engineering and Technology (ABET) defines the Program Educational Objectives as accomplishments that are expected of our graduates within a few years after graduation. In recognition of the fact that BiomedE graduates may pursue a broad range of careers, the BiomedE Program Objectives are phrased to reflect the preparation provided by the program for these career options. The Program Educational Objectives for the Department of BiomedE are that our students are:

Within 3-5 years after graduating, our students are:

1. Actively engaged in and making contributions to post-graduate opportunities, whether they are entry-level biomedical engineering positions, graduate study in engineering, medicine, or other professional degree programs, using the skills and knowledge gained from rigorous instruction in the engineering sciences and biology, with a complementary emphasis on laboratory and design experience.
2. Applying critical thinking, curiosity, teamwork, communication, and other non-technical skills, acquired through a program of related technical electives that deepens understanding in a particular subject, to a variety of careers.

Outcomes

Graduates of the Biomedical Engineering Department at the University of Michigan will have been exposed to or will have gained:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

8.

9. An ability to apply principles of engineering, biology, human physiology, chemistry, calculus-based physics, mathematics (through differential equations) and statistics [Program: 1].

10. An ability to solve bio/biomedical engineering problems, including those associated with the interaction between living and non-living systems [Program: 2].

11. An ability to analyze, model, design, and realize bio/biomedical engineering devices, systems, components, or processes [Program: 3].

12. An ability to make measurements on and interpreting data from living systems [Program: 4].

**Enrollment and Graduation Data**

In Fall 2019, 299 undergraduates were enrolled in the program. In AY19-20, 87 degrees were awarded. For other terms, the University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

**Undergraduate Degree Program**

BiomedE offers a four-year undergraduate degree along with a recommended one-year master’s degree in a Sequential Undergraduate/Graduate Studies (SUGS) program. Qualified undergraduates may pursue a combined undergraduate/graduate program in one of three concentrations: biochemical, bioelectrics, or biomechanics, leading to a Bachelor of Science in Engineering degree (B.S.E. in Biomedical Engineering) and six graduate concentrations: bioelectrics and neural engineering, biomaterials and regenerative medicine, biomechanics and biotransport, biomedical imaging and ultrasonics, biotechnology and systems biology, and medical product development, leading to a Master of Science in Engineering degree (M.S.E. in Biomedical Engineering).

**Sample Schedule**

**B.S.E. in Biomedical Engineering**

The Biomedical Engineering program is accredited by the Engineering Accreditation Commission of ABET, [http://www.abet.org](http://www.abet.org). Please see the PDF version of the sample schedule here. Additional
information can be found on the department advising website: [http://www.bme.umich.edu/programs/undergrad/current.php](http://www.bme.umich.edu/programs/undergrad/current.php).

---

**Enrollment and Graduation Data**

In Fall 2019, 299 undergraduates were enrolled in the program. In AY19-20, 87 degrees were awarded. For other terms, the University Registrar publishes [the number of students enrolled annually in this program](http://www.bme.umich.edu/programs/undergrad/current.php), and [the number of degrees granted each term by this program](http://www.bme.umich.edu/programs/undergrad/current.php).

**Sequential Undergraduate/Graduate Study (SUGS)**

The five-year Sequential Undergraduate/Graduate Study (SUGS) program permits students who enter the program in the first term of their senior year to receive the B.S.E. and M.S.E. degrees (or the B.S.E. and M.S. degrees) upon completion of a minimum of 149 credit hours. Students should speak with the department advising staff to learn more about the SUGS application process and procedures. SUGS admissions requirements will vary. [https://bulletin.engin.umich.edu/ug-ed/combined/](https://bulletin.engin.umich.edu/ug-ed/combined/)

Available programs include:

- B.S.E. in Biomedical Engineering/M.S.E. in Biomedical Engineering
- B.S. in Cell and Molecular Biology/M.S. in Biomedical Engineering
- B.S.E. in Chemical Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Electrical Engineering and Computer Science/M.S.E. in Biomedical Engineering
- B.S.E. in Industrial and Operations Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Material Science Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Mechanical Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.S.E. in Biomedical Engineering

*Students who have not completed a B.S./B.S.E. in Biomedical Engineering or Cell & Molecular Biology will be required to complete an introductory course in Biology (or have AP Biology credit) plus one additional advanced Biology or Chemistry course (i.e. Organic Chemistry, Microbiology, Immunology, or Genetics).*

**Graduate**

**Graduate Degrees**

- Master of Science (M.S.) in Biomedical Engineering
- Doctor of Philosophy (Ph.D.) in Biomedical Engineering
The Department of Biomedical Engineering's graduate program at the University of Michigan is in the Rackham School of Graduate Studies granting the M.S. and Ph.D. degrees in Biomedical Engineering.

The department is interdisciplinary. A student may plan a widely diversified educational program to advance the student’s personal goals. Research opportunities are as diversified as the range of activities conducted by the University units supporting the department.

Entrance Requirements for the Department of Biomedical Engineering

Those students with a Bachelor of Science in Engineering or Physics degree should present a minimum background of:

- Biology Course with Lab or Physiology Course with Lab
- Biological Science
- Physics (2 terms)
- Mathematics (through ordinary Differential Equations)
- Minimum of 4 Engineering Courses

Each applicant’s background and preparation is evaluated during the admissions process. Our Graduate Admissions Committee frequently recommends applicants for admission who have not completed all prerequisites as undergraduates. These applicants must complete these courses as graduate students, usually in their first year of coursework.

M.S. in Biomedical Engineering

Degree Requirements

In order to obtain the master's degree in Biomedical Engineering, students must satisfactorily complete (B or better) a minimum of 30 credit hours of graduate study beyond the bachelor’s degree. The curriculum consists of a set of advanced core biomedical engineering courses, as well as graduate-level requirements in mathematics, statistics, life sciences, and the responsible conduct of research. Students must also complete an experiential component, consisting of either a laboratory bioinstrumentation course (or equivalent), a directed research experience, or a graduate design experience, to familiarize the student with the unique problems associated with physiological systems. Within the curriculum, each student must also choose a specialized concentration to follow and complete 2-5 graduate technical electives. There are six (6) concentration options available:

- Bioelectrics and Neural Engineering
- Biomaterials and Regenerative Medicine
- Biomechanics and Biotransport
- Biomedical Imaging and Ultrasonics
- Biotechnology and Systems Biology
- Medical Product Development
Please see the department web site for further details. A grade of "B" or better must be attained in each course used toward the master's degree.

**Ph.D. in Biomedical Engineering**

The Ph.D. degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the result of the investigation in the form of a dissertation.

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. Candidacy is achieved when the student demonstrates competence in her/his broad field of knowledge through completion of a prescribed set of courses and passing a qualifying examination.

All Ph.D. students must satisfactorily complete (B or better) a minimum of nine (9) credit hours of letter graded course work (any electives with Rackham credit and approved by the student’s research advisor) beyond those which are required for a master’s degree. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.

Requirements regarding foreign language and non-technical courses are left to individual departments or programs, and to the Graduate School. A prospective doctoral student should consult the program advisor regarding specific details.

**Contacts**

**Departmental Website:** [http://www.bme.umich.edu/](http://www.bme.umich.edu/)

Biomedical Engineering Department  
1107 Carl A. Gerstacker Building  
2200 Bonisteel, Blvd.  
Ann Arbor, MI 48109-2099

E-mail: biomede@umich.edu  
Phone: (734) 764-9588  
Fax: (734) 936-1905
200 Level Courses

BIOMEDE 211. Circuits and Systems for Biomedical Engineering.
Prerequisite: MATH 216 or 256 or 286, and Physics 240 or 260. Minimum grade of a “C-” required for enforced prerequisites. (4 credits)
Students learn circuits and linear systems concepts necessary for analysis and design of biomedical systems. Theory is motivated by examples from biomedical engineering. Topics covered include electrical circuit fundamentals, operational amplifiers, frequency response, electrical transients, impulse response, transfer functions and convolution, all motivated by circuit and biomedical examples. Elements of continuous time domain-frequency domain analytical techniques are developed. CourseProfile (ATLAS)

BIOMEDE 221. Biophysical Chemistry and Thermodynamics
Prerequisite: CHEM 130 and MATH 116 or 156 or 186. Minimum grade of a “C-” for enforced prerequisites. (4 credits)
This course covers the physio-chemical concepts and processes relevant to life. The emphasis lies on the molecular level. Topics: Biomimetics; Energy and Driving Forces; Biochemical Equilibria; Aqueous Solutions; Molecular Self-Assembly; Bio-electrochemistry; Biopolymers; Molecular Recognition and Binding Equilibria in Biology. CourseProfile (ATLAS)

BIOMEDE 231. Introduction to Biomechanics
Prerequisite: MATH 116 or 156 or 186, and PHYSICS 140 or 160. Minimum grade of a “C-” for enforced prerequisites. (4 credits)
This course provides students with an introduction to topics in biomechanics, including statics, dynamics, and deformable body mechanics, as they apply to biological tissues and systems. CourseProfile (ATLAS)

BIOMEDE 241. Statistics, Computation, and Data Analysis for Biomedical Engineers
Advisory Prerequisite: Concurrent or prior enrollment in MATH 116, 156, or 186 is recommended
Prerequisite: ENGR 101 or 151. Minimum grade of a “C-” for enforced prerequisites. (4 credits)
This course integrates the fundamentals of descriptive statistics, discrete and random distributions, hypothesis testing, regression, ANOVA and post-hoc tests with computation, data analysis and visualization to address real world biomedical problems. Engaged learning class sessions focus on applying statistical and computational methods to real data sets from biomedical engineering. CourseProfile (ATLAS)

BIOMEDE 280. Undergraduate Research
Prerequisite: Permission of instructor. (1-4 credits)
This course offers research experience to first- and second-year Engineering students in an area of mutual interest to the student and to a faculty member within the College of Engineering. For each hour of credit, it is expected that the student will work a minimum of three hours per week. The grade for the course will be based on a final project/report evaluated by the faculty sponsor and participation in other required UROP activities, including bimonthly research group meetings and submission of a journal chronicling the research experience. CourseProfile (ATLAS)
BIOMEDE 295. Biomedical Engineering Seminar
*Prerequisite: none. (1 credit)*
Current research will be presented by faculty in the BME department. The goal is to help students decide if they want to pursue a B.S. in BME or choose a different undergraduate major department as part of the SGUS program leading to an M.S. in BME. [CourseProfile (ATLAS)]

### 300 Level Courses

**BIOMEDE 311. Biomedical Signals and Systems**  
*Prerequisite: BIOMEDE 211, EECS 215, or EECS 314. (4 credits)*
Theory and practice of signals and systems in both continuous and discrete time domains with examples from biomedical signal processing and control. Continuous-time linear systems convolution, steady-state responses, Fourier and Laplace transforms, transfer functions, poles and zeros, stability, sampling, feedback. Discrete-time linear systems: Z transform, filters, Fourier transform, signal processing. [CourseProfile (ATLAS)]

**BIOMEDE 321. Bioreaction Engineering and Design**  
*Prerequisite: BIOMEDE 221. Minimum grade of a “C-” for enforced prerequisite. (3 credits)*
This course introduces topics in enzyme kinetics, enzyme inhibition, biochemical pathway engineering, mass and energy balance, cell growth and differentiation, cell engineering, bioreactor design, and analysis of the human body, organs, tissues, and cells as bioreactors. The application of bioreaction/bioreactor principles to tissue engineering is also discussed. [CourseProfile (ATLAS)]

**BIOMEDE 331. Introduction to Biofluid Mechanics**  
*Prerequisite: BIOMEDE 231 and Math 215, or Math 285, and Math 216 or Math 286. Minimum grade of a “C-” required for enforced prerequisites. (4 credits)*  
**Advised Prerequisite: MATH 217**
This course introduces the fundamentals of biofluid dynamics and continuum mechanics, and covers the application of these principles to a variety of biological flows. Fluid flow in physiology and biotechnology is investigated at a variety of scales, ranging from subcellular to whole body. [CourseProfile (ATLAS)]

**BIOMEDE 332. Introduction to Biosolid Mechanics**  
*Prerequisite: BIOMEDE 231 and Math 215, or Math 285, and Math 216 or Math 286. Minimum grade of a “C-” required for enforced prerequisites. (4 credits)*  
**Advised Prerequisite: MATH 217**
This course covers the fundamentals of continuum mechanics and constitutive modeling relevant for biological tissues. Constitutive models covered include linear elasticity, nonlinear elasticity, viscoelasticity and poroelasticity. Structure-function relationships which link tissue morphology and physiology to tissue constitutive models will be covered for skeletal, cardiovascular, pulmonary, abdominal, skin, eye and nervous tissues. [CourseProfile (ATLAS)]

**BIOMEDE 350. Introduction to Biomedical Engineering Design**  
**Advisory Prerequisite: BIOMEDE 221 and 231**  
*Prerequisite: MATH 216 or 256 or 286. Minimum grade of a “C-” for enforced prerequisites. (4 credits)*
This course uses problem-based learning to introduce students to biomedical engineering design concepts, tools and methodologies. Students will work in small groups and use virtual design and computational tools to propose and validate feasible solutions to real-world biomedical engineering problems with industrial and/or clinical relevance. [CourseProfile (ATLAS)]
400 Level Courses

**BIOMEDE 410 (MATSCIE 410). Design and Applications of Biomaterials**  
*Prerequisite: MATSCIE 220 or 250 or permission of instructor. (3 credits)*  
Biomaterials and their physiological interactions. Materials used in medicine/dentistry: metals, ceramics, polymers, composites, resorbable, smart, natural materials. Material response/ degradation: mechanical breakdown, corrosion, dissolution, leaching, chemical degradation, wear. Host responses: foreign body reactions, inflammation, wound healing, carcinogenicity, immunogenicity, cytotoxicity, infection, local/systemic effects. [CourseProfile (ATLAS)]

**BIOMEDE 417 (EECS 417). Electrical Biophysics**  
*Enforced Prerequisite: BIOMEDE 211 or EECS 215 or EECS 314, senior level undergraduate and/or graduate students. Minimum grade of a “C” required for enforced prerequisites. (4 credits)*  
Electrical biophysics of nerve and muscle; electrical conduction in excitable tissue; quantitative models for nerve and muscle including the Hodgkin Huxley equations; biopotential mapping, cardiac electrophysiology and functional electrical stimulation; group projects. Lecture and recitation. [CourseProfile (ATLAS)]

**BIOMEDE 418. Quantitative Cell Biology**  
*Advisory Prerequisite: MATH 216 or 256 or 286 and PHYSICS 240.  
Prerequisite: BIOMEDE 221. Minimum grade of a “C-” for enforced prerequisites. (3 credits)*  
This course introduces the fundamentals of cell structure and functioning. The goal is to provide a general background in cell biology, with emphasis placed on physical aspects that are of particular interest to engineers. [CourseProfile (ATLAS)]

**BIOMEDE 419. Quantitative Physiology**  
*Prerequisite: BIOMEDE 221. Minimum grade of a “C-” for enforced prerequisites. (4 credits)*  
Quantitative Physiology provides learning opportunities for senior undergraduate and graduate students to understand and develop competencies in a quantitative, research oriented, systems approach to physiology. Systems examined include cellular; musculoskeletal; cardiovascular; respiratory; endocrine; gastrointestinal; and renal. Mathematical models and engineering analyses are used to describe system performance where applicable. [CourseProfile (ATLAS)]

**BIOMEDE 424. (MECHENG 424) Engineering Acoustics**  
*Prerequisite: MATH 216 and Physics 240. (3 credits)*  
Vibrating systems; acoustic wave equation; plane and spherical waves in fluid media; reflection and transmission at interfaces; propagation in lossy media; radiation and reception of acoustic waves; pipes, cavities and waveguides; resonators and filters; noise; selected topics in physiological, environmental and architectural acoustics. [CourseProfile (ATLAS)]

**BIOMEDE 430. Rehabilitation Engineering and Assistive Technology**  
*Prerequisite: Previous or simultaneous registration in IOE 333 or instructor approval. (3 credits)*  
This is a lecture course which surveys the design and application of rehabilitation engineering and assistive technologies in a wide range of areas, including wheeled mobility, seating and positioning, environmental control, computer access, augmentative communication, sensory aids, as well as emerging technologies. [CourseProfile (ATLAS)]

**BIOMEDE 442. Introduction to Biomedical Imaging**  
*Enforced Prerequisites: ENGR [101 or 151] or EECS [180 or 183 or 280]. Minimum grade requirement of “C- or above”. (3 credits)*  
This course is an introduction course on biomedical imaging for undergrad and MS students. The topics cover all major imaging modalities, such as ultrasound, MRI, optical imaging, X-ray, computed tomography (CT), and nuclear imaging. This course will include lectures and visits to imaging laboratories and the UM hospital. [CourseProfile (ATLAS)]
BIOMEDE 450. Biomedical Engineering Design
Advisory prerequisite: senior standing. prerequisite: BIOMEDE 350 and 458 (4 credits)
Interdisciplinary groups carry out biomedical instrumentation design projects sponsored by Medical School, College of Engineering, and local industry. Students are exposed to the entire design process: design problem definition, generation of a design specification, documentation, design review process, prototype fabrication, testing, and calibration. Students may receive credit for either 450 or 451, not both. CourseProfile (ATLAS)

BIOMEDE 451. Biomedical Engineering Design, Part I
Advisory Prerequisite: BIOMEDE 458
Prerequisite: BIOMEDE 350 and senior standing. Minimum grade of a “C-” for enforced prerequisites. (3 credits)
Two semester course – Interdisciplinary groups design-build-test biomedical instrumentation projects. Projects are sponsored by Medical School and Engineering research labs, and local industry. Students are exposed to the entire design process: design, problem definition, generation of a design specification, documentation, design review process, prototype fabrication, testing, and calibration. CourseProfile (ATLAS)

BIOMEDE 452. Biomedical Engineering Design, Part II
Advisory prerequisite: senior standing. Prerequisite: BIOMEDE 350, 451, and 458. (3 credits)
Two semester course — Interdisciplinary groups design-build-test biomedical instrumentation projects. Projects are sponsored by Medical School and Engineering research labs, and local industry. Students are exposed to the entire design process: design Problem definition, generation of a design specification, documentation, design review process, prototype fabrication, testing, and calibration. CourseProfile (ATLAS)

BIOMEDE 456 (MECHENG 456). Modeling in Biosolid Mechanics
Prerequisite: BIOMEDE 332. (3 credits)
Definition of biological tissue and orthopaedic device mechanics including elastic, viscoelastic and non-linear elastic behavior. Emphasis on structure function relationships. Overview of tissue adaptation and the interaction between tissue mechanics and physiology. CourseProfile (ATLAS)

BIOMEDE 458 (EECS 458). Biomedical Instrumentation and Design
Prerequisite: BIOMEDE 211 or (EECS 215 or 314) or graduate standing. (4 credits)
Students design and construct functioning biomedical instruments. Hardware includes instrumentation amplifiers and active filters constructed using operational amplifiers. Signal acquisition, processing analysis and display are performed. Project modules include measurement of respiratory volume and flow rates, biopotentials (electrocardiogram), and optical analysis of arterial blood oxygen saturation (pulse-oximetry). CourseProfile (ATLAS)

BIOMEDE 464 (MATH 464). Inverse Problems
Prerequisite: MATH 217, MATH 417, or MATH 419; and MATH 216, MATH 256, MATH 286, or MATH 316. (3 credits)
Mathematical concepts used in the solution of inverse problems and analysis of related forward operators is discussed. Topics include ill-posedness, singular-value decomposition, generalized inverses, and regularization. Inverse problems considered (e.g., tomography, inverse scattering, image restoration, inverse heat conduction) are problems in biomedical engineering with analogs throughout science and engineering. CourseProfile (ATLAS)

BIOMEDE 474. Introduction to Tissue Engineering
Prerequisite: BME 410, senior standing or permission of instructor. (3 credits)
This course focuses on understanding the principles of tissue engineering and regenerative medicine. Emphasis is on the components and design criteria of tissue engineering constructs. The course will cover multiple examples of engineering soft and hard tissue and application of new technologies in regenerative medicine. CourseProfile (ATLAS)
BIOMEDE 476 (MECHENG 476). Biofluid Mechanics
Prerequisite: BIOMEDE 331 or MECHENG 320. (4 credits)
This is an intermediate level fluid mechanics course which uses examples from biotechnology processes and physiologic applications, including the cardiovascular, respiratory, ocular, renal, musculo-skeletal and gastrointestinal systems. CourseProfile (ATLAS)

BIOMEDE 479. Biotransport
Enforced Prerequisite: MATH 216 OR Math 286 OR Math 396, AND BIOMEDE 331 (Min grade requirement of C- or above). (4 credits)
Fundamentals of mass transport as it relates to biomedical systems. Convection, diffusion, osmosis and conservation of momentum, mass and energy will be applied to cellular and organ level transport. Examples of diffusion combined with reaction will also be examined. CourseProfile (ATLAS)

BIOMEDE 481 (NERS 481). Engineering Principles of Radiation Imaging
Prerequisite: none. (2 credits)
Analytic description of radiation production, transport and detection in radiation imaging systems. Measurements methods for image quality and statistical performance of observers. Systems for radiographic and radiosotope imaging, including film/screen, storage phosphor, and electronic radiography, fluoroscopy, computed tomography, Anger camera and PET systems. Emphasis on impact of random process on observer detection. CourseProfile (ATLAS)

BIOMEDE 484 (NERS 484) (ENSCEN 484). Radiological Health Engineering Fundamentals
Prerequisite: NERS 312 or equivalent or permission of instructor. (4 credits)
Fundamental physics behind radiological health engineering and topics in quantitative radiation protection. Radiation quantities and measurement, regulations and enforcement, external and internal dose estimation, radiation biology, radioactive waste issues, radon gas, emergencies and wide variety of radiation sources from health physics perspective. CourseProfile (ATLAS)

BIOMEDE 490. Directed Research
(1-4 credits)
Provides an opportunity for undergraduate students to perform directed research devoted to BiomedE. CourseProfile (ATLAS)

BIOMEDE 495. Introduction to Bioengineering
Prerequisite: Permission of instructor; mandatory pass/fail. (1 credit)
Definition of scope, challenge, and requirements of the bioengineering field. Faculty members review engineering-life sciences interdisciplinary activities as currently pursued in the College of Engineering and Medical School. CourseProfile (ATLAS)

BIOMEDE 499. Special Topics
(1-4 credits)
Topics of special interest selected by faculty. Lecture, seminar or laboratory. CourseProfile (ATLAS)

500 Level Courses

BIOMEDE 500 (UC 500). Biomedical Engineering Seminar
Mandatory, satisfactory/unsatisfactory. (1 credit)
This seminar will feature various bioengineering-related speakers. CourseProfile (ATLAS)

BIOMEDE 503. Statistical Methods for Biomedical Engineering
Prerequisite: Graduate standing or permission of instructor. (3 credits)
This course will cover descriptive statistics, probability theory, distributions for discrete and continuous variables, hypothesis testing and analysis of variance, as well as more advanced topics.
We will make connections with real problems from engineering, biology and medicine, and computational tools will be used for examples and assignments. 

**BIOMEDE 504 (Microbiology 504). Cellular Biotechnology**  
*Prerequisite: Graduate student standing or consent of the instructor. (3 credits)*  
Biotechnology is a rapidly evolving, multi-disciplinary field that impacts nearly every aspect of our daily lives from the food we eat to the medicine we take. This course covers basic scientific and engineering principles behind this growing field, along with entrepreneurial aspects of translating innovative biotechnological solutions into new products.

**BIOMEDE 506 (MECHENG 506). Computational Modeling of Biological Tissues**  
*Prerequisite: none. (3 credits)*  
Biological tissues have multiple scales and can adapt to their physical environment. This course focuses on visualization and modeling of tissue physics and adaptation. Examples include electrical conductivity of heart muscle and mechanics of hard and soft tissues. Homogenization theory is used for multiple scale modeling.

**BIOMEDE 510. Medical Imaging Laboratory**  
*Prerequisite: BIOMEDE 516 or permission of instructor. (3 credits)*  
This course provides the student practical, hands-on experience with research grade, medical imaging systems including x-ray, magnetic resonance, nuclear medicine and ultrasound. Participants rotate through each of the respective areas and learn about and perform experiments to support previous theoretical instruction.

**BIOMEDE 516 (EECS 516). Medical Imaging Systems**  
*Advised Prerequisite: EECS 351. (3 credits)*  
Principles of modern medical imaging systems. For each modality the basic physics is described, leading to a systems model of the imager. Fundamental similarities between the imaging equations of different modalities will be stressed. Modalities covered include radiography, x-ray computed tomography (CT), NMR imaging (MRI) and real-time ultrasound.

**BIOMEDE 517 Machine Learning for Neural Interfaces**  
*Advised prerequisites: {BME 211 or EECS 215 or EECS 314}, EECS 216, Math 216, and {ENGR 101 or EECS 183}. (3 credits)*  
This course focuses on techniques for understanding and interacting with the nervous system. Students first implement quantitative models of neurons followed by models of recording and stimulation. Next, students apply machine learning techniques to extract information from large neural data sets.

**BIOMEDE 519 (Physiol 519). Bioengineering Physiology**  
*Prerequisite: MCDB 310 or Biol Chem 415, 451, 515 or CHEM 351 or permission of instructor. (4 credits)*  
Quantitative description of the structure and function of mammalian systems, including the neuromuscular, cardiovascular, respiratory, renal and endocrine systems. Mathematical models are used to describe system performance where applicable. Lectures, laboratories and problem sessions.

**BIOMEDE 522. Biomembranes: Transport, Signaling and Disease**  
*Prerequisite: MCDB 310 or Biol Chem 415, 451, 515, or CHEM 351 and BIOMEDE 221 and CHEM 210 or permission of instructor. (3 credits)*  
This course focuses on the biochemistry and biophysics of transport and signaling processes through biomembranes and on the relevance of these processes for disease and therapy. The course discusses topics including composition of biomembranes; fluidity and self-assembly of lipids; membrane proteins; membrane potential; signal transduction.
Prerequisite: Graduate Standing. (3 credits)
Advances in life science research have enhanced our understanding of the human genome, human genetic variation, and the role that genes play in our everyday health, response to treatment and susceptibility to disease. This new frontier in genomic medicine ushers in both opportunity and peril for individuals, companies and societies. The objective in this interdisciplinary graduate course is to explore the intersections between science, technology, commerce and social policy as they come together to advance (and in some cases retard) progress toward more-personalized health care. The course is intended for graduate students in medicine, biomedical and health-related science, public health, law, engineering, and business interested in the future of health care. Due to variation in student backgrounds coming into the course, efforts are made to establish a shared vocabulary and knowledge base across the disciplines. Interdisciplinary student teams are assigned to a group research project which is presented at the end of the course. CourseProfile (ATLAS)

BIOMEDE 525 (Microb 525). Cellular and Molecular Networks
Prerequisite: BIOL 105 or BIOL 112 and MATH 215. (3 credits)
This course is designed to equip the student with appropriate concepts and techniques for the quantitative analysis of the integrated behavior of complex biochemical systems. A general approach is developed from the basic postulates of enzyme catalysis and is illustrated with numerous specific examples, primarily from the microbial cell. CourseProfile (ATLAS)

BIOMEDE 530. Rehabilitation Engineering and Technology Lab I
Prerequisite: Previous or simultaneous registration in BIOMEDE 430. (1 credit)
This is a lab course which provides hands-on experience in the use of assistive technologies and in-depth consideration of rehabilitation engineering research and design of assistive technologies for a wide range of areas, including environmental control, computer access, augmentative communication, wheeled mobility, sensory aids and seating and positioning. CourseProfile (ATLAS)

BIOMEDE 533 (KINE 530). Neuromechanics
Prerequisite: Graduate standing. (3 credits)
This course focuses on interactions of the nervous and musculoskeletal systems during human and animal movement with a focus on basic biological and engineering principles. Topics will include neuromechanical control of movement, neurorehabilitation, biorobotics, and computer simulations of neuromechanical systems. CourseProfile (ATLAS)

BIOMEDE 534 (IOE 534) (MFG 534). Occupational Biomechanics
Prerequisite: IOE 333 or IOE 334. (3 credits)
Anatomical and physiological concepts are introduced to understand and predict human motor capabilities, with particular emphasis on the evaluation and design of manual activities in various occupations. Quantitative models are developed to explain: (1) muscle strength performance; (2) cumulative and acute musculoskeletal injury; (3) physical fatigue; and (4) human motion control. CourseProfile (ATLAS)

BIOMEDE 550. Ethics and Enterprise
Prerequisite: none. (1 credit)
Ethics, technology transfer and technology protection pertaining to BiomedE are studied. Ethics issues range from the proper research conduct to identifying and managing conflicts of interest. Technology transfer studies the process and its influences on relationships between academia and industry. CourseProfile (ATLAS)

BIOMEDE 551 (BIOINF 551) (CHEM 551) (BiolChem 551). Proteome Informatics
Prerequisite: Bio Chem and calculus. (3 credits)
Introduction to proteomics, mass spectrometry, peptide identification and protein inference, statistical methods and computational algorithms, post-translational modifications, genome annotation and alternative splicing, quantitative proteomics and differential protein expression analysis, protein-
protein interaction networks and protein complexes, data mining and analysis of large-scale data sets, clinical applications, related technologies such as metabolomics and protein arrays, data integration and systems biology. [CourseProfile (ATLAS)]

**BIOMEDE 552. Biomedical Optics**  
*Prerequisite: MATH 216. (3 credits)*  
This course provides students with an understanding of current research in biomedical optics. Topics include: fundamental theoretical principles of tissue optics; computational approaches to light transport in tissues; optical instrumentation; an overview of applications in clinical optical diagnostics and laser-based therapy; an introduction to biomedical microscopy and applications in biophotonic technology. [CourseProfile (ATLAS)]

**BIOMEDE 556. Molecular and Cellular Biomechanics**  
*Prerequisite: Senior standing. (3 credits)*  
This course will focus on how biomechanical and biophysical properties of subcellular structures can be determined and interpreted to reveal the workings of biological nano-machines. [CourseProfile (ATLAS)]

**BIOMEDE 561. Biological Micro-and Nanotechnology**  
*Prerequisite: Biol 172 or 174, Intro Physics and Chemistry, graduate standing, or permission of instructor. (3 credits)*  
Many life processes occur at small size-scales. This course covers scaling laws, biological solutions to coping with or taking advantage of small size, micro- and nanofabrication techniques, biochemistry and biomedical applications (genomics, proteomics, cell biology, diagnostics, etc.). There is an emphasis on micro fluidics, surface science and non-traditional fabrication techniques. [CourseProfile (ATLAS)]

**BIOMEDE 563. (CHE 563) (MATSCIE 563) Biomolecular Engineering of Interfaces**  
*Prerequisite: Senior or graduate standing. (3 credits)*  
This class focuses on biomolecular engineering of surfaces and interfaces in contact with biological systems. Recent advances in the interfacial design of materials as well as methods that enable studying such systems will be highlighted. [CourseProfile (ATLAS)]

**BIOMEDE 574. Cells in Their Environment**  
*Prerequisite: Graduate standing or permission of instructor. (3 credits)*  
This course focuses on how mammalian cells interact with the complex 3D environment that surrounds them in tissues. The goal is to provide students with a thorough understanding of how cell function is controlled and how this knowledge can be applied to the prevention and treatment of disease. [CourseProfile (ATLAS)]

**BIOMEDE 580 (NERS 580). Computation Projects in Radiation Imaging**  
*Prerequisite: Preceded or accompanied by NERS 481. (1 credit)*  
Computational projects illustrate principles of radiation imaging from NERS 481 (BIOMEDE 481). Students will model the performance of radiation systems as a function of design variables. Results will be in the form of computer displayed images. Students will evaluate results using observer experiments. Series of weekly projects are integrated to describe the performance of imaging systems. [CourseProfile (ATLAS)]

**BIOMEDE 582 (NERS 582). Medical Radiological Health Engineering**  
*Prerequisite: NERS 484 (BIOMEDE 484) or graduate status. (3 credits)*  
This course covers the fundamental approaches to radiation protection in radiology, nuclear medicine, radiotherapy and research environments at medical facilities. Topics presented include health effects, radiation dosimetry and dose estimation, quality control of imaging equipment, regulations, licensing and health physics program design. [CourseProfile (ATLAS)]
BIOMEDE 584 (CHE 584) (Biomaterials 584). Advances in Tissue Engineering
Enforced Prerequisite: Permission of Instructor; Advised Prerequisite: Graduate standing. (3 credits)
Fundamental engineering and biological principles underlying field of tissue engineering are studied, along with specific examples and strategies to engineer specific tissues for clinical use (e.g., skin). Student design teams propose new approaches to tissue engineering challenges. CourseProfile (ATLAS)

BIOMEDE 588 (CHE 588). Global Quality Systems and Regulatory Innovation
Advised Prerequisite: Senior or graduate students enrolled in the CoE and health related professional schools. (2 credits)
This course is for scientists, engineers, and clinicians to understand and interpret various relevant global and regional quality systems for traditional and cutting edge global health technologies, solutions and their implementation. Speakers from academia, the FDA, and biomedical related industries will be invited to participate in teaching this course. CourseProfile (ATLAS)

BIOMEDE 590. Directed Research
(Credits to be arranged)
Provides opportunity for Biomedical Engineering students to participate in the work of laboratories devoted to living systems studies. CourseProfile (ATLAS)

BIOMEDE 591. Thesis
Prerequisite: 2 hrs of BIOMEDE 590; mandatory satisfactory/unsatisfactory. (credit to be arranged)
To be elected by bioengineering students pursuing the master’s thesis option. May be taken more than once up to a total of 6 credit hours. Graded on a satisfactory/unsatisfactory basis only. CourseProfile (ATLAS)

BIOMEDE 594. Recent Advances in Polymer Therapeutics
Prerequisite: BIOMEDE 410, senior standing, or permission of instructor. (3 credits)
The course will review the basic principles of polymer science and controlled drug delivery. The course will discuss specific examples of biopolymer applications in protein, peptide, nucleic acids, vaccine delivery and the formulation of nanostructured devices and their application in targeted delivery of therapeutic and imaging agents. CourseProfile (ATLAS)

BIOMEDE 596 (ChE 596) (Pharm 596). Health Science and Engineering Seminar
Prerequisite: Graduate standing. I, II (1 credit)
This seminar will feature invited speakers from pharmaceutical, biomedical and other life sciences-related industries and academic institutions. CourseProfile (ATLAS)

BIOMEDE 598 (ChE 598). Global Quality Systems and Regulatory Innovation
Prerequisite: Senior or graduate students enrolled in the CoE and health related professional schools (2 credits)
This course is for scientists, engineers, and clinicians to understand and interpret various relevant global and regional quality systems for traditional and cutting edge global health technologies, solutions and their implementation. Speakers from academia, the FDA, and biomedical related industries will be invited to participate in teaching this course. CourseProfile (ATLAS)

BIOMEDE 599. Special Topics I, II
(1-6 credits)
Topics of current interest selected by the faculty. Lecture, seminar or laboratory. CourseProfile (ATLAS)
600 Level Courses

**BIOMEDE 616 (ChE 616). Analysis of Chemical Signaling**  
*Prerequisite: MATH 216, Biol Chem 415, 451, 515. (3 credits)*  
Quantitative analysis of chemical signaling systems, including receptor/ligand binding and trafficking, signal transduction and second messenger production and cellular responses such as adhesion and migration. [CourseProfile (ATLAS)]

**BIOMEDE 635 (IOE 635). Laboratory in Biomechanics and Physiology of Work**  
*Prerequisite: IOE 534 (BIOMEDE 534). (2 credits)*  
This laboratory is offered in conjunction with the Occupational Biomechanics lecture course (IOE 534) to enable students to examine experimentally: (1) musculoskeletal reactions to volitional acts; (2) the use of electromyography (EMG's) to evaluate muscle function and fatigue; (3) biomechanical models; (4) motion analysis systems; and (5) musculoskeletal reactions to vibrations. [CourseProfile (ATLAS)]

**BIOMEDE 646 (MECHENG 646). Mechanics of Human Movement**  
*Prerequisite: MECHENG 540 (AEROSP 540) or MECHENG 543 or equivalent. (3 credits)*  

900 Level Courses

**BIOMEDE 990. Dissertation/Pre-Candidate**  
(1-8 credits); (1-4 credits)  
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. [CourseProfile (ATLAS)]

**BIOMEDE 995. Dissertation/Candidate**  
*Prerequisite: Graduate School authorization for admission as a doctoral candidate. (8 credits); (4 credits)*  
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. [CourseProfile (ATLAS)]
Chemical Engineering
Overview

The degree program in chemical engineering was established in 1898 at the University of Michigan, one of four schools to introduce the profession in the United States. The University of Michigan student chapter of the American Institute of Chemical Engineers was established in 1922. Chemical engineering, among all branches of engineering, is the one most strongly and broadly based upon chemical and life sciences. Chemical engineers use their knowledge of thermodynamics, fluid mechanics, heat transfer, mass transfer, reaction kinetics, and process control to develop processes that change raw materials to more useful forms.

The work of the chemical engineer encompasses many industries, from the manufacture of chemicals and consumer products and energy generation, to biotechnology, food and polymer manufacturing and the production of pharmaceuticals. In addition, thanks to a broad and fundamental education, chemical engineers can work in a wide range of roles beyond process engineering, such as research and development, environmental protection, health and safety, marketing and sales, software development, education, law, medicine, public health, and government work. More information on careers for chemical engineers is available at the AIChE career page.

The program allows 12 credits of general electives, 4 credits of biology/life science electives, 3 credits of engineering electives, and 16 credits of Intellectual Breadth electives. A student may use this elective freedom to develop individual abilities and interests, or to prepare to continue their studies in engineering, medicine, law, business, education, public health, or public policy, among many options. The electives also provide the opportunity for combined degree programs or for preparation in fields within or related to chemical engineering such as polymers, pharmaceuticals, environmental engineering, energy and fuels, and biotechnology. Students can choose to focus their elective courses by selecting a concentration within their Chemical Engineering degree.

Department Administration

Department Chair

Prof. Sharon Glotzer, PhD, NAS, NAE

Anthony Lembke Department Chair of Chemical Engineering, John Werner Cahn Distinguished University Professor of Engineering, Stuart W. Churchill Collegiate Professor of Chemical Engineering

North Campus Research Complex, Bldg 28, Room G066W

For more specific information on contacting people, go to our People page.
Mission Statement

Mission
To provide a solid and current technical foundation that prepares students for a career in chemical engineering or related fields.

Goals
To educate and support diverse students and prepare them to be leaders in chemical engineering or related fields.

Objectives
Within a few years of graduation, UMChE graduates will have attained leadership roles among peers in chemical engineering, or another field, such as medicine, law, business and education, through:

- effectiveness as proactive and creative problem solvers and innovators
- ability to think critically to solve relevant problems
- effectiveness as communicators to gain and convey information
- competence and comfort in multifunctional and multicultural environments
- exhibiting and demanding high ethical standards

Outcomes
The outcomes we desire are that graduates of the University of Michigan Chemical Engineering Program demonstrate:

- An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- An ability to communicate effectively with a range of audiences
- An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
Enrollment and Graduation Data
In Fall 2019, 312 students enrolled in the program. In AY18-19, 130 degrees were awarded. For other terms, the University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. This information is also available in the Chemical Engineering Department’s Enrollment website.

Undergraduate Degree Program

Sample Schedule

B.S.E. in Chemical Engineering

The Chemical Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. Please see the PDF version of the sample schedule. Additional information can be found on the department advising website, https://che.engin.umich.edu/undergraduate

Concentrations

Chemical Engineering students have the option of focusing their technical and some free electives in a specific area, fulfilling a concentration within their chemical engineering degree. Concentration areas include:

- BioPharmaceutical Engineering
- Electrical Engineering
- Energy Systems Engineering
- Environmental Engineering
- Life Sciences
- Materials Science and Engineering
- Mechanical Engineering
- Nuclear Engineering
- Petroleum and Gas Exploration

All optional concentrations consist of 12 credits and must include at least one 300 or higher level course. Only elective courses can be used as part of a concentration. Students may not earn a concentration in a field in which they are also enrolled for a dual degree. More information on concentration requirements is available at https://che.engin.umich.edu/undergraduate/minors-concentrations/

Sequential Undergraduate/Graduate Study (SUGS)

The following programs are available for chemical engineering students interested in pursuing joint BSE and MSE and MEng degrees. For more information on each of these
programs, including program requirements and graduate program contact information, please visit: https://che.engin.umich.edu/undergraduate/masters-sugs/

**B.S.E. in Chemical Engineering / M.S.E. in Biomedical Engineering**

This SUGS program is open to all undergraduate students from Chemical Engineering who have achieved senior standing (85 credit hours of more) and have an overall cumulative GPA of 3.2 or higher.

**B.S.E. in Chemical Engineering / M.S.E. in Chemical Engineering**

A University of Michigan undergraduate with a GPA of 3.5 or greater may apply, after completing the first term of the junior year, for admission to the departmental SUGS combined degree program leading to both the baccalaureate and master’s degrees. Most students selecting this program have chosen not to pursue a PhD but wish to have a greater depth in the fundamentals before embarking on an industrial career.

**B.S.E. in Chemical Engineering / M.Eng. in Energy Systems Engineering**

The program aims to prepare students to design and implement energy systems for innovative applications. An overall GPA of 3.2 or above is required.

**B.S.E. in Chemical Engineering / M.S.E. in Environmental and Water Resources Engineering**

Undergraduate students who will be within 6 credit hours of graduation the term in which they start the SUGS program and have a cumulative GPA of at least 3.5 may apply.

**B.S.E. in Chemical Engineering / M.S.E. in Industrial and Operations Engineering**

Non-IOE engineering students pursue the IOE master’s degree either as the first step toward the IOE Ph.D. degree, or more typically to enhance their qualifications for business-focused professional engineering careers. Applicants must have a minimum GPA of 3.5.

**B.S.E. in Chemical Engineering / M.S.E. in Macromolecular Science and Engineering**

The Master’s in Macromolecular Science and Engineering degree is a 30-credit program focusing on polymer science and engineering, with several specializations from which to choose. A 3.5 GPA is required to apply for this program.

**B.S.E. in Chemical Engineering / M.Eng. in Manufacturing**

The Master of Engineering in Manufacturing (M.Eng. in Mfg.) degree is a professional practice-oriented degree designed to further the education of engineers who already have experienced working in industry and plan to return to an industrial environment after completing their studies. The degree requirements can be completed in one calendar year (12 months). This degree combines course work from various
engineering disciplines (80%) and business (20%). Applicants to this program must have completed 80 or more credits of course work with a GPA of 3.2 or better.

**B.S.E. in Chemical Engineering / M.S.E. in Materials Science and Engineering**

Students who enter a Chemical Engineering program out of an interest in chemistry could opt to pursue a master's in Materials Science and Engineering. This master’s degree enhances their understanding of the relationship between chemical structure, processing and material properties, which in turn prepares them to pursue careers in research, design or manufacturing of materials. A GPA of 3.5 is required to apply.

**B.S.E. in Chemical Engineering / M.Eng. in Pharmaceutical Engineering**

The Master of Engineering (M.Eng.) degree is intended to focus more on professional practice in the pharmaceutical field than the traditional Master of Science in Engineering (M.S.E.) degree. A GPA of 3.5 is required to apply. (This program is not currently accepting applications.)

**Graduate Degrees**

- Master of Science in Engineering (M.S.E.) in Chemical Engineering
- Doctor of Philosophy (Ph.D.) in Chemical Engineering

**M.S.E. in Chemical Engineering**

The minimum requirement for the M.S.E. degree for a student entering with a baccalaureate degree in chemical engineering is 30 graduate credit hours with an average grade of “B.” A thesis is not required. The coursework must include at least 21 hours in chemical engineering (courses with a CHE prefix), of which up to 6 credit hours of research are accepted (e.g., CHE 695); and at least four credits outside the chemical engineering program. The required courses are Fluid Flow (CHE 527), Statistical and Irreversible Thermodynamics (CHE 538), Chemical Reactor Engineering (CHE 528), Transport Processes (CHE 542), Chemical Engineering Research Survey (CHE 595) and Math for Chemical Engineers (CHE 505). Each student is encouraged to develop a program to fit his or her professional objective and should consult with the graduate advisor concerning a plan of study.

**Ph.D. in Chemical Engineering**

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the result of the investigation in the form of a dissertation.
A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. Candidacy is achieved when the student demonstrates competence in her/his broad field of knowledge through completion of a prescribed set of courses and passing a comprehensive examination.

The course requirements are the same as the M.S.E. degree, plus six (6) additional graduate level credits. Students must pass a comprehensive examination in chemical engineering and be recommended for candidacy for the doctorate. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.

Information on the general procedure leading to the doctorate is available at the Graduate School website, http://www.rackham.umich.edu.

Contacts

Departmental Website: http://che.engin.umich.edu/

Chemical Engineering Department
3074 H. H. Dow
2300 Hayward St.
Ann Arbor, MI 48109-2136

E-mail: ChEUGOffice@umich.edu
Phone: (734) 764-2383
Fax: (734) 763-0459

Chemical Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin
Website: https://bulletin.engin.umich.edu/courses/course-info/

200 Level Courses

CHE 230. Introduction to Material and Energy Balances
Prerequisite: ENGR 100, ENGR 101 (ENGR 151), Chem 130, and Math 116. (4 credits)
An introduction to material and energy balances in chemical engineering applications, including environmental and biological systems. Engineering problem-solving, the equilibrium concept, first law of thermodynamics. Introduction to chemical engineering as a profession. CourseProfile (ATLAS)

CHE 290. Directed Study, Research, and Special Problems
Prerequisite: First or second year standing, and permission of instructor. (1-16 credits)
Provides an opportunity for undergraduate students to work in chemical engineering research or
design problems. For each hour of credit, it is expected that the student will work four hours per week in a full term. Oral presentation and/or written report due at end of term. Not open to graduate students. 

CHE 296. Special Topics in Chemical Engineering
No Prerequisite. (1-4 credits)
Selected topics pertinent to lower-level chemical engineering students. 

300 Level Courses

CHE 330. Chemical and Engineering Thermodynamics
Prerequisite: CHE 230. (4 credits)
Development of fundamental thermodynamic property relations and complete energy and entropy balances. Analysis of heat pumps and engines and use of combined energy-entropy balance in flow devices. Calculation and application of total and partial properties in physical and chemical equilibria. Prediction and correlation of physical/chemical properties of various states and aggregates. Elements of statistical thermodynamics. 

CHE 341. Fluid Mechanics
Prerequisite: Preceded by Physics 140 and Math 215, preceded or accompanied by CHE 230 and Math 216. (4 credits)

CHE 342. Mass and Heat Transfer
Prerequisite: CHE 230, CHE 341, and Math 216. (4 credits)

CHE 343. Separation Processes
Prerequisite: CHE 230, CHE 330 and preceded or accompanied by CHE 342. (4 credits)
Introduction and survey of separations based on physical properties, phase equilibria and rate processes. Emphasis on analysis and modeling of separation processes. Staged and countercurrent operations. Includes applications to chemical, biological, and environmental systems. 

CHE 344. Reaction Engineering and Design
Prerequisite: CHE 330, CHE 342. (4 credits)

CHE 360. Chemical Engineering Laboratory I
Prerequisite: CHE 342, CHE 343. (4 credits)
Experimentation in thermodynamics and heat, mass and momentum transport on a bench scale. Measurement error estimation and analysis. Lecture, laboratory, conferences and reports. Technical communications.
400 Level Courses

CHE 405 (ENGR 405). Problem Solving and Troubleshooting in the Workplace  
*Prerequisite: Senior Standing. (3 credits)*  
The course goals are to help students enhance their problem solving, critical thinking, creative thinking and troubleshooting skills and to ease the transition from college to the workplace. The course includes a few speakers from industry. Students work in teams to complete the home problems and the term project. [CourseProfile (ATLAS)]

CHE 407. Process Safety Risk Management  
*Advisory Prerequisite: ChE 330, 341 or graduate standing. (2 credits)*  
Process safety focuses on the prevention and mitigation of catastrophic releases of hazardous materials that may lead to fires, explosions, or toxic impacts. This course prepares students for process hazard evaluation, consequence analysis, accident investigation, and risk management. Speakers from industry will present first-hand knowledge of industrial process safety. [CourseProfile (ATLAS)]

CHE 412 (MacroSE 412) (MATSCIE 412). Polymeric Materials  
*Prerequisite: MATSCIE 220 or 250. (4 credits)*  
The synthesis, characterization, microstructure, rheology and properties of polymer materials. Polymers in solution and in the liquid, liquid-crystalline, crystalline and glassy states. Engineering and design properties, including viscoelasticity, yielding and fracture. Forming and processing methods. Recycling and environmental issues. [CourseProfile (ATLAS)]

CHE 431. Engineering Statistics and Problem Solving  
*Prerequisite: ChE 342 & ChE 343. Minimum grade required for enforced prerequisite is C-. (3 credits)*  
Introduction to the application of various statistical techniques, such as regression, hypothesis testing and design of experiments, to the analysis of data, particularly as applied to solving problems in the engineering field. Examples will be drawn from situations in manufacturing, and where possible, the chemical industry specifically. [CourseProfile (ATLAS)]

CHE 444. Applied Chemical Kinetics  
*Prerequisite: Chem 260 or 261, CHE 344. (3 credits)*  
Fundamentals of chemical and engineering kinetics from a molecular perspective. Relationship between kinetics and mechanisms. Kinetics of elementary steps in gas, liquid and supercritical fluid reaction media. Gas-solid and surface reactions. Heterogeneous and homogeneous catalysis. Kinetics and mechanisms of chemical processes such as polymerization, combustion and enzymatic reactions. [CourseProfile (ATLAS)]

CHE 460. Chemical Engineering Laboratory II  
*Prerequisite: CHE 343 and CHE 360. Minimum grade required for enforced prerequisite is C-. (4 credits)*  
Experimentation in rate and separation processes on a scale that tests process models. Introduction to the use of instrumental analysis and process control. Introduction to biochemical processes. Lecture, laboratory, conferences, reports. Technical communications. [CourseProfile (ATLAS)]

CHE 466. Process Dynamics and Control  
*Prerequisites: CHE 343, CHE 344. (3 credits)*  
Introduction to process control in chemical engineering. Control architecture design, notation and implementation. Mathematical modeling and analysis of open-loop and closed-loop process dynamics. Applications to the control of level, flow, heat exchangers, reactors and elementary multivariable systems. Statistical process control concepts. [CourseProfile (ATLAS)]
CHE 470. Colloids and Interfaces
*Prerequisite: CHE 343, CHE 344. (3 credits)*
This is a first course in colloid and interface science. The repulsive forces and attractive forces at interfaces are described along with the dynamics of the interfaces. Topics include the stability of macroemulsions, the formulation and properties of microemulsions and surface metal-support interactions of catalysts. [CourseProfile (ATLAS)](https://www.atlas.indiana.edu)

CHE 472. Polymer Science and Engineering
*Prerequisite: Preceded or accompanied by CHE 344. (4 credits)*
Polymer reaction engineering, characterization and processing for chemical engineers. Polymerization mechanisms, kinetics and industrial equipment. Thermodynamics of polymer solutions, morphology, crystallization and mechanical properties. Polymer processing equipment and technology. Adhesives, diffusion in polymers, reactive polymeric resins and biological applications of macromolecules. [CourseProfile (ATLAS)](https://www.atlas.indiana.edu)

CHE 485. Chemical Engineering Process Economics
*Prerequisite: CHE 343 (1 credit)*
Economic and profitability analysis as applied to chemical engineering processes and products. Estimation of capital investment, cost of production, depreciation and cash flows. Discounted profitability analysis including net present value, internal rate of return and discounted payback period. Profitability decision making based on cost of capital and economic risk analysis. ChE process optimization based on economic profitability. Students will connect economics and business principles to real chemical engineering processes, as previously learned in the core chemical engineering courses of fluid mechanics, heat and mass transfer and separations. [CourseProfile (ATLAS)](https://www.atlas.indiana.edu)

CHE 487. Process Simulation and Design
*Prerequisite: CHE 360 and CHE 344, and (MSE 220 or MSE 250) or graduate standing; preceded or accompanied by CHE 485. (5 credits)*
Computer simulation of process and components. A major team design project with progress reports, oral presentation, and a technical report with engineering drawings and economics. [CourseProfile (ATLAS)](https://www.atlas.indiana.edu)

CHE 488. Chemical Product Design I
*Prerequisite: CHE 344, preceded or accompanied by CHE 360. Minimum grade of “C-“. (2 credits)*
Part one of a two-semester chemical product design sequence. Teams develop the process for a new chemical product that meets industrial, federal and local regulations. Survey development, literature research and development of an appropriate manufacturing process. Oral and written technology and economic feasibility reports. Safety, environmental and ethical issues. [CourseProfile (ATLAS)](https://www.atlas.indiana.edu)

CHE 489. Chemical Product Design II
*Prerequisite: CHE 488 and CHE 360, preceded or accompanied by CHE 485 and MSE 220 or 250. Minimum grade of “C-“. (3 credits)*
Part two of a two-semester chemical product design sequence. Teams produce a consumer-ready prototype of a chemical product. Development of control and regulatory tests to ensure the product meets all relevant industrial, federal and local regulations. Oral and written technology and economic reports. Safety, environmental and ethical issues. [CourseProfile (ATLAS)](https://www.atlas.indiana.edu)

CHE 490. Advanced Directed Study, Research and Special Problems
*Prerequisite: CHE 230 & CHE 341 or CHE 290 or equivalent and permission of instructor. (1-16 credits) (Up to 8 credits of ChE 490 may be taken for a grade. Beyond that, ChE 490 credits must be taken pass/fail.)*
Provides an opportunity for undergraduate students to work in chemical engineering research or design problems. For each hour of credit, it is expected that the student will work four hours per
week in a full term. Oral presentation and/or written report due at end of term. Not open to graduate students. CourseProfile (ATLAS)

**CHE 496. Advanced Special Topics in Chemical Engineering**  
Prerequisite: CHE 342 & CHE 343. Minimum grade of “C-” required for enforced prerequisites. (1-16 credits)  
Selected advanced undergraduate topics pertinent to chemical engineering. CourseProfile (ATLAS)

**CHE 497. Special Topics in Chemical Engineering**  
Prerequisite: CHE 342 & CHE 343. Minimum grade of “C-” required for enforced prerequisites. (1-16 credits)  
Selected topics pertinent to chemical engineering. CourseProfile (ATLAS)

## 500 Level Courses

**CHE 500/CEE 500/ENSCEN 500 Environmental Systems and Processes**  
Prerequisite: CEE 460. (3 credits)  
Concepts of environmental systems and principles of related transport and transformation phenomena and processes; development of fundamental models for articulation of relevant process dynamics; system and process scaling factors and methods; extension of process models to ideal and nonideal natural and engineered homogeneous environmental systems. CourseProfile (ATLAS)

**CHE 505. Applied Mathematics for Chemical Engineers**  
Prerequisite: graduate standing. (3 credits)  
Analytical and numerical techniques applicable to statistical mechanics, transport phenomena, fluid mechanics and reaction engineering. Groups and linear spaces; tensors and linear operators; computational approaches to nonlinear systems and integration; special functions; spectral theory of ordinary and partial differential equations; series expansions; coordinate transformations; complex algebra and analysis; integral transformations. CourseProfile (ATLAS)

**CHE 510. Mathematical Methods in Chemical Engineering**  
Prerequisite: graduate standing, differential equations. (3 credits)  
Linear algebra, ordinary and partial differential equations, integral equations with chemical engineering applications. Analytical techniques and preliminaries for numerical methods, including: spectral analysis, orthogonal polynomials, Green’s functions, separation of variables, existence and uniqueness of solutions. CourseProfile (ATLAS)

**CHE 511. (MacroSE 511) (MATSCIE 511). Rheology of Polymeric Materials**  
Prerequisite: a course in fluid mechanics or permission of instructor. (3 credits)  
An introduction to the relationships between the chemical structure of polymer chains and their rheological behavior. The course will make frequent reference to synthesis, processing, characterization and use of polymers for high technology applications. CourseProfile (ATLAS)

**CHE 512. (MacroSE 512) (MATSCIE 512). Physical Polymers**  
Prerequisite: senior or graduate standing in engineering or physical science. (3 credits)  
Structure and properties of polymers as related to their composition, annealing and mechanical treatments. Topics include creep, stress-relaxation, dynamic mechanical properties, viscoelasticity, transitions, fracture, impact response, dielectric properties, permeation and morphology. CourseProfile (ATLAS)

**CHE 516. Applied Pharmacokinetics and Toxicokinetics**  
Prerequisite: CHE 344 or equivalent. (3 credits)  
This course focuses on (1) ADME process (Absorption, Distribution, Metabolism, Elimination) and the major pathways and mechanisms (e.g. transporters, liver enzymes, etc.); (2) basic concepts of
pharmacokinetics/pharmacodynamics and their application in drug discovery/development; (3) introduction to pharmacokinetic analysis using WINNONLIN. CourseProfile (ATLAS)

CHE 517 (MFG 517) (PHARMSCI 717). Biopharmaceutical Engineering
Advisory prerequisite: BIO 172 or equivalent AND CHE 330 or BIOMEDE 221 or CHEM 230, or graduate standing or enrollment in PharmD program. (3 credits)
Covers fundamental concepts essential for the discovery, development and characterization of biopharmaceuticals. Topics include basic immunology, molecular biology and cloning, in vitro protein library generation and screening, antibody discovery and engineering, biophysical characterization, and protein expression and purification. CourseProfile (ATLAS)

CHE 519 (Pharm 519). Pharmaceutical Engineering
Prerequisite: Senior or graduate standing, permission by instructor. (3 credits)
Concepts necessary in the adaptation of engineering principles to pharmaceutical and life sciences related industries. Topics include process engineering in drug discovery, high throughput characterization and optimization of new chemical entities, solid-state engineering and intelligent pharmaceutical manufacturing systems. CourseProfile (ATLAS)

CHE 520 (Pharm 761). Population Pharmacokinetics
Prerequisite: Pharm Sci 560 or permission of instructor (2 credits)
This course teaches the basic concepts in population pharmacokinetic (PK) and pharmacodynamic (PD) modeling and its application in drug development. The material covers both the theoretical and practical aspects of the population approach. Software (WINNONLIN, NONMEN, and SPLUS) will be installed in a centralized area for hands-on training and learning. CourseProfile (ATLAS)

CHE 527. Fluid Flow
Prerequisite: CHE 341. (3 credits)
Applications of fluid dynamics to chemical engineering systems. Theory and practice of laminar and turbulent flow of Newtonian and non-Newtonian fluids in conduits and other equipment. Multi-phase flow. Introduction to the dynamics of suspended particles, drops, bubbles, foams and froth. Selected topics relevant to chemical and other engineering disciplines. CourseProfile (ATLAS)

CHE 528. Chemical Reactor Engineering
Prerequisite: CHE 344. (3 credits)
Analysis of kinetic, thermal, diffusive and flow factors on reactor performance. Topics include batch, plug flow, backmix reactors, empirical rate expressions, residence time analysis, catalytic reactions, stability and optimization. CourseProfile (ATLAS)

CHE 531. Introduction to Chemoinformatics
Prerequisite: Senior or Graduate Standing. Permission by Instructor. (3 credits)
This course is designed to give students an overview of chemoinformatics techniques, in particular their application in the pharmaceutical industry. Topics include: representation and use of chemical structures, chemical databases, molecular modeling, 3D visualization and computation, ADME/tox prediction and hot topics in the pharmaceutical industry. CourseProfile (ATLAS)

CHE 538. Statistical and Irreversible Thermodynamics
Prerequisite: CHE 330. (3 credits)
The laws of probability and statistics are applied to microscopic matter to yield properties of macroscopic systems. Relations between classical and statistical thermodynamics are developed. Coupling of irreversible processes is treated through the entropy balance and microscopic reversibility. CourseProfile (ATLAS)

CHE 540. Mathematical Methods for Biological Network Analysis
Prerequisite: senior or graduate standing, permission by instructor. (3 credits)
This course focuses on methods and applications. Methods include ordinary differential equations, mathematical programming, Bayesian networks and statistical analysis, etc. Applications to the
modeling of various biological systems are discussed and students perform a critical evaluation of current literature as well as hands-on computational projects using high level computing languages. **CourseProfile (ATLAS)**

**CHE 542. Intermediate Transport Phenomena**  
*Prerequisite: graduate standing. (3 credits)*  

**CHE 543. Advanced Separation Processes**  
*Prerequisite: CHE 343. (3 credits)*  
Forces for adsorption, equilibrium adsorption isotherms, sorbent materials, pore size distribution, heterogeneity, predicting mixture adsorption, rate processes in adsorption/adsorbers, adsorber dynamics, cyclic adsorption processes, temperature and pressure swing adsorption, membrane separation processes, polymer membranes, dialysis electrolysis, pervaporation, reverse osmosis, research projects. **CourseProfile (ATLAS)**

**CHE 548. Electrochemical Engineering**  
*Prerequisite: CHE 344. (3 credits)*  
Analysis of electrochemical systems from a theoretical and practical point of view. Topics include the application of electrochemical thermodynamics and kinetics to batteries, fuel cells, electroplating, electrosynthesis and corrosion. **CourseProfile (ATLAS)**

**CHE 554. (MATSCIE 554). Computational Methods in MS&E and CHE**  
*Prerequisite: none. (3 credits)*  
Broad introduction to the methods of numerical problem solving in Materials Science and Chemical Engineering. Topics include numerical techniques, computer algorithms and the formulation and use of computational approaches for the modeling and analysis of phenomena peculiar to these disciplines. **CourseProfile (ATLAS)**

**CHE 557 (MATSCIE 557). Computational Nanoscience of Soft Matter**  
*Prerequisite: Differential equations course, and a statistical thermodynamics or statistical mechanics course. (3 credits)*  
Provides an understanding of strategies, methods, capabilities and limitations of computer simulation as it pertains to the modeling and simulation of soft materials at the nanoscale. The course consists of lectures and hands-on, interactive simulation labs using research codes and commercial codes. Ab initio, molecular dynamics, Monte Carlo and mesoscale methods. **CourseProfile (ATLAS)**

**CHE 558 (MATSCIE 558) (Macro 558). Foundations of Nanotechnology**  
*Prerequisite: senior or graduate standing. (3 credits)*  
The focus of this course is on the scientific foundations of nanotechnology. The effects of nanoscale dimensions on optical, electrical, and mechanical properties are explained based on atomistic properties and related to applications in electronics, optics, structural materials and medicine. Projects and discussions include startup technological assessment and societal implications of the nanotechnology revolution. **CourseProfile (ATLAS)**

**CHE 559 (MATSCIE 559) (MACROMOL 559). Foundations of Nanotechnology II**  
*Prerequisite: senior or graduate standing. (3 credits)*  
This course will cover the synthesis and processing of nano-sized metal, metal oxide, and semiconductor powders. It will also include organic/inorganic and nanobiomaterials. Emphasis will be on particle properties and their use in making nonstructured materials with novel properties. **CourseProfile (ATLAS)**
CHE 563. (BIOMEDE 563) (MATSCIE 563) Biomolecular Engineering of Interfaces
Prerequisite: senior or graduate standing. (3 credits)
This class focuses on biomolecular engineering of surfaces and interfaces in contact with biological systems. Recent advances in the interfacial design of materials as well as methods that enable studying such systems will be highlighted. CourseProfile (ATLAS)

CHE 568. Fuel Cells and Fuel Processors
Prerequisite: ChE 344 and senior or graduate standing (3 credits)
This course provides a comprehensive overview of the major fuel cell types, with emphasis on PEM and SOFC fuel cells. The scientific and engineering principles of fuel cell technology and catalytic fuel processing will be covered. The course also reviews hydrogen properties, storage and safety issues. CourseProfile (ATLAS)

CHE 574. Engineering Principles in Drug Delivery and Targeting
Prerequisite: senior or graduate standing. (3 credits)
This course focuses on engineering aspects of designing Drug Delivery and Targeted Systems for human use. Sample topics include: carriers and biocompatibility issues in DDT; passive and active targeting; organ and disease specific targeting; and barriers to use of DDTS. Assessment will include problem sets, a student project and exams. CourseProfile (ATLAS)

CHE 578. Molecular Heterogeneous Catalysis and Electro-Catalysis
Prerequisite: Senior or graduate standing. (3 credits)
The course will address numerous topics including: 1) Chemical bonding on metal surfaces; 2) Various experimental and theoretical tools that are used to study chemical transformations on surfaces at molecular level. The material will be discussed through a number of examples addressing contemporary issues related to the fields of energy and environment. We will also discuss strategies that can be utilized to employ molecular insights to identify optimal electrocatalysts for different electrochemical processes. CourseProfile (ATLAS)

CHE 584 (BiomedE 584) (Biomat 584). Tissue Engineering
Prerequisite: Biology 310 or 311, ChE 517, or equivalent biology course; senior standing. (3 credits)
Fundamental engineering and biological principles underlying field of tissue engineering are studied, along with specific examples and strategies to engineer specific tissues for clinical use (e.g. skin). Student design teams propose new approaches to tissue engineering challenges. CourseProfile (ATLAS)

CHE 588 (BIOMEDE 588). Global Quality Systems and Regulatory Innovation
Prerequisite: senior or graduate students enrolled in the CoE and health related professional schools. (2 credits)
This course is for scientists, engineers, and clinicians to understand and interpret various relevant global and regional quality systems for traditional and cutting edge global health technologies, solutions and their implementation. Speakers from academia, the FDA, and biomedical related industries will be invited to participate in teaching this course. CourseProfile (ATLAS)

CHE 590 (CEE 588). Sustainability Finance: Investment Models for Green Growth
Advisory Prerequisite: senior or graduate standing. (3 credits)
The course reviews a range of financial innovations and investment models to scale capital allocations and reduce climate risks in portfolios, while driving green growth. CourseProfile (ATLAS)

CHE 595. Chemical Engineering Research Survey
(2 credits)
Research activities and opportunities in Chemical Engineering program. Lectures by University of Michigan faculty and guest lecturers. Topics are drawn from current research interests of the faculty. CourseProfile (ATLAS)
CHE 596 (Pharm 596). Health Science and Engineering Seminar
Prerequisite: graduate standing advised. (1 credit)
This seminar will feature invited speakers from pharmaceutical, biomedical and other life sciences-related industries, and academic institutions. CourseProfile (ATLAS)

CHE 597 (Pharm 597). Regulatory Issues for Scientists, Engineers, and Managers
Prerequisite: permission of instructor. (2 credits)
Science- and technology-based rationale behind various regulatory issues involved in pharmaceutical and related industries. CourseProfile (ATLAS)

CHE 598. Advanced Special Topics in Chemical Engineering
Prerequisite: none. (min. 2, max. 4 credits)
Selected topics pertinent to chemical engineering. CourseProfile (ATLAS)

600 Level Courses

CHE 601. Chemical Engineering Seminar
Prerequisite: Graduate standing (1 credit)
This seminar will feature various chemical engineering-related speakers. CourseProfile (ATLAS)

CHE 606. Microfluidic Science and Engineering
Advisory Prerequisite: Graduate standing or permission from the instructor. (3 credits)
This course exposes students to both the theoretical and applied aspects of microfluidics, with a particular emphasis on designing microfluidic biological assays. The class provides broad exposure to fluid dynamic, surface phenomena and mass transfer concepts related to microfluidics in an effort to provide a theoretical underpinning for microfluidic device design. CourseProfile (ATLAS)

CHE 616 (BiomedE 616). Analysis of Chemical Signaling
Prerequisite: Math 216, Biochemistry 415. (3 credits)
Quantitative analysis of chemical signaling systems, including receptor/ligand binding and trafficking, signal transduction and second messenger production and cellular responses such as adhesion and migration. CourseProfile (ATLAS)

CHE 617 (Mfg 617). Advanced Biochemical Technology
Prerequisite: CHE 517 or permission of instructor. (3 credits)
Practical and theoretical aspects of various unit operations required to separate and purify cells, proteins and other biological compounds. Topics covered include various types of chromatography, liquid/liquid extractions, solid/liquid separations, membrane processing and field-enhanced separations. This course will focus on new and non-traditional separation methods. CourseProfile (ATLAS)

CHE 628. Industrial Catalysis
Prerequisite: CHE 528. (3 credits)
Theoretical and experimental aspects of heterogeneous catalysis and surface science. Design, preparation, and characterization of catalysts. Kinetics of heterogeneous catalytic reactions, thermal and diffusional effects in catalytic reactors. Case studies of important industrial catalytic processes. CourseProfile (ATLAS)

CHE 629 (Physics 629). Complex Fluids
Prerequisite: CHE 527. (3 credits)
Structure, dynamics, and flow properties of polymers, colloids, liquid crystals and other substances with both liquid and solid-like characteristics. CourseProfile (ATLAS)

CHE 686 (CEE 686) (ENSCEN 686). Case Studies in Environmental Sustainability
Prerequisite: Senior or Graduate Standing. (2-3 credits)
Case studies focusing on utilization of principles of environmental sustainability in professional practice. Development of environmental literacy through study of both current and historical environmental issues. CourseProfile (ATLAS)

**CHE 695. Research Problems in Chemical Engineering**  
*Prerequisite: Graduate students and admitted SGUS students with graduate advisor's permission.*  
(1-16 credits)  
Laboratory and conferences. Provides an opportunity for individual or group work in a particular field or on a problem of special interest to the student. The program of work is arranged at the beginning of each term by mutual agreement between the student and a member of the faculty. Any problem in the field of chemical engineering may be selected. The student writes a final report on his project. CourseProfile (ATLAS)

**CHE 696. Selected Topics in Chemical Engineering**  
*Selected topics pertinent to chemical engineering. CourseProfile (ATLAS)*

**CHE 697. Problems in Chemical Engineering**  
*(to be arranged) CourseProfile (ATLAS)*

**CHE 698. Directed Study in Chemical Engineering**  
(1-16 credits)  
This project course is intended to provide students with relevant industrial project experience. The program of work is arranged at the beginning of each term by mutual agreement between the student and a member of the faculty. Any problem in the field of chemical engineering may be selected. The student writes a final report on his project. CourseProfile (ATLAS)

### 700 Level Courses

**CHE 751 (Chem 751) (MacroSE 751) (MATSCIE 751) (Physics 751). Special Topics in Macromolecular Science**  
*Prerequisite: permission of instructor. (2 credits)*  
Advanced topics of current interest will be stressed. The specific topics will vary with the instructor. CourseProfile (ATLAS)

### 900 Level Courses

**CHE 990. Dissertation/Pre-Candidate**  
*(1-8 credits)*  
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

**CHE 995. Dissertation/Candidate**  
*Prerequisite: Graduate School authorization for admission as a doctoral candidate. (4 or 8 credits)*
Civil
and
Environmental Engineering
Overview

Civil and environmental engineers design, plan and construct infrastructure systems including buildings, bridges, highways, airports, tunnels, pipelines, channels, wastewater systems, waste site, remediation systems, power generating plants, manufacturing facilities, dams and harbors. These infrastructure systems are key to sustaining human development and activities, and civil and environmental engineers must consider technical as well as economic, environmental, aesthetic and social aspects.

To recognize the distinct qualifications of engineers entering the fields of Civil and Environmental Engineering, the Department offers undergraduate programs leading to a Bachelor of Science in Engineering in Civil Engineering and a Bachelor of Science in Engineering in Environmental Engineering. The Civil Engineering major offers several focus areas of specialization including: Construction Engineering & Management, Environmental Engineering, Geotechnical Engineering, Hydraulic and Hydrological Engineering, Civil Engineering Materials, Structural Engineering, and Transportation Systems Engineering. The Environmental Engineering major allows curricular focus in the areas of Water Quality and Health, Earth Systems, Environmental Fluid Dynamics and Environmental Policy and Sustainable Infrastructure. For more information on these fields and majors, please visit: http://cee.umich.edu/research.

A minor in Environmental Engineering is also offered through the Department. Eligibility information and requirements of the minor are described at http://cee.engin.umich.edu/minor-environmental-engineering.

Students who do well in their undergraduate program are encouraged to consider graduate work and may take some of their electives in preparation for graduate study. The Sequential Undergraduate/Graduate Studies program available in this department is described http://cee.engin.umich.edu/sequentialapplicants.

Information and assistance regarding fellowships and assistantships for graduate studies may be obtained in the Graduate Student Services of the Department of Civil and Environmental Engineering.

Department Administration

Department Chair

Professor Jerome P. Lynch, Donald Malloure Department Chair of Civil and Environmental Engineering

2120 G G Brown Laboratory

For more specific information on contacting people, go to http://cee.umich.edu/people.
Mission Statements

Civil Engineering

Civil engineers design, plan, and improve the built environment and infrastructure systems, including buildings, power generation facilities, water supply networks, pollution control works, flood protection structures, dams, and canals, as well as vital network systems for commerce such as roadways, airports, railroads, and ports. Civil engineering encompasses several subdisciplines, including hydraulics and hydrology, structural, geotechnical, construction, environmental, civil engineering materials, and transportation engineering.

Coursework in the major builds especially on a strong foundation in math and physics, and exposes students to these subdisciplines. An emphasis in the sustainable engineering of civil infrastructure is also provided by the curriculum.

Mission

As a leading educational and research institution, we are driving the development of innovative technologies that:

- Enhance the performance and sustainability of civil and environmental infrastructure
- Have a favorable impact on the natural environment; and
- Manage complex issues at the intersection of built and natural systems.

We are committed to solving major societal problems by providing forward-looking education, enhancing multidisciplinary research and performing broad-based service.

Goals

To accomplish our mission, we must:

- Provide an enriching educational environment, together with extracurricular and service opportunities, that prepare our students to:
  - Excel as leaders in the understanding, design, construction, operation and maintenance of civil and environmental infrastructural systems,
  - Be ethical stewards of the built and natural environments, and
  - Adapt to an ever-changing profession through lifelong learning.
- Recruit, educate and support students, researchers, staff and faculty from diverse backgrounds, and provide them with the foundation to become global leaders;
- Enhance the department’s positive impact nationally and internationally and make transformative contributions within the State of Michigan;
- Champion the translation of research findings into professional practice;
- Provide a technical foundation for shaping policy that addresses the complex issues facing civil and environmental infrastructure systems and the natural environment;
• Foster a leading-edge collaborative environment that is well-positioned to address high-impact research issues and provide solutions to critical societal challenges; and
• Foster and support the spirit of entrepreneurship among our students, faculty, and staff.

Objectives
The following set of objectives describes what our graduates are expected to achieve within several years of graduation.

• The graduates of the Civil Engineering Program at Michigan will have the necessary intellectual tools and technical skills to take on careers of leadership in the development of new technologies, construction of innovative and sustainable infrastructure, the design of engineered systems at the intersection of natural and built environments, and to contribute to society through participation in policy making and governance.
• Graduates will have a solid foundation in civil engineering and will achieve success in graduate education and a broad range of career opportunities.
• Our graduates will become team leaders, and will successfully address open-ended problems applying critical thinking.
• The U-M Civil Engineering graduates will become effective communicators of technical and professional information in written, oral, visual and graphical form.
• Professional careers of U-M graduates will be distinguished with a high degree of awareness of moral, ethical, legal and professional obligations to protect human health, human welfare, and the environment.

Outcomes
The outcomes we desire are that graduates of the University of Michigan Civil Engineering Program demonstrate:

• An ability to apply knowledge of mathematics, science, and engineering.
• An ability to design and conduct experiments, as well as to analyze and interpret data.
• An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
• An ability to function in multi-disciplinary teams.
• An ability to identify, formulate and solve engineering problems.
• An understanding of professional and ethical responsibility.
• An ability to communicate effectively.
• The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
• A recognition of the need for, and an ability to engage in life-long learning.
• A knowledge of contemporary issues.
An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Civil Engineering Focus Areas

The following are areas of focus within Civil Engineering at Michigan:

**Construction Engineering and Management**

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

**Environmental Engineering**

The principles, design and methods for implementation of sustainable environmental and earth systems; water resource development, management, conservation and systems design; engineering of water quality and pollution control processes and systems; treatment, distribution and collection networks and infrastructures for optimal municipal and industrial water use, recovery and recycle; environmental design for efficient energy and resource utilization and minimization of water and air pollution and solid wastes generation; modeling of the fate and transport of contaminants in environmental media and systems and quantitative assessment of associated human and ecological risks.

**Geotechnical Engineering**

Evaluation of soil properties and environmental conditions in foundations of earth-supported structures; mass stability in excavations and subsurface construction; use of soil characteristics and properties and soil classification in design and construction of highways, railways, airports, and other surface facilities; landslides, levees and slope stability.

**Hydraulic and Hydrological Engineering**

Development of surface water and ground-water resources; flood prediction and flood control, flow of contaminant transport in surface and ground waters, transients in pipelines and channels, coastal engineering and design of structures to interface with the water environment.

**Civil Engineering Materials**

Analysis, engineering, and testing of civil engineering materials pertaining to infrastructure renewal and high-performance structures, including the study of infrastructure rehabilitation (including bridge and pavement technology), advanced emerging materials (including cement-based composites, polymers and ceramics), micro-mechanics of composite materials and durability of materials.
**Structural Engineering**

Theory, analysis, design and construction of structures such as bridges, buildings, towers, and housing, involving the use of steel, reinforced concrete, pre-stressed concrete, fiber reinforced concrete, advanced composites, and wood; studies of inelastic behavior of materials and structures; studies of dynamic forces and their effects on structures. Response of structures to earthquakes, fires and terrorist attacks.

**Transportation Systems Engineering**

Analysis, develop, and test of ongoing issues with the existing transportation system: high fatality and injury rates, growing levels of congestion and pollution, rising transportation costs, and inefficient use of resources; development of information for vehicular technologies. Connected and automated vehicle (CAV) technologies will further revolutionize urban and rural mobility and support a range of uses, from sole vehicle ownership to shared ownership, ridership, and subscription services. These technologies hold the potential to substantially improve traffic safety, facilitate mobility, and reduce traffic congestion, fuel consumption, and emissions.

**Environmental Engineering**

Environmental engineers design systems to provide safe water, air, and land for human habitation, and to address the impact of human activities on the environment. For example, environmental engineers may be involved in the design of technologies to remove emerging contaminants from drinking water, monitor and mitigate greenhouse gas compounds, recover resources and energy from waste streams, design sustainable alternative energy sources, clean up hazardous waste sites, or restore streams and lakes damaged by human activities.

In this major, a strong foundation in math, chemistry, physics, biology, and earth science is important, and the engineering tools to apply them are provided in the curriculum. The social and policy issues associated with environmental problems are also explored.

**Mission**

To provide an outstanding education in environmental engineering that prepares students for leadership positions in the improvement of human and ecological health at the intersection of built and natural systems.

**Goals**

To provide an enriching educational environment that prepares students with the environmental science and engineering design principles to develop sustainable solutions to environmental problems and the professional skills to become leaders in the discipline.
Objectives

The following objectives describe what our graduates are expected to achieve within several years of graduation:

- The graduates of the Environmental Engineering Program at Michigan will have the necessary intellectual tools and technical skills to take on careers of leadership in the development of new technologies for environmental protection and the design of sustainable modern environmental infrastructure, analysis of natural and engineered environmental systems and to contribute to society through participation in policy making and governance (**Objective 1**);
- Graduates will have a solid foundation in environmental engineering and achieve success in graduate education and a broad range of career opportunities (**Objective 2**);
- Our graduates will become team leaders and have the critical thinking skills to successfully address open-ended problems (**Objective 3**);
- U-M Environmental Engineering graduates will become effective communicators of technical and professional information in written, oral, visual, and graphical form (**Objective 4**); and
- Professional careers of U-M graduates will be distinguished with a high degree of awareness of moral, ethical, legal and professional obligations to protect human health, human welfare and the environment (**Objective 5**).

Outcomes

The outcomes we desire are that graduates of the program demonstrate:

- An ability to apply knowledge of mathematics, science and engineering;
- An ability to design and conduct experiments, and to critically analyze and interpret data;
- An ability to design a system, component or process to meet desired needs;
- An ability to function on multidisciplinary teams;
- An ability to identify, formulate and solve engineering problems;
- An understanding of professional and ethical responsibility;
- An ability to communicate effectively;
- The broad education necessary to understand the impact of engineering solutions in a global/societal context;
- A recognition of the need for and an ability to engage in life-long learning
- A knowledge of contemporary issues;
- An ability to use the techniques, skills and modern engineering tools necessary for engineering practice;
Enrollment and Graduation Data

Civil Engineering

In AY 18-19, 103 students enrolled in the program. In AY18-19, 44 degrees were awarded.

For other terms, the University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

Environmental Engineering

In AY 18-19, 93 students enrolled in the program. In AY18-19, 28 degrees were awarded. For other terms, the University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

Undergraduate Degree Programs

Sample Schedules

B.S.E. in Civil Engineering

The Civil Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. Please see the PDF version of the sample schedule here. Additional information can be found on the department advising website, https://cee.engin.umich.edu/academics/undergraduate/bse-civil-engineering/

B.S.E. in Environmental Engineering

The Environmental Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. Please see the PDF version of the sample schedule here. Additional information can be found on the department advising website, https://cee.engin.umich.edu/academics/undergraduate/bse-environmental-engineering/

Program in Sustainable Engineering

Sustainable engineering is achieved by finding economically viable technology solutions that reduce important environmental and societal concerns. Sustainable Engineering includes finding market and policy pathways to implement technologies that allow people and the plant to prosper and thrive.

The Program in Sustainable Engineering is an academic program that allows undergraduate engineering students to take 9 credit hours of courses focused on sustainability to earn the following notation on their transcript: “Program in Sustainable Engineering”. Individual advising available by emailing
sustainable.engineering@umich.edu. Course requirements and additional information can be found on the PISE website: http://pise.engin.umich.edu.

Sequential Undergraduate/Graduate Studies (SUGS)

SUGS is a program of the Rackham Graduate School which enables students to pursue a five-year combined BSE/MSE. Civil and Environmental Engineering undergraduate students who have a cumulative GPA of at least 3.5 may apply. Students earning dual bachelor’s degrees are not eligible for SUGS. Please contact the department or see the website for more information: http://cee.engin.umich.edu/sequentialapplicants.

The following degree combinations are available through SUGS:

- B.S.E in Civil Engineering / M.S.E. in Civil Engineering
- B.S.E. in Civil Engineering / M.S.E. in Construction Engineering and Management
- B.S.E. in Civil Engineering / M.Eng. in Construction Engineering and Management
- B.S.E. in Civil Engineering/M.S.E. in Environmental Engineering
- B.S.E. in Environmental Engineering / M.S.E. in Environmental Engineering

Graduate

Civil and Environmental Engineering Graduate Programs

Graduate programs of advanced study, research and design are available in the six major areas listed below. The strength of the curriculum is enhanced by a variety of complementary programs of study and research available throughout the University of Michigan.

Construction Engineering and Management

- Construction Organization
- Construction Project
- Construction Operations

Environmental and Water Resources Engineering

Graduate degrees offered in either Civil or Environmental Engineering.

- Ecohydrology and Hydraulic Engineering
- Environmental Microbiology and Biotechnology
- Environmental Chemistry and Soil Physics
- Energy and Clean Tech

Geotechnical Engineering

- Site Characterization
- Stability of Earth Masses
• Geotechnical Earthquake Engineering
• Engineering Geology
• Rock Mechanics
• Foundation Design
• Soil Behavior
• Soil Improvement
• Soil and Foundation Dynamics
• Numerical and Analytical Modeling

**Structural and Materials Engineering**
• Earthquake Resistant Design
• Behavior of Buildings and Bridges under Extreme Loading
• Design and Validation of Smart Structure Technologies
• Evaluation and Improvement of New and Existing Highway Bridges
• Design and Development of High Performance
• Mechanistic Evaluation of Properties of Concrete Pavement

**Intelligent Systems**
• Dynamical Modeling of Complex Intelligent Systems
• Cyber-Physical Intelligent Systems
• Resilience Through Adaptation
• Ultra-low Power Sensing and State Estimation for Civil Intelligent Systems
• Advanced Functional Materials for Intelligent Infrastructure Systems
• Integrated Structure and Materials Design for Infrastructure Resiliency and Sustainability
• Intelligent Water Grids
• Energy Harvesting

**Next Generation Transportation Systems**
• Planning, design, operations, and management of next-generation transportation systems

**Graduate Degrees**
• Master of Science in Engineering (M.S.E.) in Civil Engineering
• Master of Science in Engineering (M.S.E.) in Construction Engineering and Management
• Master of Science in Engineering (M.S.E.) in Environmental Engineering
• Master of Engineering (M.Eng.) in Construction Engineering and Management
• Master of Engineering (M.Eng.) in Structural Engineering
• Master of Engineering (M.Eng.) in Smart Infrastructure Finance
• Dual M.Eng. in Construction Engineering and Management/Master of Architecture
• Dual M.Eng. in Construction Engineering and Management/Master of Business Administration (student initiated dual degree)
- Dual M.S.E. in Construction Engineering and Management/Master of Business Administration
- Dual M.S.E. in Construction Engineering and Management/Master of Science in Engineering
- Dual M.S.E. in Environmental Engineering/MS in Natural Resources and Environment
- Doctor of Philosophy (Ph.D.) in Civil Engineering
- Doctor of Philosophy (Ph.D.) in Environmental Engineering

**Master of Science Programs / Master of Engineering Programs**

The Department of Civil and Environmental Engineering (CEE) offers three Master of Science in Engineering (M.S.E.) degree programs and two Master of Engineering (M.Eng.) degree programs, as well as multiple options for dual degrees in collaboration with other programs at the university. The M.S.E. programs require 30 credit hours of graduate work (typically 10 courses) and has the option to include up to 6 credits of research. The M.Eng. programs require 26 credit hours of graduate work (typically 8 courses and 2 seminars) and do not require a thesis or other major research project.

The Graduate Record Examination (GRE) is required for application to the M.S.E. program. Letters of recommendation are also required. Degree programs differ in the undergraduate degrees they require for regular admission.

Students who do not meet undergraduate degree requirements for regular admission may be granted conditional admission. Students may be required to take courses without graduate credit to remedy the deficiencies in their undergraduate programs.

**M.S.E. in Civil Engineering**

This program requires at least 15 hours of CEE courses. A student should expect to take at least eight hours in the area of specialization but will not be permitted to apply more than 21 hours in one area of specialization toward the M.S.E. degree. Study programs are available in the following areas of specialization:

- Construction Engineering and Management
- Geotechnical Engineering
- Hydraulic and Hydrologic Engineering
- Intelligent Systems
- Materials and Highway Engineering
- Structural Engineering
- Transportation Systems Engineering

Regular admission is open to students holding an undergraduate degree in Civil Engineering or an equivalent.
M.S.E. in Construction Engineering and Management

This program requires at least 18 hours of graduate courses in the Construction Engineering and Management Program. Also available are dual degree programs by which a student can receive a M.S.E. in Construction Engineering and Management and a Master of Business Administration degree. Regular admission is open to students holding a degree in any engineering discipline.

Dual M.S.E. in Construction Engineering and Management/Master of Business Administration

The dual degree program requires the 12 hours of core courses and 9 hours of graduate construction electives in the M.S.E. (CE&M) program and the 30 hours of core courses and 15 hours of electives in the MBA program. Students also take a 3-hour independent study course (CEE 630) to integrate general Construction Engineering and Management skills. Students also take Construction Contracting (CEE 331) if they have not taken it or its equivalent previously. The dual degree program combines the two-year, 60-hour MBA program with the one-year, 30-hour M.S.E. (CE&M) program, resulting in a two-year (including Spring and/or Summer terms) 66- or 69-hour program. The dual degree program can be completed in two years if the first year is devoted to core MBA courses.

Dual M.S.E. in Construction Engineering and Management/Master of Science in Engineering

Dual MSE degree programs combine a 30-hour MSE (CE&M) program with another 30-hour Master's program resulting in a 51-hour program, 9 hours of which satisfy requirements for both programs. Usually these 9 hours are core courses from the other Master's program, used as electives in the Construction Engineering and Management program. An applicant who has recently received or is working toward a Master's degree in another area of engineering at Michigan can complete the MSE (CE&M) with an additional 21 hours of coursework.

M.Eng in Construction Engineering and Management

This two-semester, 26-credit program is designed for those with a bachelor’s degree in civil engineering or equivalent and who want to pursue a professional career in the construction industry. Students with degrees from other disciplines will be accepted into this program but may require additional coursework. The MEng (CE&M) program includes core CE&M courses covering fundamentals, a CE&M elective allowing students to gain in-depth knowledge in specific knowledge areas, and electives in related subjects.

Dual M.Eng in Construction Engineering and Management/Master of Architecture

The dual degree program combines the two-year 60-hour M.Arch. program with the one-year, 26-hour M.Eng. (CE&M) program, resulting in a two and one-half year, 71-hour program.
Dual M.Eng in Construction Engineering and Management/Master of Business Administration

The dual degree program requires the 12 hours of core courses and 9 hours of graduate construction electives in the MEng (CE&M) program and the 30 hours of core courses and 15 hours of electives in the MBA program. Students also take a 3-hour independent study course (CEE 630) to integrate general Construction Engineering and Management skills. Students also take Construction Contracting (CEE 431) if they have not taken it or its equivalent previously. The dual degree program combines the two-year, 60-hour MBA program with the one-year, 26-hour M.Eng. (CE&M) program, resulting in a two-year (including Spring and/or Summer terms) 66- or 69-hour program. The dual degree program can be completed in two years if the first year is devoted to core MBA courses.

M.Eng. in Structural Engineering

This two-semester, 26-credit program is designed for those with a bachelor’s degree in civil engineering or equivalent and who want to pursue a professional career in structural design practice. Students with degrees from other disciplines will be accepted into this program but may require additional coursework. Students in this program will take at least five graduate-level structural engineering courses and will also select a minor area of professional emphasis.

M.S.E. in Environmental Engineering

This program requires at least 18 hours of graduate courses in the Environmental and Water Resources Engineering Program. Specific course requirements are given in the departmental Guidelines for this MSE degree. Students holding an engineering or science degree will be considered for regular admission.

Dual M.S.E. in Environmental Engineering / MS in Natural Resources and Environment:” Engineering Sustainable Systems: Specialization in Sustainable Water Resources or Energy Systems”

This dual degree program combines a Master of Science in Engineering (M.S.E.) in Civil Engineering or in Environmental Engineering, and a Master of Science (M.S.) degree in Natural Resources and Environment. More detailed information is available in the program guidelines.

Ph.D. Programs

The Department of Civil and Environmental Engineering (CEE) offers the Doctor of Philosophy (Ph.D.) with two designations: Civil Engineering and Environmental Engineering. Ph.D. programs usually include 50 to 60 hours of graduate coursework beyond the bachelor’s degree level. Foreign languages are not required. The focus of doctoral studies is the student’s dissertation research, which must make a significant contribution to professional knowledge in the field. Major steps toward the Ph.D. degree include:
• preliminary examination appointment of dissertation committee
• completion of coursework and English proficiency requirement
• advancement to candidacy
• research proposal defense
• final oral exam
• completion of dissertation

Admission to the Ph.D. program is granted only to students who show promise and provide sufficient evidence that they can meet scholastic requirements of study, including independent research, at an advanced level. The preliminary examination is only open to students with a GPA of better than B+.

**Ph.D. in Civil Engineering**

Areas of specialization include:

• Construction Engineering and Management
• Geotechnical Engineering
• Hydraulic and Hydrologic Engineering
• Intelligent Systems
• Materials and Highway Engineering
• Structural Engineering
• Next Generation Transportation Systems

**Ph.D. in Environmental Engineering**

Areas of specialization include:

• Environmental Chemistry and Microbiology
• Hazardous Substance Treatment and Control
• Hydraulics and Fluid Mechanics
• Management Policy and Economics
• Surface and Groundwater Hydrology
• Watershed Hydrology and Ecohydrology
• Water Quality Engineering
• Geostatistical Modeling and Optimization
• Atmospheric Modeling

**Contacts**

• **Departmental Website:** [http://cee.engin.umich.edu/](http://cee.engin.umich.edu/)
• Civil and Environmental Engineering Department
  2105 G. G. Brown Building
  2350 Hayward St.
  Ann Arbor, MI 48109-2125
Civil and Environmental Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under “How to Read a Course Description”, in the CoE Bulletin Website: [https://bulletin.engin.umich.edu/courses/course-info/](https://bulletin.engin.umich.edu/courses/course-info/)

200 Level Courses

- **CEE 200. Introduction to Civil and Environmental Engineering**  
  *Prerequisite: None; mandatory pass/fail. (1 credit)*  
  An introduction to the nature and scope of the civil and environmental engineering disciplines and specialty programs. Includes case studies from practice and information about academic and professional opportunities for CEE students. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

- **CEE 211. Statics and Dynamics**  
  *Prerequisite: Physics 140. (4 credits)*  
  Statics: review of vector mathematics; moment and force resultants; static equilibrium in two & three dimensions; centroids; center of gravity; distributed loadings.  
  Dynamics: review of concepts of velocity and acceleration; dynamics of particles and rigid bodies; concepts of work, energy, momentum; introduction to vibrations. Four lectures per week. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

- **CEE 212. Solid and Structural Mechanics**  
  *Prerequisite: CEE 211 or equivalent. (3 credits). No credit granted to those who have completed or are enrolled in MECHENG 211.*  
  Fundamental principles of solid and structural mechanics and their application in engineering disciplines. Covered: concepts of stress and strain, stress and strain transformations, axial, torsion, bending and combined loading and elastic deformations. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

- **CEE 230. Thermodynamics and the Environment**  
  *Prerequisite: Math 116; Chem 130 & 125/126 or Chem 210 & 211 advised. (3 credits)*  
  The First and Second Laws of thermodynamics are applied to systems impacting built and natural environments to determine the performance requirements and thermodynamic efficiencies of engineered processes. Topics of coverage include the properties of pure substances and mixtures, phase changes, reaction and phase equilibrium, heating, air conditioning, and power generation. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

- **CEE 265. Sustainable Engineering Principles**  
  *Prerequisite: Chem 130, Math 116. (3 credits)*  
  *Credit for only one: CEE 265 or MECHENG 489*  
  Sustainable engineering principles include calculations of environmental emissions and resource consumption. Mass and energy balance calculations in context of pollution generation and prevention, resource recovery and life-cycle assessment. Economic aspects of sustainable engineering decision-making. Social impacts of technology system design decisions including ethical frameworks, government legislation and health risks. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

300 Level Courses

- **CEE 303. Computational Methods for Engineers and Scientists**  
  *Prerequisite: ENGR 101, Math 216. (4 credits)*  
  Applications of numerical methods to infrastructure and environmental problems.
Development of mathematical models and computer programs using a compiled language (FORTRAN). Formulation and solution of initial and boundary-value problems with emphasis on structural analysis, fluid flow and transport of contaminants. Lecture, recitation and computation. CourseProfile (ATLAS)

- **CEE 307 (Envir0n 407). Sustainable Cities**  
  *Advisory Prerequisite: Junior or Senior Standing and two environmental science classes. (3 credits)*  
  As economic and ecological pressures increase, it has become increasingly important that greater efforts be expended to have more sustainable urban environments. Specifically, it is essential that the future operation of cities become more sustainable in terms of energy and resource use, while also safeguarding the health and well-being of local citizens. This course will discuss how multiple disciplines can be integrated to identify and discuss this broad goal. A combination of individual and team assignments will be given, culminating in a team term project that provides alternative strategies for consideration by a panel of experts. CourseProfile (ATLAS)

- **CEE 312. Structural Engineering**  
  *Prerequisite: CEE 212 or equivalent. (4 credits)*  
  Introduction to the field of structural engineering. Discussion of structural analysis techniques and concepts such as virtual work, flexibility method, stiffness method, influence lines and matrix structural analysis. Training in AutoCAD and exposure to commonly used structural analysis computer program(s). Discussion of basic design concepts and principles. CourseProfile (ATLAS)

- **CEE 325. Fluid Mechanics**  
  *Prerequisite: CEE 211. (4 credits)*  
  Principles of mechanics applied to real and ideal fluids. Fluid properties and statics; continuity, energy, and momentum equations by control volume analysis; differential equations of motion for laminar and turbulent flow; dimensional analysis and similitude; boundary layers, drag and lift; incompressible flow in pipes; fluid measurement and turbomachinery. Lecture and laboratory. CourseProfile (ATLAS)

- **CEE 331. Construction Management**  
  *Advisory Prerequisite: Junior Standing. (4 credits)*  
  Introduction to a construction management process for engineers in which the project life-cycle is broken into organizing, evaluating, planning, monitoring and controlling. Students will learn about the project delivery, financial and procurement systems; legal issues; cost estimation; scheduling; bonding and insurance; and project resource planning and control. CourseProfile (ATLAS)

- **CEE 345. Geotechnical Engineering**  
  *Prerequisite: Physics 140. (4 credits)*  
  Soil origins, classification and index properties; phase relationships; earth moving and soil compaction; groundwater seepage; compressibility and consolidation; settlement; shear strength and failure; applications to foundations; retaining structures and slopes. Lecture and laboratory. CourseProfile (ATLAS)

- **CEE 351. Civil Engineering Materials**  
  *Prerequisite: CEE 212 or equivalent. (4 credits)*  
  Discussion of basic mechanical and physical properties of a variety of civil engineering materials such as concrete, asphalt, wood and fiber composites. Evaluation and design for properties, load-time deformation characteristics, response to typical service environments. Lecture and laboratory. CourseProfile (ATLAS)

- **CEE 365. Environmental Engineering Principles**  
  *Prerequisite: CHEM 130, MATH 116. (4 credits)*  
  An introduction to mass balance modeling of contaminant fate, transport and removal in the environment; commonly used reactor configurations for water and air quality control;
partitioning of contaminant types and sources; regional and global contemporary environmental issues. CourseProfile (ATLAS)

- **CEE 366. Environmental Engineering Laboratory**  
  Advisory Prerequisite: CEE 365 and CEE 373. (3 credits)  
  Weekly lecture and experimental projects designed to illustrate key analytical measurements of water and air quality parameters, soil properties, and environmental process engineering. Emphasis on data analysis, report writing, oral presentations, experimental design and teamwork. CourseProfile (ATLAS)

- **CEE 373. Statistical Methods for Data Analysis and Uncertainty Modeling**  
  Prerequisite: MATH 215 and MATH 216. Minimum grade of “C” required for enforced prerequisites. (3 credits)  
  Introductory probability and statistics with emphasis on data analysis and uncertainty modeling for engineering and environmental systems. Descriptive statistics, graphical representation of data, linear regression, correlation, discrete and continuous probability distributions, conditional probability, estimation, statistical inference, extreme events, reliability analysis and techniques for design under uncertainty. CourseProfile (ATLAS)

- **CEE 375. Sensors, Circuits, and Signals**  
  Prerequisite: Physics 240. (3 credits)  
  This course introduces students to the fundamentals of collecting and processing experimental data. The course begins with an introduction to DC and AC circuits. The design and operation of sensors are then introduced followed by an introduction to digital signal processing. CourseProfile (ATLAS)

### 400 Level Courses

- **CEE 402. Professional Issues and Design**  
  Prerequisite: Senior standing. (4 credits)  
  Multidisciplinary team design experience including consideration of codes, regulations, alternate solutions, economic factors, sustainability, constructability, reliability and aesthetics in the solution of a civil or environmental engineering problem. Professionalism and ethics in the practice of engineering. CourseProfile (ATLAS)

- **CEE 412. Matrix Structural Analysis**  
  Prerequisite: MATH 216 and CEE 312 or equivalent. (3 credits)  
  Displacement-based linear analysis of truss, beam, frame, and cable structures, including axial loading and structural pre-tension effects. Analytical derivation of stiffness equations from first principles. Matrix assembly techniques and implementation of computational solution techniques. Approximate stability analysis. Elementary plasticity analysis, using incremental loading techniques. Introduction to structural dynamics. CourseProfile (ATLAS)

- **CEE 413. Design of Metal Structures**  
  Prerequisite: CEE 312. (3 credits)  
  Design of metal members and connections and their use in buildings and bridges. Application of relevant design specifications with emphasis on structural steel. CourseProfile (ATLAS)

- **CEE 415. Design of Reinforced Concrete Structures**  
  Prerequisite: CEE 312. (3 credits)  
  Design of reinforced concrete members and slabs, and their use in buildings and bridges. Application of relevant design specifications. CourseProfile (ATLAS)

- **CEE 421. Hydrology and Floodplain Hydraulics**  
  Prerequisite: CEE 303, CEE 325. (4 credits)  
  Fundamentals of surface-water hydrology, flow in open channels and flood hazard mitigation. Rainfall-runoff relations. Unit hydrograph method. Uniform and nonuniform flow in open channels. Measurement and control of river flow. Flood waves in rivers, floodplains and
reservoirs. Design of storage basins, storm channels and culverts. Lecture, laboratory and computation. CourseProfile (ATLAS)

- CEE 428. (ENSCEN 428) Groundwater Hydrology
  Prerequisite: CEE 325 and (CEE 345 or CEE 366) advised. (3 credits)
  Basic principles which govern the flow of water in the subsurface. Development and solution of groundwater flow and contaminant transport equations, in presence and absence of pumping wells, for both confined and phreatic aquifers. Measurement and estimation of parameters governing flow and transport. Use of computer software for the simulation of flow. CourseProfile (ATLAS)

- CEE 430. Special Problems in Construction Engineering
  Prerequisite: Permission of instructor. (1-3 credits)
  Individual student may choose his or her special problem from a wide range of construction engineering and management areas. CourseProfile (ATLAS)

- CEE 435. Building Information Modeling
  Prerequisite: CEE 431 (331 effective Winter 2020) or graduate standing. Minimum grade of a “C” for enforced prerequisite. (3 credits)
  Fundamentals of Building Information Modeling (BIM) and its significance in construction project management; Application of BIM in construction engineering and management functions such as coordination, clash detection, sequencing, safety, and communication; BIM-based Integrated Project Delivery (IPD); Reality capture methods for as-built BIM; BIM in facility management; BIM standards and interoperability. CourseProfile (ATLAS)

- CEE 446. Engineering Geology & Site Characterization
  Prerequisite: CEE 345 or permission of instructor. (3 credits)
  Composition and properties of rocks and soil, geologic processes, geologic structures and engineering consequences, mapping and map analysis, airphoto interpretation, in-situ testing of soils and rock, field demonstration, civil engineering facility siting. CourseProfile (ATLAS)

- CEE 450. Introduction to Transportation Engineering
  Prerequisite: MATH 215 and Physics 240 or graduate standing. Minimum grade of “C” required for enforced prerequisites. (4 credits)
  Fundamentals of planning, design and operation of highway transportation facilities. Topics covered include driver and vehicle performance characteristics, highway geometric design principles, basics of traffic analysis, traffic signal operations, transportation planning, connected and automated vehicle technologies and their impacts to the transportation infrastructure. CourseProfile (ATLAS)

- CEE 465. Environmental Process Engineering
  Prerequisite: CEE 325 and CEE 365. (3 credits)
  An introduction to the analysis, characterization and principles of physical, chemical and biological processes, operations and reactor configurations commonly used for water quality control; preliminary design of specific water and wastewater treatment processes and operations; discussion of economic and legislative constraints and requirements. CourseProfile (ATLAS)

- CEE 480. Design of Environmental Engineering Systems
  Prerequisite: CEE 465 advised. (3 credits)
  Design and theoretical understanding of environmental processes; biological, physical and chemical processes and reactor configurations commonly used for water quality control; applications to the design of specific water and wastewater treatment operations; discussion of pollution prevention and green engineering options. CourseProfile (ATLAS)

- CEE 481. Aquatic Chemistry
  Prerequisite: CHEM 130 and senior standing. Credit for only one: CEE 481 or CEE 581. Minimum grade of a "C-" required for enforced prerequisite. (3 credits)
  Chemical principles applicable to the analysis of the chemical composition of natural waters and engineered water treatment systems; covers acid-base, precipitation-dissolution, complexation, and oxidation-reduction reactions; emphasis on graphical and analytical
speciation methods; presented in the context of contemporary environmental issues including water quality, climate change and pollution prevention and abatement. CourseProfile (ATLAS)

- **CEE 482. Environmental Microbiology**  
  Prerequisite: CHEM 130 advised. (3 credits)  
  Introductions to microbial metabolic processes and nutrition, thermodynamics of growth and energy generation, genetic and metabolic diversity, evolution and systematics, and microbial ecology. Emphasis is placed on the application of these concepts to environmental biotechnology. CourseProfile (ATLAS)

- **CEE 490. Independent Study in Civil and Environmental Engineering**  
  Prerequisite: Permission of instructor. (1-4 credits)  
  Individual or group experimental or theoretical research in any area of Civil and Environmental Engineering. The program of work is arranged at the beginning of each term by mutual agreement between the student and a faculty member. Written and oral reports may be required. CourseProfile (ATLAS)

### 500 Level Courses

- **CEE 500. Environmental Systems and Processes I**  
  Advisory Prerequisite: CEE 460. (3 credits)  
  Concepts of environmental systems and principles of related transport and transformation phenomena and processes, focusing on aquatic systems; development of fundamental models for articulation of relevant process dynamics; system and process scaling factors and methods; extension of process models to ideal and nonideal natural and engineer homogeneous environmental systems. CourseProfile (ATLAS)

- **CEE 504. Engineering Economics and Finance**  
  Advisory Prerequisite: Econ 101 and CEE 373 or equivalents. (3 credits)  
  Engineering Economics and Finance focuses on evolving financial decision making in engineering practice. Topics like accounting, public and private investment decision making, project management and risk and uncertainty are covered and linked to practical problems that are meaningful to (smart) infrastructure systems and the students' professional futures. CourseProfile (ATLAS)

- **CEE 505. Infrastructure Finance Internship**  
  Prerequisite: Permission of Instructor. (1 credit)  
  This internship is required for the MEng in Smart Infrastructure Finance (SIF). The course consists of a 6-week internship at financial services, data analytics or construction/project development firms. Required deliverables to the SIF MEng committee include a workplan/approach and a final report. CourseProfile (ATLAS)

- **CEE 509. (MECHENG 512) Theory of Elasticity**  
  Prerequisite: MECHENG 412 or MECHENG 511. (3 credits)  
  Stress, strain and displacement, equilibrium and compatibility. Use of airy stress function in rectangular and polar coordinates, asymptotic fields at discontinuities, forces and dislocations, contact and crack problems, rotating and accelerating bodies. Galerkin and Papcovich-Neuber solutions, singular solutions, spherical harmonics. Thermoelasticity. Axisymmetric contact and crack problem. Axisymmetric torsion. CourseProfile (ATLAS)

- **CEE 510. (NAVARCH 512) Finite Element Methods in Solid and Structural Mechanics**  
  Prerequisite: graduate standing. (3 credits)  
• **CEE 511. Dynamics of Structures**  
*Prerequisite: CEE 412 or equivalent. (3 credits)*  

• **CEE 512. Nonlinear Analysis of Structures**  
*Prerequisite: CEE 412 or equivalent. (3 credits)*  
Extension of matrix structural analysis to solve geometric and material nonlinear problems in structural engineering. Topics include elastic stability of columns, P-delta effects, large-displacement analysis of cable structures, inelastic analysis of frames using lumped and distributed plasticity models, and solution algorithms for nonlinear systems of equations. [CourseProfile (ATLAS)](https://example.com)

• **CEE 513. Plastic Analysis and Design of Frames**  
*Prerequisite: CEE 413. (3 credits)*  
Plastic analysis and design of steel framed structures. Stepwise incremental load and mechanism methods. Behavior beyond elastic range; failure mechanisms. Use of computer programs and AISC specifications. Application to earthquake resistant design. [CourseProfile (ATLAS)](https://example.com)

• **CEE 514. Prestressed Concrete**  
*Prerequisite: CEE 415. (3 credits)*  
Fundamental principles of prestressing; prestressing materials; prestress losses; allowable stress and ultimate strength design methods; analysis and design of beams for flexure, shear and deflection; composite construction; bridges; slab systems; partial prestressings; FRP tendons. [CourseProfile (ATLAS)](https://example.com)

• **CEE 515. Advanced Design of Reinforced Concrete Structures**  
*Prerequisite: CEE 415. (3 credits)*  
Analysis and design of concrete structural systems including two-way floor systems, slender columns, members subjected to torsion, structural walls and connections. Applications of computer-aided design programs. Use of design code provisions. Design projects. [CourseProfile (ATLAS)](https://example.com)

• **CEE 516. Bridge Structures**  
*Prerequisite: CEE 413, CEE 415. (3 credits)*  
Advanced concepts and modern trends in design of bridges. Rehabilitation, repair and retrofit of existing bridges. Use of relevant codes. Study of alternative structural forms and materials for efficiency and economy. Design problems and reports. [CourseProfile (ATLAS)](https://example.com)

• **CEE 517. Reliability of Structures**  
*Prerequisite: CEE 270 or equivalent. (3 credits)*  
Fundamental concepts related to structural reliability, safety measures, load models, resistance models, system reliability, optimum safety levels and optimization of design codes. [CourseProfile (ATLAS)](https://example.com)

• **CEE 519. Hybrid and Composite Structures**  
*Prerequisite: CEE 415 or equivalent and CEE 413 or equivalent. (3 credits)*  
Behavior and design of hybrid and composite structural members, connections and systems, including composite frame construction, structural walls systems and braced frames; design of advanced fiber cementitious materials and applications in new and deficient structural systems; Fiber Reinforced Polymers (FRP) for structural repair and retrofit. [CourseProfile (ATLAS)](https://example.com)

• **CEE 520. Physical Processes of Land-Surface Hydrology**  
*Prerequisite: CEE 421 or graduate standing. (3 credits)*  
physical properties; water flow in unsaturated soils; infiltration. Snow hydrology. Runoff generation. Probabilistic approaches to describing spatial variability. CourseProfile (ATLAS)

- **CEE 521. Flow in Open Channels**  
  *Prerequisite: CEE 325 or equivalent. (3 credits)*  
  Conservation laws for transient flow in open channels; shallow-water approximation; the method of characteristics; simple waves and hydraulic jumps; nonreflective boundary conditions; dam-break analysis; overland flow; prediction and mitigation of flood waves. CourseProfile (ATLAS)

- **CEE 522. Sediment Transport**  
  *Prerequisite: CEE 325 or equivalent. (3 credits)*  
  Mechanics of sediment transport processes in Fluvial systems; initiation of motion; bed forms; resistance to flow; suspended sediment transport; bed load transport; cohesive sediments; geomorphology principles. CourseProfile (ATLAS)

- **CEE 524. Restoration Fundamentals and Practice in Aquatic Systems**  
  *Advisory Prerequisite: MATH 115 (3 credits)*  
  The topics to be covered in the lectures are Sediment transport, Fluid mechanics/bluff body flows—Hydraulics, Geomorphology, Dimensional analysis, Field measurement techniques—Particle Image Velocimetry, Acoustic Doppler Velocimetry, flow and wave gauges. Biological overview: fishes, macrobenthos, plants. Current restoration techniques in a variety of environments. CourseProfile (ATLAS)

- **CEE 525. Environmental Turbulence**  
  *Advisory Prerequisite: CEE 325 or equivalent. (3 credits)*  
  Introduction to the topic of turbulence with special emphasis on physical processes; characterization of fundamental turbulent flows such as shear layers, wakes, jets, plumes and thermals; effect of stratification on turbulence; forcing and control of turbulence by acceleration and pulsation. CourseProfile (ATLAS)

- **CEE 526. Design of Hydraulic Systems**  
  *Prerequisite: CEE 325 or equivalent. (3 credits)*  
  Hydraulic design of piping systems including pumps and networks; pump system design including variable speed operation, cavitation and wet well design; waterhammer and other transient phenomena; control valves and flow metering considerations; hydraulic control structures. CourseProfile (ATLAS)

- **CEE 527. Coastal Hydraulics**  
  *Prerequisite: CEE 325 or equivalent. (3 credits)*  
  General description of wave systems including spectral representation; solutions to oscillatory wave equation; wave breaking; harbor resonance; wave shoaling, refraction and diffraction; wave forecasting; selection of design wave conditions; forces on coastal structures; shoreline erosion processes. CourseProfile (ATLAS)

- **CEE 530. Construction Professional Practice**  
  *Advisory Prerequisite: Permission of instructor. (3 credits)*  
  Capstone project in CEM where student teams work with construction industry clients as volunteer consultants to investigate technological and best practice solutions to current industry problems. Clients receive a compiled professional report and video. Faculty and industry speakers discuss technologies and innovations related to CEM, and elements for professional leadership. CourseProfile (ATLAS)

- **CEE 531. Construction Cost Engineering**  
  *Prerequisite: graduate standing and preceded or accompanied by CEE 431. (3 credits)*  
  Cost engineering for construction organizations, projects and operations. Construction financing; break-even, profit and cash flow analyses; capital budgeting. Equipment cost and procurement decisions. Construction financial accounting, cost accounting, cost control systems, databases. Cost indices, parametric estimates, unit price proposals, measuring work and settling claims. CourseProfile (ATLAS)
• CEE 532. Construction Project Engineering
  \textit{Prerequisite:} graduate standing and preceded or accompanied by CEE 431. (3 credits)
  Project, company organization. Manpower training, planning, procurement; union, nonunion
  operation planning, supervision, measurement, analysis, improvement. Dimensions of
  performance: safety, quality, quality of work life, productivity, innovation. Examples, cases
  from construction. \textit{CourseProfile (ATLAS)}

• CEE 533. Engineering Process Modeling and Risk Analysis
  \textit{Advisory Prerequisite:} CEE 373. (3 credits)
  Modeling, simulation and risk analysis of engineering systems. Monte Carlo and discrete-
  event simulation model development for practical engineering problems using advanced
  computational tools. Applications from on-site construction, prefabrication, tunneling,
  earthmoving, bridges, land, air, and marine transportation systems. \textit{CourseProfile (ATLAS)}

• CEE 534. Construction Engineering, Equipment, and Methods
  \textit{Prerequisite:} junior standing. (3 credits)
  Major construction equipment and concrete construction. Selection of scrapers, dozers,
  cranes, etc. based on applications, methods, and production requirements. Power
  generation, transmission, and output capacity of equipment engines. Calculation of transport
  cycle times. Concrete methods include mixing, delivery and placement. Design of forms for
  concrete walls and supported slabs. \textit{CourseProfile (ATLAS)}

• CEE 535. Excavation and Tunneling
  \textit{Prerequisite:} CEE 345. (3 credits)
  Selection of methods of attack for excavation of tunnels and deep vertical-sided openings.
  Tunneling procedures based on behavioral characteristics of soil and rock. Study of tunnel
  boring machines, shielded and drill-and-blast operations, linings. Soil liner interaction. Deep
  excavation procedures related to support of excavation systems, methods of installation and
  dewatering. \textit{CourseProfile (ATLAS)}

• CEE 536 (MFG 536). Critical Path Methods
  \textit{Advisory Prerequisite:} senior or graduate standing. (3 credits)
  Construction project planning, scheduling, and control, using activity-on-arrow, activity-on-
  node, and overlapping network models. CPM: Start, finish, float, critical path
  calculations. PERT: Probabilistic scheduling, merge-event bias, schedule simulation. Time-
  cost tradeoff, resource allocation, resource leveling algorithms. Cost-schedule integration,
  computerized control systems. Repetitive scheduling. Case studies, term
  project. \textit{CourseProfile (ATLAS)}

• CEE 537. Construction of Buildings
  \textit{Prerequisite:} CEE 351. (3 credits)
  Material selection, construction details, manufacture, fabrication and erection of building
  structures using steel, light wood, timber, cast-in-place concrete, precast concrete and
  masonry; and materials for roof, floor and wall surfaces. Zoning, building codes and other
  legal issues. Introduction to HVAC and electrical systems. Field trips to construction
  sites. \textit{CourseProfile (ATLAS)}

• CEE 538. Computer-aided Project Management
  \textit{Prerequisite:} Preceded or accompanied by CEE 536/MFG 536. Minimum grade of a “C” for
  enforced prerequisites. (2 credits)
  Introduction to the application of modern project management computer systems, for
  example, Primavera P6 Professional and Microsoft Project, for construction project planning,
  scheduling and control. \textit{CourseProfile (ATLAS)}

• CEE 539. Construction Management Information Systems
  \textit{Prerequisite:} Senior or graduate standing (3 credits)
  Automation of construction engineering and management functions using modern analysis,
  design and productivity tools. Modeling and graphical 3D visualization of construction
  processes and products. Mobile computing and information systems to support field
engineering tasks. Students apply computerized systems to solve construction problems and case studies. CourseProfile (ATLAS)

- **CEE 540. Advanced Soil Mechanics**  
  *Prerequisite: CEE 345 or equivalent. (3 credits)*  

- **CEE 541. Soil Sampling and Testing**  
  *Prerequisite: Preceded or accompanied by CEE 345. (3 credits)*  
  Field and laboratory practice in sampling and testing of soils for engineering purposes. Field sampling and testing; standard split-spoon sampler, Dutch Cone penetrometer, field vane, Iowa borehole shear device. Lab tests; direct shear, unconfined compression, triaxial compression, consolidation. Laboratory and lecture. CourseProfile (ATLAS)

- **CEE 542. Soil and Site Improvement**  
  *Prerequisite: CEE 345 or equivalent. (3 credits)*  
  Analysis of geotechnical problems affecting site use including weak, compressible soil; high shrink-swell potential; and liquefiable soils. Stabilization techniques including compaction, earth reinforcement, admixture stabilization, deep mixing, grouting, precompression, thermal and electrokinetic stabilization and vitro-compaction. CourseProfile (ATLAS)

- **CEE 543. Numerical Modeling in Geotechnical Engineering**  
  *Prerequisite: CEE 345 or equivalent advised. (3 credits)*  

- **CEE 544. Rock Mechanics**  
  *Prerequisite: CEE 212 or equivalent. (3 credits)*  
  Engineering properties and classification of rocks. Strength and deformability of intact and jointed rock; in situ stresses; lab and field test methods. Stereonets and structural geology. Rock slopes; stability and reinforcement. Foundations on rock. CourseProfile (ATLAS)

- **CEE 545. Foundation Engineering**  
  *Prerequisite: CEE 345 or equivalent. (3 credits)*  
  Application of principles of soil mechanics to: determination of bearing capacity and settlement of spread footings, mats, single piles and pile groups; site investigation, evaluation of data from field and laboratory tests; estimation of stresses in soil masses; soil structure interaction. CourseProfile (ATLAS)

- **CEE 546. Slopes, Dams and Retaining Structures**  
  *Prerequisite: CEE 345 or equivalent. (3 credits)*  
  Slope stability analyses, seepage through soils, settlements and horizontal movements in embankments, earthen embankment and dam design, landslide and embankment stabilization, earth pressures and retaining structure design. CourseProfile (ATLAS)

- **CEE 547. Soils Engineering and Pavement Systems**  
  *Prerequisite: CEE 345 or equivalent. (3 credits)*  
  Soils engineering as applied to the design, construction and rehabilitation of pavement systems. The design, evaluation and rehabilitation of rigid, flexible and composite pavements. CourseProfile (ATLAS)

- **CEE 548. Geotechnical Earthquake Engineering**  
  *Prerequisite: CEE 345 or equivalent recommended. (3 credits)*  
  Ground motion attenuation relationships, seismic site response analysis, evaluation and modeling of dynamic soil properties, soil structure interaction, evaluation and mitigation of
soil liquefaction, seismic code provisions and practice, seismic earth pressures, slope stability and deformation analysis, safety of dams and embankments, performance of pile foundations and additional current topics. CourseProfile (ATLAS)

- **CEE 549. Geoenvironmental Engineering**  
  *Prerequisite: CEE 345 or equivalent. (3 credits)*  
  Waste generation/disposal; waste types; waste facilities regulations; geoenvironmental site characterization; soil-water-contaminant interactions; design and construction of base and cover containment systems; geosynthetic materials in geoenvironmental applications; landfill settlement and stability; introduction to bioreactor landfills and emerging technologies for waste disposal; technologies for site restoration and clean up. CourseProfile (ATLAS)

- **CEE 550. Quality Control of Construction Materials**  
  *Prerequisite: CEE 351. (3 credits)*  
  Construction material specification and test procedures. Sampling methods, data collection and statistical data distributions. Quality control charts, development of quality assurance specifications and acceptance plans. Examples using data from actual field construction and laboratory experiments collected by destructive and non-destructive methods. CourseProfile (ATLAS)

- **CEE 551. Traffic Science**  
  *Prerequisite: CEE 450 or graduate standing. Minimum grade of “C” required for enforced prerequisite. (3 credits)*  
  This course provides fundamentals of traffic science, including data collection, analysis, design, and operations. Main components include traffic flow theory, traffic simulation, and traffic operations. An introduction to connected and automated vehicle technology and its applications in traffic flow and signal control will be introduced. CourseProfile (ATLAS)

- **CEE 552. Travel Behavior Analysis and Forecasting**  
  *Prerequisite: (CEE 373 and CEE 450) or graduate standing. Minimum grade of “C” required for enforced prerequisites. (3 credits)*  
  This course provides an introduction to analysis and forecasting of passenger travel demand. The objective is for students to understand the fundamentals of discrete choice models. Using case studies and participating in a group project, students will also understand how these models are applied in practice. CourseProfile (ATLAS)

- **CEE 553. Infrastructure Systems Optimization**  
  *Prerequisite: none. (3 credits)*  
  Systems-level approach to the analysis and design of civil infrastructure systems. The fundamental concepts are taught through a series of examples drawn from various infrastructure systems applications. Optimization techniques covered include model building, linear programming, nonlinear programming and the use of algebraic modeling languages. CourseProfile (ATLAS)

- **CEE 554. Data Mining in Transportation**  
  *Prerequisite: Senior or graduate standing. (3 credits)*  
  This course covers topics in predictive data analytics where computers are enabled to learn hidden structures from data without being explicitly programmed. The focus of the course is on supervised (classification and regression) and unsupervised (clustering) learning methods. Examples are drawn from the field of transportation systems. CourseProfile (ATLAS)

- **CEE 555. Sustainability of Civil Infrastructure Systems**  
  *Prerequisite: none. (3 credits)*  
  Life Cycle Cost Analysis and Life Cycle Analysis – Methods and Applications in Civil Infrastructure Systems; Building Energy Modeling and Simulation; Energy Management in Buildings; Impact of Building Occupants and Behavioral Challenges; Renewable Energy and Efficiency in Buildings; Existing Buildings and Technical/Social Challenges of Energy Retrofits; and Building Certifications (e.g., LEED). CourseProfile (ATLAS)
• CEE 556. Economics of Transportation Systems
  Advisory Prerequisite: CEE 552 or equivalent. (3 credits)
  The course will acquaint students with central insights and concepts in the economics of transportation systems, including travel demand, transportation costs, pricing of transportation systems, financing transportation infrastructure, cost-benefit analysis, and decision analysis. The scope of the course involves all modes of transportation with emphasis on highways and transit. CourseProfile (ATLAS)

• CEE 557. Large-scale Transportation Systems Optimization
  Advisory Prerequisite: CEE 553 or equivalent. (3 credits)
  Methods to solve large-scale optimization problems. Topics include a summary of linear and integer programming, network simplex, primal-dual methods, Bender’s decomposition, Lagrangian optimization, column generation, Dantzig-Wolfe decomposition, and aggregation methods. CourseProfile (ATLAS)

• CEE 558. Urban Traffic Operations
  Advisory Prerequisite: CEE 551 or equivalent. (3 credits)
  This class discusses advanced topics on urban traffic operations. Main topics include optimal control theory, traffic signal optimization, vehicle trajectory control, and data driven traffic control. Next generation traffic control system with connected and automated vehicles will be a focus of this class. CourseProfile (ATLAS)

• CEE 559. Transportation Network Modeling
  Advisory Prerequisite: CEE 552 or equivalent. (3 credits)
  This course discusses formulations and algorithms for finding equilibrium flow patterns through transportation networks. Emphasis is placed on the understanding of the paradigm of equilibrium analysis of transportation systems. Topics discussed in the class include user equilibrium, system optimum, bi-level programming models, bottleneck models, and transportation network reliability/vulnerability analysis. CourseProfile (ATLAS)

• CEE 563. Air Quality Engineering Fundamentals
  Prerequisite: CEE 230 and CEE 325 or equivalents. (3 credits)

• CEE 564. Greenhouse Gas Control
  Advisory Prerequisite: CEE 230 or equivalent. (3 credits)
  A review of strategies for reduction of greenhouse gas emissions in power generation, transportation, and the built environment. Sources, discharges, and physical properties of greenhouse gases are surveyed; technologies for greenhouse gas emission avoidance or sequestration are discussed. Policy options for greenhouse gas control and carbon footprint reduction are considered. CourseProfile (ATLAS)

• CEE 565. (ESENG 501) Seminars on Energy Systems Technology and Policy
  Prerequisite: Graduate student or permission of instructor (3 credits)
  This course is intended to provide students with an understanding of the critical issues in energy technologies. Researchers, industry leaders, entrepreneurs and policymakers discuss technology, policy and economic drivers for sustainable global energy systems. Students complete homework assignments and a term paper on an energy-themed subject. CourseProfile (ATLAS)

• CEE 567. (ESENG 567) Energy Infrastructure Systems
  Prerequisite: CEE 230 or MechE 336 or ChemE 330 or equivalent recommended (3 credits)
  Technologies and economics of electric power generation, transmission and distribution are discussed. Centralized versus distributed generation and fossil fuels versus renewable resources, are considered in regard to engineering, market and regulatory principles.
Students develop an understanding of energy challenges confronting society and investigate technologies that seek to address future needs. **CourseProfile (ATLAS)**

- **CEE 568. Decentralized Water Supply, Hygiene and Sanitation**  
  *Advisory Prerequisite: CEE 465 or equivalent. (3 credits)*  
  Design of decentralized approaches that provide access to useful water sources, safe drinking water and sanitation services. The class covers the factors associated with poor water quality; appropriate physical, chemical, and biological technologies and design principles; water safety planning; and consideration for resource recovery, sustainability, policy, environmental justice, and economics. **CourseProfile (ATLAS)**

- **CEE 571. (AEROSP 550) (EECS 560) (MECHENG 564). Linear Systems Theory**  
  *Prerequisite: graduate standing. (4 credits)*  

- **CEE 572. Dynamic Infrastructure Systems**  
  *Prerequisite: Math 417 or equivalent advised. (3 credits)*  
  Introduction to the fundamentals of dynamics system theory applied to infrastructure systems including system modeling as well as monitoring and controlling structural, transportation, hydraulic, and electrical grid systems. Continuous-time and discrete-time linear systems are emphasized but elementary concepts in nonlinear systems are also presented. **CourseProfile (ATLAS)**

- **CEE 573. Data Analysis in Civil and Environmental Engineering**  
  *Prerequisite: CEE 270 or equivalent. (3 credits)*  
  Course topics address practical problems of analysis of manipulation and monitoring datasets in environmental sciences and engineering: hypothesis testing, uncertainty, linear regressions, data of high dimension and time domain and frequency domain analysis of series. Examples are drawn from the fields of environmental and civil engineering and surface and subsurface hydrology. **CourseProfile (ATLAS)**

- **CEE 574 (ARCH 595). Materials Selection for Sustainable Design**  
  *Prerequisite: CEE 212 or ARCH 324 or equivalent. (3 credits)*  
  Integrated study of material properties, performance and economic and environmental cost, as related to engineering and architectural design. Topics include material properties and selection, materials database, processing and design, ecological considerations and optimization. Examples will be drawn from cementitious materials and ceramics, metals, polymers and composites. **CourseProfile (ATLAS)**

- **CEE 575. Sensing for Civil Infrastructure Systems**  
  *Prerequisite: Physics 240. (3 credits)*  

- **CEE 576 (MECHENG 549). Stochastic Systems**  
  *Advisory Prerequisite: CEE 373 or equivalent, MECHENG 360 or CEE 572 or equivalent, MECHENG 564/CEE 571 or equivalent. (3 credits)*  
• **CEE 580. Physicochemical Processes in Environmental Engineering**  
  *Prerequisite: CEE 460. (3 credits)*  
  Physicochemical separated and transformation processes in natural and engineered environmental systems; process modeling; design of operations involving state and phase transformation; chemical oxidation, reduction, sorption, stripping and exchange processes, membrane separations, particle aggregation and coagulation, sedimentation and filtration. [CourseProfile (ATLAS)]

• **CEE 581 (EARTH 581). Aquatic Chemistry**  
  *Prerequisite: (CHEM 130 and senior standing) or graduate standing. Credit for only one: CEE 481 or CEE 581. Minimum grade of “C-” required for prerequisite. (3 credits)*  
  Chemical principles applicable to the analysis of the chemical composition of natural waters and engineered water treatment systems; covers acid-base, precipitation-dissolution, complexation, and oxidation-reduction reactions; emphasis on graphical, analytical and computer-speciation methods; presented in the context of contemporary environmental issues including water quality, climate change and pollution prevention and abatement. [CourseProfile (ATLAS)]

• **CEE 582. Environmental Microbiology**  
  *Prerequisite: CHEM 130 and senior or graduate standing. (3 credits)*  
  Introductions to microbial metabolic processes and nutrition, thermodynamics of growth and energy generation, genetic and metabolic diversity, evolution and systematics, laboratory methods and microbial ecology. Emphasis is placed on the application of these concepts to environmental biotechnology, including microbial treatment of water and wastewater, bioenergy production and pollutant degradation. [CourseProfile (ATLAS)]

• **CEE 584 (EIHLTH 667). Hazardous Waste Processes**  
  *(3 credits)*  
  The study of thermal, chemical and other systems and processes used in the detoxification of hazardous wastes, other than radioactive wastes. [CourseProfile (ATLAS)]

• **CEE 585 (ENSCEN 585). Solid Waste Management**  
  *(3 credits)*  
  The study of methods for managing the solid wastes generated by urban communities, evaluating alternatives and design of disposal facilities. Methods for minimizing adverse effects on the human health and environment are included. [CourseProfile (ATLAS)]

• **CEE 586 (NRE 557). Industrial Ecology**  
  *Prerequisite: senior standing. (3-4 credits)*  
  Analysis of material and energy flows in industrial systems to enhance eco-efficiency and sustainability. Methods: life cycle assessment quantifies energy, waste, emissions (greenhouse gases) for materials production, manufacturing, product use, recovery/disposition. Life cycle design integrate environmental, performance, economic and regulatory objectives. Multi-objective analysis, engineering design analysis, cross-functional teamwork, large sea modeling skills. [CourseProfile (ATLAS)]

• **CEE 587 (NRE 558). Water Resource Policy**  
  *Prerequisite: senior or graduate standing. (3 credits)*  
  Consideration of policy processes associated with the development and utilization of water resources. Special attention is given to the history and development of policy related to water quality. Multi-objective planning is presented. Consideration of institutional problems associated with the implementation of water policy in the federal, state, regional and local arenas. [CourseProfile (ATLAS)]

• **CEE 588 (CHE 590). Sustainability Finance: Investment Models for Green Growth**  
  *Advisory Prerequisite: Senior or graduate standing. (3 credits)*  
  The course reviews a range of financial innovations and investment models to scale capital allocations and reduce climate risks in portfolios, while driving green growth. [CourseProfile (ATLAS)]
• **CEE 589 (NRE 595). Risk and Benefit Analysis in Environmental Engineering**  
*Prerequisite: Senior or graduate standing. (3 credits)*  
Introduction to techniques of risk-benefit analysis as applied to water resources and environmental engineering. Techniques of multi-objective water resource planning. The engineering political interfaces; consideration of political bargaining and decision-making. [CourseProfile (ATLAS)]

• **CEE 590. Stream, Lake, and Estuary Analysis**  
*Prerequisite: CEE 460 or permission of instructor. (3 credits)*  
Development of mass balance equations for the characteristics and spatial and temporal distributions of contaminants in natural aquatic systems. Role of biochemical kinetics and mass transfer processes on oxygen resources in streams, lakes and estuaries. Demonstration of case studies and applied problems. [CourseProfile (ATLAS)]

• **CEE 591. Environmental Fluid Mechanics**  
*Prerequisite: CEE 325 or equivalent (3 credits)*  

• **CEE 592. Biological Processes in Environmental Engineering**  
*Prerequisite: CEE 460. (3 credits)*  
Theoretical principles, qualitative and quantitative description of suspended growth and biofilm processes, as applicable to wastewater treatment and the bioremediation of soils, sediments and groundwater. Bioremediation processes discussed include bioventing and biosparging, in situ intrinsic and enhanced bioremediation of chlorinated and non-chlorinated compounds. [CourseProfile (ATLAS)]

• **CEE 593. Environmental Soil Physics**  
*Prerequisite: CEE 428 or CEE 345. (3 credits)*  
Principles of soil physics with emphasis on environmental problems. Topics include characteristics of solid, liquid and gaseous components of soil; capillarity, air entrapment and the static distribution of water in the unsaturated zone; infiltration, exfiltration and the redistribution of water. Extension of principles to movement of organic liquids in subsurface. [CourseProfile (ATLAS)]

• **CEE 594. Environmental Soil Chemistry**  
*Prerequisite: CEE 581. (3 credits)*  
Introduction to the principles of soil chemistry. Topics covered include chemical composition of soils, chemical structure of minerals and soil organic matter, soil colloidal phenomena, sorption, ion-exchange, surface complexation theory, reactivity of soil constituents with inorganic and organic environmental contaminants. Emphasis on the relationship between chemical structure and reactivity. [CourseProfile (ATLAS)]

• **CEE 596. Chemical Fate and Transport**  
*Prerequisite: CEE 365 or equivalent. (3 credits)*  
Analysis of the fate, transport and persistence of chemical using fugacity-based modeling methods. Identification of key chemical properties affecting fate and transport. Characterization of environmental and biological media. Distribution mechanisms: partitioning, advection, reaction, diffusion. Hierarchical assessment of chemical fate for steady-state, transient, equilibrium and non-equilibrium conditions. Application to multi-media environmental systems; bioaccumulation in food webs; pharmacokinetic modeling; exposure and risk assessment. [CourseProfile (ATLAS)]

• **CEE 597. Environmental Organic Chemistry**  
*Prerequisite: CHEM 130 or equivalent. (3 credits)*  
The behavior and transformation of anthropogenic chemicals in the environment. Specific topics will include sorption, volatilization, air-water exchange, and transformation processes.
(e.g. hydrolysis, photolysis, redox, etc.). Predictive tools for the fate and transport of chemicals in the environment are developed using chemical molecular properties. CourseProfile (ATLAS)

- **CEE 599 (EIHLTH 699). Hazardous Wastes: Regulation, Remediation, and Worker Protection**  
  **Prerequisites:** Graduate standing and EIHLTH 503 or EIHLTH 508 or EIHLTH 541 or EIHLTH 650 or EIHLTH 667 or permission of instructor. (3 credits)  
  Integration of information on current regulatory climate and governmental guidelines with case studies in hazardous wastes/substances. Case studies provide examples of hazardous waste and remedial actions, with emphasis on site worker exposure and protection and community exposures to chemical and radiological agents. Lectures, problem-solving sessions and guest speakers. CourseProfile (ATLAS)

### 600 Level Courses

- **CEE 611. Performance-Based Earthquake Engineering**  
  **Advisory Prerequisite:** CEE 511, CEE 512, and CEE 517 or equivalent. (3 credits)  
  Introduction to state-of-the-art performance-based earthquake-resistant design, including both theoretical and practical aspects. Topics include probabilistic seismic hazard analysis; uniform and conditional mean spectrum; ground motion selection and scaling; inelastic dynamic analysis; incremental dynamic analysis; collapse fragilities; damage analysis and fragility functions; probabilistic seismic loss analysis. CourseProfile (ATLAS)

- **CEE 613. Metal Structural Members**  
  **Prerequisite:** CEE 413. (3 credits)  

- **CEE 614. Advanced Prestressed Concrete**  
  **Prerequisite:** CEE 514. (3 credits)  
  Prestressing in statically indeterminate structures: prestressed concrete slabs; analysis and design of partially prestressed concrete beams; nonlinear analysis; optimum design; members prestressed with unbonded tendons; external prestressing; prestressed tensile members; prestressing with FRPs. Special research and/or application related topics. CourseProfile (ATLAS)

- **CEE 615. Reinforced Concrete Members**  
  **Prerequisite:** CEE 415. (3 credits)  
  Inelastic behavior of reinforced concrete beams, columns and connections. Combined bending, shear and torsion in beams. Use of strut and tie models. Behavior under load reversals and development of appropriate hysteresis models. CourseProfile (ATLAS)

- **CEE 621. Free Surface Flow**  
  **Prerequisite:** CEE 325 or equivalent. (3 credits)  

- **CEE 622. Special Problems in Hydraulic Engineering or Hydrology**  
  **Prerequisite:** Permission of instructor. (to be arranged)  
  Assigned work on an individual basis. Problems of an advanced nature may be selected from a wide variety of topics. CourseProfile (ATLAS)

- **CEE 625 (NRE 624). Geostatistical Modeling of Uncertainty**  
  **Prerequisite:** CEE 570. (3 credits)

- **CEE 628. Numerical Modeling of Subsurface Flow**  
  *Prerequisite: CEE 528 or CEE 593 and Math 471. (3 credits)*  
  Application of numerical solution methods, including finite differences, finite elements, boundary elements and method of characteristics to various subsurface flow problems: saturated isothermal flow, solute transport, multiphase flow, geothermal reservoirs, use and modification of existing models in addition to new code development. 

- **CEE 630. Directed Studies in Construction Engineering**  
  *Prerequisite: Graduate standing. (1-3 credits)*  
  Selected reading in specific construction areas.

- **CEE 631. Construction Decisions Under Uncertainty**  
  *Prerequisite: A course in probability or statistics such as Stat 310 or Stat 311 or SMS 301. (3 credits)*  
  Construction project and organization decisions for the uncertain future. Selection of construction method, equipment, contract, markup and financing alternatives having the highest expected values. Uses decision theory, competitive bid analysis, probabilistic modeling and simulation and multiple regression analysis in managing construction.

- **CEE 645. Theoretical Soil Mechanics**  
  *Prerequisite: Permission of instructor. (3 credits)*  
  Stress conditions for failure of soils; earth pressures and retaining walls; arching in soils; theories for elastic and plastic deformations of soil masses; theory of bearing capacity; theories for stresses in semi-infinite and layered elastic solids; theory of elastic subgrade reaction.

- **CEE 646. Geophysical Techniques in Environmental Geotechnology**  
  *Prerequisite: CEE 345. (3 credits)*  
  Introduction to geophysical techniques currently available for use in environmental geotechnology. Principles on which methods are based. Site characterization, pore fluid identification, buried object location by these non-intrusive, non-destructive tests. AI programming for selection of appropriate methods. Case studies in use of geophysical methods.

- **CEE 648. Dynamics of Soils and Foundations**  
  *Prerequisite: CEE 345. (3 credits)*  
  Transient and steady state vibrations of foundations; phase plane analysis of foundations with one and two degrees of freedom; dynamic properties of soils; vibration transmission through soils.

- **CEE 649. Civil Engineering Vibrations Laboratory**  
  *Prerequisites: CEE 611, preceded or accompanied by CEE 648. (2 credits)*  
  Field and laboratory determination of dynamic material properties; measurement of vibration of structures and foundations; introduction to electronics for dynamic measurements; introduction to holographic interferometry.

- **CEE 650. Advanced Fiber Reinforced Concrete for Sustainable Infrastructure**  
  *Prerequisite: CEE 351 or graduate standing. (3 credits)*  
  This course surveys scale linkage in built infrastructure systems and its interaction with the natural environment. Fundamental analytic tools from fracture mechanics and micromechanics are introduced. Topics include elastic crack mechanics, energy principles, fiber cement composite design, infrastructure durability and material damage mechanics as it impacts infrastructure life cycle analyses.
• **CEE 651. Directed Studies in Civil Engineering Materials**  
  *Prerequisite: Graduate standing. (1-3 credits)*  
  Individual studies in specific civil engineering materials areas. [CourseProfile (ATLAS)]

• **CEE 679. Infrastructure Systems Project**  
  *(3 credits)*  
  This course provides students in the Infrastructure Systems program with an integrated view of how fundamental system theory is applied to the civil and environmental engineering domains. Students undertake a semester long research project as an independent study effort and are expected to attend weekly seminars involving students and faculty. [CourseProfile (ATLAS)]

• **CEE 682. Special Problems in Environmental Engineering**  
  *Prerequisite: permission of instructor. (to be arranged)*  
  Special problems designed to develop perspective and depth of comprehension in selected areas of sanitary, environmental or water resources engineering. [CourseProfile (ATLAS)]

• **CEE 687 (EIHLTH 617). Special Problems in Solid Waste Engineering**  
  *Prerequisite: CEE 585 and permission of instructor; mandatory satisfactory/unsatisfactory. (to be arranged)*  
  Application of principles presented in CEE 585 to engineering and environmental health problems in the collection and disposal of solid wastes; comprehensive analysis and report assigned on individual student basis. [CourseProfile (ATLAS)]

• **CEE 693. Environmental Molecular Biology**  
  *Prerequisite: CEE 592 or permission of instructor. (3 credits)*  
  Principles and techniques of molecular biology with an emphasis on genetic analysis of enzymatic systems capable of pollutant degradation: Genetic systems and gene probing in unusual prokaryotes: Use of molecular biological techniques for the enumeration and characterization of natural microbial communities: Biochemistry and kinetics of enzymatic systems. Lectures and laboratory. [CourseProfile (ATLAS)]

800 Level Courses

• **CEE 810. Special Topics in Structures and Materials**  
  *(to be arranged)*  
  Preparation and presentation of reports covering assigned topics. [CourseProfile (ATLAS)]

• **CEE 812. Structural Engineering Graduate Seminar**  
  *Prerequisite: Graduate standing. (1 credit)*  
  Presentation and discussion of selected topics relating to structural engineering practice and research by invited lecturers. [CourseProfile (ATLAS)]

• **CEE 830. Construction Engineering and Management Seminar**  
  *(to be arranged)*  
  Assigned reading and student reports on problems selected from the field of construction engineering and management. [CourseProfile (ATLAS)]

• **CEE 840. Geotechnical Engineering Seminar**  
  *Prerequisite: Graduate standing (1 credit)*  
  Presentation and discussion of selected topics relating to geotechnical engineering practice and research by invited lecturers. [CourseProfile (ATLAS)]

• **CEE 880. Seminar in Environmental and Water Resources Engineering**  
  *Prerequisite: none. (1 credit)*  
  Presentation and discussion of selected topics relating to environmental and water resources engineering. Student participation and guest lecturers. [CourseProfile (ATLAS)]

• **CEE 881. Environmental and Water Resources Engineering Seminar**  
  *Prerequisite: graduate standing (1 credit)*
Presentation and discussion of selected topics relating to environmental and water resources engineering. Student participation and guest lectures. CourseProfile (ATLAS)

900 Level Courses

- **CEE 910. Structural Engineering Research**  
  *(to be arranged)*  
  Assigned work in structural engineering as approved by the professor of structural engineering. A wide range of subject matter is available, including laboratory and library studies. CourseProfile (ATLAS)

- **CEE 921. Hydraulic and Hydrological Engineering Research**  
  *Prerequisite: permission of instructor. (to be arranged)*  
  Assigned work in hydraulic and hydrological research; a wide range of matter and method permissible. CourseProfile (ATLAS)

- **CEE 930. Construction Engineering Research**  
  *(to be arranged)*  
  Selected work from a wide range of construction engineering areas including planning, equipment, methods, estimating and costs. CourseProfile (ATLAS)

- **CEE 946. Soil Mechanics Research**  
  *(to be arranged)*  
  Advanced problems in soil mechanics, foundations or underground construction, selected to provide the student with knowledge of recent application and development in engineering design and construction practice. Assigned problems must be carried to a stage of completion sufficient for a written report which will normally be required for credit. CourseProfile (ATLAS)

- **CEE 950. Structural Materials Research**  
  *Prerequisite: Permission of instructor.*  
  *(to be arranged)*  
  Topics dealing with mechanics and engineering of structural materials. Assigned reading and student reports. CourseProfile (ATLAS)

- **CEE 955. Transportation Systems Engineering Research**  
  *Prerequisite: Permission of instructor.*  
  Advanced problems in transportation systems engineering; a wide range of subject matter and method is available, including field investigations, laboratory experimentation, library and public record searches, and engineering design work. CourseProfile (ATLAS)

- **CEE 970. Infrastructure Systems Engineering Research**  
  *Prerequisite: Permission of instructor. (1-16 credits)*  
  Advanced problems in infrastructure systems engineering; a wide range of subject matter and method is available, including field investigations, laboratory experimentation, library and public record searches, and engineering design work. CourseProfile (ATLAS)

- **CEE 980. Research in Environmental Engineering**  
  *Prerequisite: Permission of instructor. (to be arranged)*  
  A research study of some problems relating to water resource development and water supply, waste treatment and pollution control or sanitation and environmental health; a wide range of both subject matter and method is available, including field investigations, laboratory experimentation, library and public record searches and engineering design work. CourseProfile (ATLAS)

- **CEE 990. Dissertation/Pre-Candidate**  
  *(2-8 credits); (1-4 credits)*  
  Dissertation work by doctoral student not admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)
• **CEE 995. Dissertation/Candidate**
  *Prerequisite: Graduate School authorization for admission as a doctoral candidate. (8 credits); (4 credits)*
  Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. [CourseProfile (ATLAS)]
Overview

Climate & Space interests bridge both engineering and science and prepare students to answer a growing demand for expertise in atmospheric, climate and space science. Climate & Space programs focus on the description of atmospheric characteristics and phenomena on the Earth and other planets and the interrelationships between the Earth and the Sun. Because of the integrated nature of the program, Climate & Space students have an extensive background in atmospheric and space science, weather and climate, and the engineering of complex and highly reliable space systems and instrumentation.

Climate & Space students are prepared for positions in space engineering, climate, meteorology, space science research and teaching, environmental assessment, resource management, risk management, or in one of the growing number of fields interested in climate change. Climate & Space has actively participated in the Nation’s space program since its inception. For more than 70 years, Climate and Space Sciences and Engineering faculty members have been at the forefront of many engineering and theoretical breakthroughs. In 1946, a probe was deployed on a V-2 rocket to measure electrons in the upper atmosphere. In 1956, Climate & Space researchers were studying atmospheric pollution by aeroallergens, penetration of particulates into buildings, dynamic wind loading of structures, and industrial air pollution. Climate & Space was involved with NASA’s Pioneer Venus and Dynamic Explorer Program from its inception in the early 1970s to its completion in the 1990s. Today, Climate & Space researchers are involved in many space missions exploring Mercury, Earth, Mars, Jupiter, and Saturn as well as new initiatives in climate change.

Climate & Space offers high quality academic programs that combine extensive hands-on experience at all levels with a strong emphasis on the theoretical and applied aspects of a student’s area of concentration.

Atmospheric scientists are focused on the weather and climate of the Earth, with topics ranging from fundamental research of basic processes to preparing for adaptation to climate change. The focus of planetary/space scientists includes the effects of space weather on Earth, planetary atmospheres and environments, and the construction of satellite-platform instruments for observation of the Earth-atmosphere-ocean system.

Department Administration

Department Chair

Dr. Tuija Pulkkinen

1517 Climate and Space Research Building

For more specific information on contacting people, go to our Contacts page.
Undergraduate

Undergraduate Degree Program

The Department of Climate and Space Sciences and Engineering offers two degree programs in Climate and Meteorology (CM) and Space Science and Engineering (SSE). CM students begin to understand the interactions among all of the Earth system components while gaining in-depth knowledge in one of two concentrations: Meteorology or Climate Science and Impact Engineering. SSE students begin to understand the space environments of the Sun and planets (especially Earth) as they develop a deep understanding of the fundamental physical processes of energy transfer throughout the solar system.

The B.S.E. degrees in Climate & Space prepares graduates for employment in the National Weather Service, private weather forecasting companies, air- and water-quality management firms, NASA and the growing number of fields interested in climate change. As importantly, Climate & Space students who complete either of the two degree programs will be exceptionally well prepared for graduate studies in atmospheric science, environmental sciences, space science or space engineering.

Graduates of the Space Sciences and Engineering degree program are prepared to pursue graduate degrees in the space sciences or join the space industry, which is facing a severe workforce shortage. They can also join government agencies and federal laboratories that deal with space related disciplines.

In addition to the College of Engineering core courses, all Climate & Space undergraduate students take five Climate & Space core courses that introduce the various aspects of atmospheric, oceanic and space sciences, emphasizing the common elements of, and the interactions between, the various disciplines and the scientific basis of the phenomena that are observed. Additional courses are specific to the degree and concentration. Students have a number of technical and general electives they may also take to complete 128 credit hours. The electives must be at the 300 level or above. Completion of a concentration will be noted on the student’s transcript. For the most current information, visit http://clasp.engin.umich.edu.

B.S.E. in Climate and Meteorology

Sample Schedule

Not an ABET accredited program. Click to view the current sample schedule here.

Additional information can be found on the department advising website: http://clasp.engin.umich.edu/pages/undergraduate

Concentrations

Climate Science and Impact Engineering Concentration

The aim of the Climate Science and Impact Engineering concentration is to provide a flexible program for those interested in pursuing further graduate education or careers in
industry. The Climate Science and Impact Engineering concentration prepares you for graduate studies, climate modeling, and a position in “value added” industries that provide water resource, agricultural, seasonal recreation, and transportation industries with near-term climate analyses and predictions. Positions in government agencies serving to make policy or federal laboratories conducting climate research are also open to you. The program also provides students who are interested in both climate science and in a second area of expertise, such as the traditional engineering disciplines, policy, or law the option to take courses in those areas. There is a need for scientists and engineers who can carry out evaluation and engineering activities that require expertise both in climate science and in the engineering disciplines. These include issues related to air quality, energy engineering, sustainability, and water resources.

**Meteorology Concentration**

Graduates with a concentration in Meteorology are prepared for careers in weather forecasting, corporations that are increasingly the source of weather analyses and predictions modeling, and for graduate studies in meteorology and the technologies that enable weather and climate prediction.

Students electing this concentration are encouraged to complete an internship in a weather forecasting office.

**B.S.E. in Space Sciences and Engineering**

**Sample Schedule**

Not an ABET accredited program. Click to view the current sample schedule. Additional information can be found on the department advising website: [http://clasp.engin.umich.edu/pages/undergraduate](http://clasp.engin.umich.edu/pages/undergraduate)

**Concentrations**

**Space Science Concentration**

The Space Sciences concentration is for students interested in space physics and allows students to develop their quantitative, theoretical and computational skills necessary to understand the Sun-Earth space system. Requiring depth in fundamental physical understanding enables students to be prepared for research and further graduate training.

**Space Instrumentation Concentration**

This concentration is for students interested in observational solar and space physics and provides a foundation of the Earth and Space Sciences with technical, laboratory and project-based learning experiences within space instrumentation and space systems.
Climate and Space Sciences and Engineering Minor

The primary goal of the Climate and Space Sciences and Engineering (Climate & Space) Minor is to provide exposure to research opportunities in atmospheric, climate and space science and engineering for those students who wish to work in the geoscience or space industry but are not majoring in Climate and Space Sciences and Engineering. The secondary goal is to increase awareness of the Climate and Space Sciences and Engineering and the educational and research opportunities within Climate & Space within the College of Engineering as a whole. This program is for undergraduate students in the College of Engineering and LSA.

Students must have:

- Registered no later than the last day to add courses for the semester in which they complete the last courses for the minor
- Submitted his or her program of study for the minor to the Climate & Space undergraduate advisor
- Attained a minimum GPA of 2.0 in the designated courses
- Completed the Climate & Space Minor as part of a degree program

Requirements

A. Prerequisite coursework:

- Math (8 Credits)
  - MATH 115, and
  - MATH 116
- Physics: (10 Credits)
  - PHYSICS 140, 141, and
  - PHYSICS 240, 241

B. Required Coursework (9 credits)

- One course from SPACE 101 (Introduction to Rocket Science – 3 credits)
  - CLIMATE 102 (Extreme Weather – 3 credits), SPACE 103 (Introduction to Space Weather – 3 credits), or CLIMATE 105 (Our Changing Climate – 3 credits)
- CLIMATE 320/SPACE 320 (Earth and Space System Evolution, 3 credits)
- Students declaring prior to FA18, CLIMATE 321/SPACE 321 (Earth and Space System Dynamics, 3 credits) is required (with 6 credits remaining for focus courses).
- Students declaring FA18 or later are not required to take CLIMATE 321/SPACE 321 (with 9 credits remaining for focus courses).

C. Core Focus Courses (minimum 6 credits)

- At least two courses from one of the following tracks:
  - Meteorology
Sequential Undergraduate/Graduate Study (SUGS)

In our increasingly technical world, master’s degrees are becoming the minimum accepted level of education in the industry. Climate & Space SUGS programs are designed to provide a comprehensive knowledge of atmospheric/space sciences or space engineering and to increase your depth of knowledge beyond the baccalaureate degree level. The SUGS program offers breadth, depth and hands-on experience in both areas of concentration. Students interested in completing their undergraduate and master’s level education in five years may select either the SUGS in Atmospheric Science or in Space Engineering.

Each degree (B.S.E. and M.S. or M.Eng.) is awarded upon completion of the requirements. Students will typically enter the SUGS program by provisional enrollment in the senior year. Once SUGS students are within six credit hours of completing the required undergraduate degree, they must officially enroll in the Climate & Space M.S. or M.Eng. program for a minimum of two full terms, normally the last two semesters, and pay full graduate tuition for these two terms. Students are allowed to “double count” a certain number of credit hours for the two degrees.

SUGS in Applied Climate

The Climate & Space M.Eng. in Applied Climate, effectively a subset of the broad discipline of environmental engineering, is a professional degree designed for students whose interests lie in applying a basic understanding of climate science to engineered solutions requiring: adaptation to intensities and frequencies of extremes of weather associated with regional climate change, and mitigation of regional and global climate change through actions such as altered emission of short- and long-lived radiatively active gases and aerosols.

SUGS in Climate and Space Science

This program is designed to provide a comprehensive knowledge of atmospheric or space science and the various components of each system. Students enjoy extensive computational facilities as well as laboratories for measurement of the chemical and physical properties of the atmosphere and space weather. Climate & Space atmospheric scientists and students are solving problems related to short- and long-
term forecasting, air quality, atmospheric turbulence and convection, biogeochemical cycling, and precipitation processes, among a growing list of areas. Space Science faculty and students are studying planetary, solar and cosmic weather used in determining the systemic relationships between a planet and its atmosphere.

**SUGS in Space Engineering**

For students interested in studying the scientific, engineering and management aspects of space engineering, this program, developed with Aerospace Engineering and Electrical Engineering and Computer Science, allows them to structure the program to a specific area of interest. The program is designed to provide a comprehensive knowledge of space science and engineering and their interrelationship; to teach the systems approach to conceiving, designing, manufacturing, managing and operating complex space systems; and to provide practical experience in space system design, project development and management. Eight program concentrations are currently available: Space Science; Propulsion; Plasma Electrodynamics and Sensors; Instrumentation and Sensor Payloads; Launch Vehicles; Telemetry and Spacecraft Communication; Astrodynamics; and Computer Control and Data Handling.

The most up-to-date information on the Climate & Space SUGS programs, including example concentration course schedules is available at: [https://clasp.engin.umich.edu/academics/sugs/](https://clasp.engin.umich.edu/academics/sugs/). Or, for more information, contact the SUGS Advisor, Lindsay Coleman at clasp--um@umich.edu.

**Graduate**

**Graduate Degrees**

- Master of Engineering (M.Eng.) in Applied Climate
- Master of Engineering (M.Eng.) in Space Engineering
- Master of Science (M.S.) in Climate and Space Sciences and Engineering
- Doctor of Philosophy (Ph.D.) in Climate and Space Sciences and Engineering

**M.Eng. in Applied Climate**

The CLaSP M.Eng Program in Applied Climate combines theoretical and applied aspects of weather and climate with a significant design or monitoring project. This design ensures that students graduate with skills necessary for success as practicing engineers. The Program offers an interdisciplinary education at the nexus of Earth system science and engineering, with opportunities for breadth through courses in such areas as public policy, public health, or business. Students are allowed to structure their coursework to meet the needs of their individual areas of interest. Specific concentrations are suggested to assist students and their advisors with course planning.

Students will learn:

- Current tenets of climate science and practices useful for their continuing education in this evolving science;
• An engineering approach to managing the complexity of the Earth’s climate-related environment, its systems components, and a number of closely coupled internal sub-systems including those involving human society;
• A set of tools and skills useful in practical engineering problem solving in team environments; and
• Technologies of climate adaptation and associated mitigation strategies that minimize risks to commercial and government operations, and to their physical assets.

Areas of Study
Course concentrations will be defined through discussions between students and their program advisors to match the student’s career aspirations.

• Climatological and meteorological observing systems
• Emission inventory modeling principles, methods and practices
• Data analysis, Geographical Information Systems (GIS) and processing tools
• Climate and Weather modeling
• The intersection of climate and water resources
• Integrated Assessment

M.Eng. in Space Engineering
The ClaSP M.Eng. program in Space Engineering combines strong emphasis on both theoretical and applied aspects with extensive hands-on experience at all levels. The program is designed to develop students into a new type of interdisciplinary engineer prepared for future managerial and systems engineering roles in space related industries and government agencies.

If you are interested in studying the scientific, engineering and management aspects of space engineering, this program, developed with the Aerospace Engineering and Electrical Engineering and Computer Science departments, allows you to structure the program to your specific area of interest.

Program Objectives
• To provide a comprehensive knowledge of space science and engineering and their interrelationship.
• To increase depth beyond the baccalaureate level in a space-related discipline.
• To teach the systems approach to conceiving, designing, manufacturing, managing, and operating complex space systems.
• To provide practical experience in space system design, project development and management.

Program Concentrations
While your specific concentration curriculum will be decided through discussions with your program advisors, suggested programs have been developed in the following areas:
• Space Science Program
• Propulsion Program
• Plasma Electrodynamics and Sensors Program
• Instrumentation and Sensor Payloads Program
• Launch Vehicles Program
• Telemetry and Spacecraft Communications Program
• Astrodynamics Program
• Computer Control and Data Handling Program

**M.S. in Atmospheric, Oceanic and Space Sciences**

Applicants to the master's program may have a bachelor’s degree in any field of study, but they are expected to have completed minimum requirements in mathematics, physics and chemistry. Normally this would include five semesters of mathematics; eight credit hours of physics including two laboratories; and five credit hours of chemistry. Thirty semester hours are required for the master’s degree, fifteen of which must be from the Department’s offerings. A minimum of four additional hours must be in mathematics and/or natural science.

**Ph.D. in Climate and Space Sciences and Engineering**

Applicants for a doctorate are expected to have the ability and scholarship of a high order in one of the following areas: atmospheric science, space and planetary physics, or geoscience and remote sensing. Doctoral students are expected to carry a course load of nine to twelve semester hours (three to four courses) each semester until the dissertation work is begun. There are no foreign language requirements. During the first year, students must select courses from among the core courses for their particular program. After the second year, students must pass a qualifying examination before they can be advanced to candidacy. After reaching candidate status, students will concentrate on a dissertation topic under the guidance of an advisor.

This program gives students the basic courses to allow them to specialize later in a broad range of sub-disciplines. Students are expected to learn the basic morphology of the atmosphere and the space environment, as well as the necessary physics, chemistry, and mathematics.

The most up-to-date information on the Climate and Space Sciences and Engineering graduate programs is available online at [https://clasp.engin.umich.edu/academics/graduate-studies/](https://clasp.engin.umich.edu/academics/graduate-studies/).

**Contacts**

**Departmental Website:** [http://clasp.engin.umich.edu/](http://clasp.engin.umich.edu/)

Climate and Space Sciences and Engineering
Space Research Building
2455 Hayward St.
Ann Arbor, MI 48109-2143
Climate and Space Sciences and Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under “How to Read a Course Description”, in the CoE Bulletin Website: [https://bulletin.engin.umich.edu/courses/course-info/](https://bulletin.engin.umich.edu/courses/course-info/)

100 Level Courses

**SPACE 101 (ASTRO 183). Rocket Science**
*Prerequisite: None. (3 credits)*
An introduction to the science of space and space exploration. Topics covered include history of spaceflight, rockets, orbits, the space environment, satellites, remote sensing and the future human presence in space. The mathematics will be at the level of algebra and trigonometry. [CourseProfile (ATLAS)]

**CLIMATE 102 (EARTH 122) (ENVIRON 102). Extreme Weather**
*Prerequisite: None. (3 credits)*
This course provides an introduction to the physics of extreme weather events. The course uses examples of the thunderstorms, jet stream, floods, lake-effect snow storms, lightning, thunder, hail, hurricanes and tornadoes to illustrate the physical laws governing the atmosphere. Participants apply these principles in hands-on storm forecasting and weather analysis assignments. [CourseProfile (ATLAS)]

**SPACE 103. Intro Space Weather**
*Prerequisite: None. (3 credits)*
“Space weather” is an emerging discipline of space science that studies the conditions in space that impact society and Earth’s technological systems. Space weather is a consequence of the behavior of the sun, the nature of Earth’s magnetic field and atmosphere, and our location in the solar system. [CourseProfile (ATLAS)]

**CLIMATE 105 (Chemistry 105) (ENSCEN 105) (ENVIRON 105). Our Changing Atmosphere**
*Prerequisite: None. (3 credits)*
The science of the greenhouse effect, stratospheric ozone depletion, polar ozone holes and urban smog. These phenomena and their possible consequences are discussed, along with the properties and behavior of the atmosphere and its interactions with other components of the environment. [CourseProfile (ATLAS)]

**CLIMATE 110 (SPACE 110). Climate and Space Science and Engineering Seminar**
*Prerequisite: None. (1 credit)*
Seminars by noted speakers, faculty and research scientists, designed to acquaint undergraduates with contemporary science and engineering problems, technologies and broader issues in the global climate and space sciences. Technical communication assignments include written and/or oral reports based upon the seminars. [CourseProfile (ATLAS)]

**CLIMATE 171 (Biology 110) (Univ Course 110) (EARTH 171). Introduction to Global Change-Part I**
Prerequisite: None. (4 credits)
The course will consider the evolution of the universe, the Earth and its environments and the evolution of living organisms. Consideration will be given to fundamental processes by which organisms grow and reproduce, how they interact with their environments and the distribution of major groups of organisms on earth. CourseProfile (ATLAS)

CLIMATE 172 (ENVIRON 111) (EARTH 172) (ENSCEN 172) (GEOG 111). Climate Change and Sustainability: Environmental Challenges of the 21st Century
Prerequisite: None. (4 credits)
This course explores impacts of modern human society on land, ocean and atmosphere, considering all aspects relevant to a sustainable future. Throughout the semester, students work on a sustainability pledge to apply class material to everyday life. CourseProfile (ATLAS)

200 Level Courses

SPACE 204 (ASTRO 204) (EARTH 204). The Planets: Their Geology and Climates
Prerequisite: None. (3 credits)
Structure, composition and evolutionary history of the surfaces and atmospheres of the planets and their satellites, with special emphasis given to comparative aspects of geology and climatology. Intended for non-science majors with a background in high school math and science. CourseProfile (ATLAS)

SPACE 205. Mathematics of Rocket Science
Prerequisite: None. (1 credit)
This class delves into the mathematics and computer programming involved in launching a satellite into orbit, changing orbits, and planetary and lunar missions. CourseProfile (ATLAS)

CLIMATE 280 (SPACE 280). Undergraduate Research Experience
Prerequisites: None. (1-4 credits)
Individual or group research experience in atmospheric and space sciences. The Individual or group research experience in atmospheric and space sciences. The program of work is arranged at the beginning of the semester by mutual agreement between the student and a faculty member. Written and/or oral reports will be required. CourseProfile (ATLAS)

300 Level Courses

CLIMATE 300 (SPACE 300). Global Environmental Impact of Technological Change
Advisory Prerequisite: CHEM 130, MATH 116. (3 credits)
This course provides a scientific exploration of the unexpected global environmental side effects of technological innovation. Case studies are presented and discussed illustrating how technological advances can sometimes produce unexpected and undesirable environmental results. Lessons learned from previous environmental crises including new tools for assessing risk are discussed and applied. CourseProfile (ATLAS)

SPACE 310. Introduction to Satellite Mission Design
Advisory Prerequisite: ENGR 100 and ENGR 101. (3 credits)
This class teaches the fundamentals of designing a satellite mission, using projects. Topics that will be discussed include: (1) different subsystems; (2) formulating instrument requirements; (3) power, mass, data, and financial budgets; (5) solar power and depth of discharge; (6) thermal design; (7) orbits and launch vehicles; and (8) attitude control. CourseProfile (ATLAS)

CLIMATE 320. (SPACE 320) (EARTH 320) Earth System Evolution
Advisory Prerequisite: MATH 115, MATH 116. Minimum grade of “C” for advised prerequisites. (3
Credits
Introduction to the physics and chemistry of Earth and space. Gravitational energy, radiative energy, Earth’s energy budget and Earth tectonics are discussed along with chemical evolution and biogeochemical cycles. The connections among the carbon cycle, silicate weathering and the natural greenhouse effect are discussed. CourseProfile (ATLAS)

CLIMATE 321 (SPACE 321) (EARTH 321). Earth and Space Systems Dynamics
Advisory Prerequisite: CLIMATE/SPACE 320. Preceded or accompanied by MATH 215 and MATH 216. (3 credits)
This course will describe the major wind systems and ocean currents that are important to climate studies. The primary equations will be developed and simple solutions derived that will explain many of these motions. The relations among the dynamics and other parameters in the climate system will be illustrated by examples from both paleo and present day systems. CourseProfile (ATLAS)

CLIMATE 323 (SPACE 323) (EARTH 323). Earth System Analysis
Prerequisite: none. (4 credits)
Introduction to the analysis of Earth and Atmospheric Science Systems. Topics include linear systems, harmonic analysis, sampling theory and statistical error analysis. Lectures emphasize underlying mathematical concepts. Labs emphasize application of mathematical methods to analysis of field data in a computer programming environment. Applications include turbulent air motion in the planetary boundary layer, cloud and precipitation microphysical composition, oceanic wave propagation, stratospheric ozone depletion and satellite remote sensing. CourseProfile (ATLAS)

CLIMATE 324 (SPACE 324). Instrumentation for Atmospheric and Space Science
Prerequisite: none. (4 credits)
Introduction to fundamentals of atmospheric, space-based, and meteorological instrumentation. Includes basics of electronic sensors, optics, lasers, radar, data acquisition/management, error analysis, and data presentation. Consists of two lectures and one lab each week, and a team-based term project. CourseProfile (ATLAS)

CLIMATE 350 (SPACE 350) (EARTH 350). Atmospheric Thermodynamics
Prerequisite: MATH 216 or equivalent. Minimum grade of “C” required for enforced prerequisite. (3 credits)
Fundamentals of thermodynamics are presented, including the First, Second and Third Laws, ideal gases, adiabatic processes, phase changes, vapor pressure, humidity and atmospheric stability. The Kinetic Theory of Gases provides a molecular perspective on the various forms of atmospheric water substance and on macroscopic phenomenology in general. CourseProfile (ATLAS)

SPACE 370 (EARTH 370). Solar Terrestrial Relations
Prerequisite: MATH 216, Physics 240. (4 credits)
Introduction to solar terrestrial relations with an overview of solar radiation and its variability on all time-scales. The effects of this variability on the near-Earth space environment and upper atmosphere are considered, as well as effects on the lower and middle atmosphere with connections to weather and climate. Subjects are approached through extensive data analysis, including weekly computer lab sessions. CourseProfile (ATLAS)

SPACE 371. Space Engineering to Solve Society’s Challenges
Advisory Prerequisite: SPACE 310, SPACE 370. Enforced Prerequisite: CLIMATE 320/SPACE 320, CLIMATE 324/SPACE 324. Minimum grade requirement of “C- or above”. (3 credits)
This course explores how to implement a successful space mission given a set of science objectives. Space science, spacecraft design, error analysis, and signal detection are integrated through a series of case studies. Example space, planetary, astrophysical, and earth science missions will be discussed and explored to illustrate these topics. CourseProfile (ATLAS)

CLIMATE 380 (SPACE 380) (EARTH 381). Introduction to Atmospheric Radiation
Prerequisite: MATH 216 or equivalent. Minimum grade of “C” required for enforced prerequisite. (3 credits)
Basic concepts and processes of radiative transfer including radiometric quantities, electromagnetic spectrum, absorption, emission and scattering. The physics laws governing these processes including the Planck Law and the Kirchhoff Law. Radiative properties of atmospheric constituents. Reflection and refraction. Introductory-level descriptions of relevant applications in atmospheric sciences and climate physics. CourseProfile (ATLAS)

CLIMATE 381 (SPACE 381). Undergraduate Research Experience II
Prerequisite: CLIMATE 280, SPACE 280 or junior/senior standing. (1-4 credits)(Requires successful completion of 4 credits of CLIMATE/SPACE 280.)
Individual or group research experience in atmospheric, space science or space technology. The program of work is arranged at the beginning of the semester by mutual agreement between the student and a faculty member. Written and/or oral reports will be required. CourseProfile (ATLAS)

400 Level Courses

CLIMATE 401 (EARTH 401). Geophysical Fluid Dynamics
Advisory Prerequisites: Physics 240, MATH 215, MATH 216, CLIMATE 323, SPACE 323. (4 credits)
Dynamics of the oceans and atmosphere. Equations of motion in spherical coordinates, beta-plane approximation, wave properties in the oceans and atmosphere. CourseProfile (ATLAS)

CLIMATE 405 (SPACE 405). Special Topics
Prerequisite: None. (1-4 credits)
Advances in specific fields of Atmospheric, Oceanic and Space Sciences as revealed by recent research. CourseProfile (ATLAS)

CLIMATE 407 (SPACE 407). Mathematical Methods in Geophysics
Advisory Prerequisite: MATH 216. (4 credits)
Vector calculus and Cartesian tensors; Sturm-Liouville systems, Green's Functions and solution of boundary value problems; Fourier series, Fourier and Laplace transforms, discrete Fourier transform, fast Fourier transforms, and energy spectra and singular perturbation theory. CourseProfile (ATLAS)

CLIMATE 410. Earth System Modeling
Advisory Prerequisite: CLIMATE 320, CLIMATE 321, SPACE 320, SPACE 321. (4 credits)
Introduction to Earth System Modeling; discussion of energy balance models, carbon cycle models and atmospheric chemistry models with multiple time scales; methods for numerical solution and practice building and analyzing results from models. CourseProfile (ATLAS)

CLIMATE 411 (EARTH 411). Cloud and Precipitation Processes
Advisory Prerequisite: CLIMATE 350, SPACE 350, MATH 216. (3 credits)
The special nature of water substance; nucleation of phase changes in the free atmosphere; the structure and content of clouds; the development of physical characteristics of precipitation; and the dynamics of rain systems. CourseProfile (ATLAS)

CLIMATE 414 (EARTH 414). Weather Systems
Advisory Prerequisite: CLIMATE 350, SPACE 350, CLIMATE 401 or CLIMATE 551. (3 credits)
Introduction to the basic characteristics, thermodynamics and dynamics of atmospheric weather systems on Earth and other planets. The students are exposed to observations of weather systems while reviewing non-dimensional analysis, dynamics and thermodynamics. Weather systems on earth are compared to that of other planets and analytical tools are used to gain insights into their basic physics. CourseProfile (ATLAS)

CLIMATE 420 (NAVARCH 420) (ENSCEN 420). Environmental Ocean Dynamics
Prerequisite: NAVARCH 320 or AOSS 305 or CEE 325. (4 credits)
Physical conditions and physical processes of the oceans; integration of observations into comprehensive descriptions and explanations of oceanic phenomena. Emphasis on wave and current prediction, optical and acoustical properties of sea water, currents, tides, waves and pollutant transport. CourseProfile (ATLAS)

CLIMATE 421. (EARTH 421) (ENVIRON 426). Introduction of Physical Oceanography
Prerequisite: Introductory science course, MATH 115 and MATH 116 or permission of instructor. (3 credits)
This course examines the fundamentals of physical oceanography; the physical properties of the ocean and water masses; circulation of the atmosphere; wind-driven and buoyancy-driven ocean circulation; tides; surface and internal waves; eddies; and mixing. CourseProfile (ATLAS)

CLIMATE 422 (EARTH 423). Boundary Layer Meteorology
Advisory Prerequisite: CLIMATE 350, SPACE 350 or equivalent. (4 credits)
Explores processes in the atmospheric boundary layer, which plays an important role in the exchange of energy, mass and momentum between land and atmosphere. Topics include applications of governing atmospheric equations, atmospheric turbulence, turbulent kinetic energy, the surface energy balance and the collection and analysis of field flux tower data. CourseProfile (ATLAS)

CLIMATE 423 (Clasp – SPACE – 423). Data Analysis and Visualization for Geoscientists
Prerequisite: ENGR 101. Minimum grade of “C-“. (4 credits)
Fundamental data science, data and error analysis, data-model comparison tests and metrics, and visualization techniques. Taught through a combination of lecture and interactive laboratory sessions with datasets from space and climate sciences using Python for analysis. Culminates in a final project with a dataset chosen by the students and guided by the instructor. By course end, students will be able to produce publication-ready scientific data visualization, read and write data sets using Python, perform large data set analysis, conduct data-model comparisons, and interpret basic hypothesis testing. CourseProfile (ATLAS)

CLIMATE 431 (SPACE 431) (EECS 430). Radiowave Propagation and Link Design
Prerequisite: Physics 405 or EECS 330. (4 credits)
Fundamentals of electromagnetic propagation and radiation; radiowave propagation in different environments (near Earth, troposphere, ionosphere, indoor and urban); antenna parameters; practical antennas; link analysis; system noise; fading and multipath interference. Course includes lectures, labs and a project in which student teams develop and implement practical wireless systems. CourseProfile (ATLAS)

CLIMATE 440 (EARTH 454). Meteorological Analysis Laboratory
Advisory Prerequisite: CLIMATE 350, SPACE 350, CLIMATE 401. (4 credits)
This course provides an introduction into the analysis of both surface-based and remotely-sensed meteorological data. The development and application of operational numerical forecast models will be discussed. Techniques for the prediction of both synoptic and mesoscale meteorological phenomena will also be presented. CourseProfile (ATLAS)

CLIMATE 441. Meteorology and Climate of the Rockies
Advisory Prerequisite: CLIMATE/SPACE 320, CLIMATE/SPACE 321, CLIMATE/SPACE 323. (3 credits)
This course introduces principles of atmospheric and environmental sciences using the Rocky Mountains as a field laboratory. Students will develop an understanding of meteorological processes to explain variations in microclimates, and the importance of mountainous regions on the earth’s climate. Students will gain field-based knowledge of mountain climates and instrumentation. CourseProfile (ATLAS)

CLIMATE 442 (ENSCEN 442). Oceanic Dynamics I
Prerequisite: CLIMATE 401. (3 credits)
Wave motions; group velocity and dispersion. Gravity waves, wave statistics and prediction methods; long period waves; the tides. Steady state circulation, including theories of boundary currents and the thermocline. CourseProfile (ATLAS)

CLIMATE 450 (SPACE 450). Geophysical Electromagnetics
Advisory Prerequisite: MATH 216. (4 credits)
The fundamentals of electricity, magnetism and electrodynamics in the context of the Earth. The first segment will cover electrostatics, the electric structure and circuit of the Earth, electricity in clouds and lightning. The second segment will cover magnetostatics, currents, the magnetic field and magnetic dynamo of the Earth, and the Earth’s magnetosphere. The third segment will cover electrodynamics, electromagnetic waves, radiation in the Earth environment, waveguides and radiation from sources. CourseProfile (ATLAS)

CLIMATE 451 (ENSCEN 451) (EARTH 457). Atmospheric Dynamics I
Advisory Prerequisite: CLIMATE 401 or MATH 450. (4 credits)
Quasi-geostrophic energetics; fronts; the mean circulation; planetary and equatorial waves: overview of the dynamics of the middle atmosphere; wave-mean flow interaction; spectral methods; and tropical meteorology. CourseProfile (ATLAS)

CLIMATE 455 (SPACE 455). Senior Capstone Design
Advisory Prerequisite: Senior Standing. Not open to graduate students. (1-4 credits)
A CLIMATE or SPACE SCIENCE and engineering design project by which the student is exposed to the design process from concept through analysis to layout and report. Projects are proposed from the different areas of study within Climate and Space Sciences and Engineering and reflect the expertise of instructional faculty and industrial or laboratory representatives. CourseProfile (ATLAS)

CLIMATE 463 (ENSCEN 463). Air Pollution Meteorology
Prerequisite: MATH 215. (3 credits)
Weather and motion systems of the atmosphere; topographic influences on winds, atmospheric stability and inversions; atmospheric diffusion; natural cleansing processes; meteorological factors in plant location, design and operation. CourseProfile (ATLAS)

CLIMATE 466. Carbon-Climate Interaction
Advisory Prerequisite: For undergraduates: CLIMATE/SCIENCE 320 and CLIMATE/SCIENCE 321. (3 credits)
The class will focus on the exchange of carbon among reservoirs in the Earth system — atmosphere, ocean, lithosphere and biosphere — and the role of carbon dioxide, CO2, as a greenhouse gas. CourseProfile (ATLAS)

CLIMATE 467 (CHEM 467) (EARTH 465) (ENSCEN 467) (Environ 467). Biogeochemical Cycles
Advisory Prerequisite: MATH 116, CHEM 210, Physics 240. (3 credits)
The biogeochemical cycles of water, carbon, nitrogen and sulfur; the atmosphere and oceans as reservoirs and reaction media; the fate of natural and man-made sources of carbon, nitrogen, and sulfur compounds; the interactions among the major biogeochemical cycles and resultant global change; greenhouse gases, acid rain and ozone depletion. CourseProfile (ATLAS)

SPACE 471. Space Instrumentation
Advisory Prerequisite: SPACE 310 or SPACE 370 or Graduate Standing. Minimum grade of “C-“(3 credits)
Fundamental principles and techniques of space physics observations and discussion of hardware and analysis techniques including in situ and remote sensing. The physical measurement principles, details of the designs of different instrumentation, and how instrument measurement output is converted to different parameters. The assumptions, limitations, and errors of different techniques to measure magnetized plasma, particle and field environments of the Earth, solar system objects and the Sun. CourseProfile (ATLAS)
CLIMATE 473. Climate Physics  
*Advisory Prerequisite: Senior or graduate standing in science or engineering (3 credits)*  
Introduction to physical mechanisms that determine climate, including relevant atmospheric, hydrologic, cryospheric, solar/orbital, volcanic and human processes. Discusses qualitative and descriptive techniques to understand how radiative, thermodynamic and dynamic processes distribute energy throughout the Earth System, drive climate feedbacks and determine the sensitivity of Earth’s climate to external perturbations. [CourseProfile (ATLAS)]

CLIMATE 474 (EARTH 474). Ice Sheets, Glaciers and Climate Change  
*Advisory Prerequisite: MATH 115 and 116. (3 credits)*  
The dynamics and mass balance of ice sheets and glaciers introduced along with mathematical theories describing how ice sheets and glaciers flow and current methods of observation. The course integrates lectures, assignments and discussion of journal articles. [CourseProfile (ATLAS)]

CLIMATE 475. (ENSCEN 475) (EARTH 475). Earth System Interactions  
*Prerequisite: Senior standing in science or engineering. (4 credits)*  
Students will work on open-ended research problems with mathematical models from Earth System Science. The models may include, for example, surface characteristics, hydrology, solar-land-ocean-atmosphere exchanges and space-based observations. Numerical experiments will promote further understanding and interpretation of earth system interactions, team building and scientific communication. [CourseProfile (ATLAS)]

CLIMATE 476. Ocean Dynamics and Climate  
*Advisory Prerequisite: CLIMATE 401 or CLIMATE 551 or SPACE 551. (4 credits)*  
Large-scale physical oceanography and the role of the ocean in climate. Theory and observations in the wind-driven and thermohaline circulation, vortices and planetary waves. [CourseProfile (ATLAS)]

SPACE 477. Space Weather Modeling  
*Prerequisite: SPACE 370. Minimum grade of “C” required for enforced prerequisites. (4 credits)*  
An introduction to a variety of models of the space environment, including models of the sun, magnetosphere, ring current, ionosphere, thermosphere and ionospheric electrodynamics. Students will learn the origins of different models, what each represents, to run the models and become familiar with the output. [CourseProfile (ATLAS)]

SPACE 478. Engineering for Space Environment  
*Advisory Prerequisite: Senior or graduate standing advised. (4 credits)*  
This course will cover the basics of the Sun and the solar wind and their influence on the space environment. In addition, atmospheric effects on spacecraft are considered. We discuss not only the physics of the drivers of space weather, but also the implications for satellite systems and their design and operation. [CourseProfile (ATLAS)]

CLIMATE 479 (ENSCEN 479). Atmospheric Chemistry  
*Prerequisite: CHEM 130, MATH 216. (4 credits)*  
Thermochemistry, photochemistry and chemical kinetics of the atmosphere; geochemical cycles, generation of atmospheric layers and effects of pollutants are discussed. [CourseProfile (ATLAS)]

CLIMATE 480 (EAS 480). Climate Change: A Multidisciplinary Approach to Problem Solving  
*Advisory Prerequisite: Senior or graduate standing, MATH 116. (3 credits)*  
All sectors of society are affected by climate change: science, policy, business, economics, public health, energy, ecosystems, environmental engineering, journalism, religion, etc. This course explores the intersections of these communities and exposes students the factual and contextual elements that will allow effective participation in the adaption to climate change. [CourseProfile (ATLAS)]

SPACE 495 (ENSCEN 495). Upper Atmosphere and Ionosphere  
*Prerequisite: None. (4 credits)*
Basic physical and chemical processes important in controlling the upper/middle atmosphere and ionosphere: photochemistry, convection, diffusion, wave activity, ionization, heating and cooling. The terrestrial, as well as planetary atmospheres and ionospheres are to be considered. 

**CLIMATE 498 (SPACE 498). Practicum in Climate and Space Science**  
*Prerequisite: Permission of instructor. (1 or 2 credits)*  
Course may be repeated to a maximum of 8 credit hours. Students taking this course will participate in research and/or engineering tasks. Supervision will be undertaken by faculty and engineers of the Climate & Science department. Reporting requirements include a final written summary. Diverse tasks include aircraft spacecraft and rocket payload design field campaign support calibration simulation test. Students will join an active research program of Climate & Science for a given semester. 

**CLIMATE 499 (SPACE 499). Directed Study**  
*Prerequisite: Permission of instructor. (1-16 credits) (Only 4 credits can be applied as a Technical Elective.)*  
Offers research or directed study experience for students in an area of interest to the student and faculty member. An oral presentation and/or written report is due at the end of the term. 

**SPACE 499 (CLIMATE 499). Directed Study**  
*Prerequisite: Permission of instructor. (1-16 credits) (Only 8 credits can be applied as a Technical Elective.)*  
Offers research or directed study experience for students in an area of interest to the student and faculty member. An oral presentation and/or written report is due at the end of the term. 

**500 Level Courses**

**CLIMATE 501 (SPACE 501). Seminars in Climate, Atmospheres and Space Sciences**  
*Prerequisite: Graduate Standing. (1 credit)*  
Current research efforts will be presented by graduate students and faculty dealing with all phases of the climate, atmospheric and space sciences. 

**CLIMATE 511. Aerosol Physics and Chemistry**  
*Prerequisite: Senior or graduate standing (3 credits)*  
Introduction to fundamental principles and latest developments in aerosol science. The dependence of aerosol composition and size distributions on the underlying atmospheric thermodynamics, dynamics, chemistry and physics will be presented. Recent observations and theoretical treatments are used to illustrate aspects of aerosol science that are poorly quantified at present. 

**CLIMATE 524 (ENSCEN 524). General Circulation**  
*Prerequisite: Previous or concurrent with CLIMATE 401. (3 credits)*  
Processes that maintain the general circulation of the Earth’s atmosphere; the observed general circulation; energetics; balance requirements; comparison of observations with simple theories and results from general circulation model simulations. 

**CLIMATE 528 (NAVARCH 528) (ENSCEN 529) (SPACE 528). Remote Sensing of Ocean Dynamics**  
*Prerequisite: AOSS 425 (NAVARCH 425) or permission of instructor. (3 credits)*  
The dynamics of ocean wave motion, both surface and internal waves, and ocean circulation are explored utilizing active and passive remote sensing techniques. Emphasis is placed upon the
synoptic perspective of ocean dynamics provided by remote sensing which is not obtainable by conventional means. 

**CLIMATE 530. Using Climate-Change Knowledge in Planning and Design**

Prerequisite: Basic knowledge of climate change and its impact. (2 credits)

This seminar focuses on special topics on the use of climate-change data and knowledge in planning, design, engineering and management. Topics include, for example, uncertainty in the context of decision making, nonstationarity in design and engineering, and vulnerability and risk assessment.

**CourseProfile (ATLAS)**

**CLIMATE 532 (SPACE 532). Radiative Transfer**

Advisory Prerequisite: PHYSICS 405. (4 credits)

Physical processes, mathematical representation and numerical modeling of radiative transfer through atmospheres. Rayleigh and Mie scattering. Gaseous absorption and emission lines and line broadening. Numerical considerations and approximations. Applications include radiative energy balance and global climate, satellite remote sensing of atmospheres, and propagation through ionized media.

**CourseProfile (ATLAS)**

**SPACE 545. High Energy Density Physics**

Prerequisite: MATH 450, PHYSICS 405 & PHYSICS 406. (3 credits)

Introduces students to fundamental tools and discoveries of high-energy density physics, where pressures are above a million atmospheres. Discusses fundamental physical models, equations of state, hydrodynamics including shocks and instabilities, radiation transport, radiation hydrodynamics, experimental technique, inertial fusion, experimental astrophysics and relativistic systems.

**CourseProfile (ATLAS)**

**CLIMATE 551 (SPACE 551). Fluid Dynamics for Climate and Space Sciences**

Advisory Prerequisite: MATH 215, MATH 216, and MATH 450. (4 credits)

Covers the fundamentals of fluid dynamics. The purpose of the course is to provide fundamental grounding in fluid dynamics and in fundamental mathematical technique at the level required to do serious quantitative graduate research that involves fluid dynamics effects. The emphasis of the examples is on geophysical and space applications.

**CourseProfile (ATLAS)**

**CLIMATE 555 (SPACE 555). Spectral Methods**

Advisory Prerequisite: MATH 216. ENGR 103. (4 credits)

An introduction to numerical methods based on Fourier Series, Chebyshev polynomials and other orthogonal expansions. Although the necessary theory is developed, the emphasis is on algorithms and practical applications in geophysics and engineering, especially fluid mechanics. Many homework assignments will be actual problem-solving on the computer.

**CourseProfile (ATLAS)**

**CLIMATE 563 (ENSCEN 563). Air Pollution Dispersion Modeling**

Prerequisite: CLIMATE 463. (3 credits)

Principles of modeling air pollution transport and dispersion. Discussion of models for line sources, area sources and point sources. Analysis of individual model data requirements, founding assumptions and inherent limitations. Practical experience using currently operational models.

**CourseProfile (ATLAS)**

**CLIMATE 564 (ENSCEN 564)(SPACE 564). The Stratosphere and Mesosphere**

Prerequisite: CLIMATE 464. (3 credits)

Physical, chemical and dynamical properties of the atmosphere between the tropopause and the turbopause. Among the topics covered are the heat and radiation budgets, atmospheric ozone, stratospheric warmings, the biennial stratospheric oscillation, airglow.

**CourseProfile (ATLAS)**

**CLIMATE 565 (SPACE 565). Planetary Science**

Advisory Prerequisite: Graduate standing. (4 credits)

Solar system formation; giant planets and origin of their atmospheres; biogeochemical evolution of
terrestrial planet atmospheres; radiative transfer, internal energy and thermal structure; thermochemical cloud formation; radiative and charged particle energetic processes for neutrals and ions; origin of satellite atmospheres; extrasolar planets; life in the universe; planetary exploration. CourseProfile (ATLAS)

CLIMATE 567 (CHEM 567). Chemical Kinetics
*Prerequisite: CHEM 461 or CLIMATE 479. (3 credits)*
A general course in chemical kinetics, useful for any branch of chemistry where reaction rates and mechanisms are important. Scope of subject matter: practical analysis of chemical reaction rates and mechanisms, theoretical concepts relating to gas and solution phase reactions. CourseProfile (ATLAS)

CLIMATE 574 (AEROSP 574). Introduction to Space Physics
*Prerequisite: Senior or Graduate Standing. (4 credits)*
A graduate level introduction to physical and aeronomical processes in the space environment. Discussion of theoretical tools, the Sun, solar wind, heliosphere, magnetosphere, ionosphere and the upper atmosphere. Spacecraft interaction with radiation, spacecraft-plasma interactions. CourseProfile (ATLAS)

CLIMATE 575 (ENSCEN 575). Air Pollution Monitoring
*Advisory Prerequisite: CLIMATE 463, CLIMATE 578, NRE 538 (previously or concurrently). (3 credits) (Graduate students only.)*
A practical introduction to the fundamentals of gas and aerosol measurements with a focus on ozone and acidic gases, their precursors and aerosols; operation of the suite of instruments, detection and sampling techniques and calibration practices. An important feature will be team-oriented tasks involving air quality monitoring. CourseProfile (ATLAS)

CLIMATE 576 (ENSCEN 576). Air Quality Field Project
*Advisory Prerequisite: CLIMATE 578, NRE 538, CLIMATE 575, or CLIMATE 563. (4 credits) (Graduate students only.)*
Practical experience in all aspects of air quality field measurements from the design and planning stage through implementation and data analysis and interpretation. Emphasis on research design, sampling, data management systems, sample tracking, computerized data acquisition and processing, error analysis and reporting; team-oriented practicum for modelers and experimentalists. CourseProfile (ATLAS)

CLIMATE 578 (ENSCEN 578). Air Pollution Chemistry
*Prerequisite: CLIMATE 479 or CHEM 365. (3 credits)*
Tropospheric and stratospheric air pollution are discussed following a review of thermochemistry, photochemistry and chemical kinetics. Gaseous and particulate air pollutants are considered in terms of their origins and transformations. CourseProfile (ATLAS)

CLIMATE 580 (SPACE 580). Remote Sensing and Geographic Information System Project Laboratory
*Prerequisite: MATH 216, Physics 140. (2 credits)*
Lectures and hands-on demonstrations train students in acquiring and processing remote sensing and field data using computer based image processing and geographic information systems. Students apply this knowledge in individual and small team projects oriented toward student interests. Research project results are communicated in formal presentations and written reports. CourseProfile (ATLAS)

SPACE 581 (AEROSP 581). Space Policy and Management
*Prerequisite: Graduate Standing. (3 credits)*
The first part of the course will provide detailed information on how space policy is developed in the United States and the international space community and how these policies result in specific missions. The second part will provide detailed information on modern management techniques and
processes. Project managers from NASA centers and industry will lecture on the detailed management techniques and processes. CourseProfile (ATLAS)

SPACE 582 (AEROSP 582). Spacecraft Technology
Prerequisite: Graduate standing. (4 credits)
Systematic and comprehensive review of spacecraft and space mission design and key technologies for space missions. Discussions on project management and the economic and political factors that affect space missions. Specific space mission designs are developed in teams. Students of AEROSP 483/583 choose their projects based on these designs. CourseProfile (ATLAS)

SPACE 583 (AEROSP 583). Management of Space Systems Design
Prerequisite: AEROSP/SPACE 582. (4 credits)
Students in this course lead teams in high level project design of a space system. Modern methods of concurrent engineering manufacturing, marketing and finance, etc., are incorporated. CourseProfile (ATLAS)

SPACE 584. Space Mission Design and Implementation on a High-Altitude Balloon
Prerequisite: Senior or graduate standing. (4 credits)
This class teaches students how to design, build, test and deploy a completely autonomous, sophisticated system that is designed to accomplish a specific task. The primary system is a small-satellite, deployed on a high-altitude balloon. This system involves communication, position tracking, microcontrollers, instruments and a power system. CourseProfile (ATLAS)

CLIMATE 585 (SPACE 585). Inverse Methods for Remote Sensing
Advisory Prerequisite: Graduate standing. (3 credits)
Introduction to active (radar and lidar) and passive (thermal emission) visible, infrared and microwave remote sensing. Fundamentals of electromagnetic emission, absorption and scattering. Sensor performance characteristics. Mathematical methods for inversion of integral transforms and ill-conditioned systems of equations commonly encountered in remote sensing applications. CourseProfile (ATLAS)

CLIMATE 586 (SPACE 586). Advanced Data Analysis Techniques
Advisory Prerequisite: Graduate standing (3 credits)
Objective methods are introduced for analyzing climate data with inherent spatial and/or temporal correlation scales. These include time series analysis, pattern recognition techniques, regression, and linear modeling. The emphases are both the usage of such methods and critical evaluation of literature that employ them. CourseProfile (ATLAS)

CLIMATE 587 (EECS 532) (SPACE 587). Microwave Remote Sensing I: Radiometry
Prerequisite: EECS 330, graduate standing. (3 credits)
Radiative transfer theory: blackbody radiation; microwave radiometry; atmospheric propagation and emission; radiometer receivers; surface and volume scattering and emission; applications to meteorology, oceanography and hydrology. CourseProfile (ATLAS)

CLIMATE 588. Regional Scale Climate
Prerequisite: graduate standing. (4 credits)
Regional scale climate processes are introduced along with the tools needed for their analysis, including downscaling techniques. The course integrates lectures, assigned journal papers and hands-on data analysis. In a course project, students will apply the analytical tools to a subject chosen by the student. CourseProfile (ATLAS)

CLIMATE 589. The Art of Climate Modeling
Prerequisite: Graduate standing, basic understanding of Atmospheric dynamics and the general circulation of the atmosphere; Unix; higher level programming language; numerical methods. (4 credits)
The course introduces the newest climate modeling techniques by surveying the design decisions in
atmospheric General Circulation Models (GCMs), the trends in GCM and dynamical core modeling and how GCMs are coupled. It is built upon hands-on GCM modeling and data projects, journal paper discussions, lectures, shared cyber-infrastructure and computational tools. CourseProfile (ATLAS)

SPACE 590. Space Systems Projects  
*Prerequisite: Graduate standing. (1-4 credits)*  
Space science and application mission related team project. Student teams will participate in ongoing projects in the Space Physics Research Laboratory in conjunction with industry and government sponsors. CourseProfile (ATLAS)

CLIMATE 591. Climate Practicum I  
*Advisory Prerequisite: Senior or graduate standing. (4 credits)*  
Introduction to individual and team research on real-world problems in the area of applied climate. A mentor from a commercial or governmental laboratory will pose the problem and help to guide the research. Students will learn how to apply knowledge they have already acquired. This course followed by CLIMATE 592. CourseProfile (ATLAS)

CLIMATE 592. Climate Practicum II  
*Prerequisite: Senior or graduate standing and CLIMATE 591. (4 credits)*  
Introduction to individual and team research on real-world problems in the area of applied climate. On a research project started in CLIMATE 591 and guided by a mentor from a commercial or government laboratory, students will apply the principles of risk analysis and objective assessment of adaptive strategies. CourseProfile (ATLAS)

SPACE 595 (EECS 518). Magnetosphere and Solar Wind  
*Prerequisite: Graduate standing. (3 credits)*  
General principles of magnetohydrodynamics; theory of the expanding atmosphere; properties of solar wind, interaction of solar wind with the magnetosphere of the Earth and other planets; bow shock and magnetotail, trapped particles, auroras. CourseProfile (ATLAS)

SPACE 596. Gaskinetic Theory  
*Advisory Prerequisite: Graduate standing. (3 credits)*  

SPACE 597 (AEROSP 597). Fundamentals of Space Plasma Physics  
*Prerequisite: senior-level statistical physics course. (3 credits)*  
Basic plasma concepts, Boltzmann equation, higher order moments equations, MHD equations, double adiabatic theory. Plasma expansion to vacuum, transonic flows, solar wind, polar wind. Collisionless shocks, propagating and planetary shocks. Fokker-Planck equation, quasilinear theory, velocity diffusion, cosmic ray transport, shock acceleration. Spacecraft charging, mass loading. CourseProfile (ATLAS)

SPACE 598. The Sun and the Heliosphere  
*Prerequisite: SPACE 574 & PHYSICS 505 or equivalent. (3 credits)*  
A complete description of the physical processes that govern the behavior of the Sun and the heliosphere with emphasis on recent theoretical and observational results. CourseProfile (ATLAS)
600 Level Courses

CLIMATE 605 (SPACE 605). Current Topics in Climate and Space Sciences and Engineering
Prerequisite: None. (1-4 credits)
Advances in specific fields of climate and space sciences, as revealed by recent research. Lecture, discussion and assigned reading. CourseProfile (ATLAS)

CLIMATE 606 (SPACE 606). Computer Applications to Geo-Fluid Problems
Advisory Prerequisite: CLIMATE 442 or CLIMATE 451, ENGR 103, MATH 450. (3-4 credits)
Solution of geo-fluid problems by numerical techniques using a digital computer. Lectures, laboratory, exercises using the digital computer. CourseProfile (ATLAS)

CLIMATE 651 (SPACE 651). Dynamics of Planetary Atmospheres and the Upper Atmosphere
Advisory Prerequisite: CLIMATE 451. (3 credits)
Dynamic meteorology of other planets (Mars, Venus, Jupiter and Titan), the Earth’s middle atmosphere and thermosphere. Tides, solitary waves, quasi-geostrophic turbulence and dynamics and chemistry are among the phenomena discussed. CourseProfile (ATLAS)

SPACE 690 (CLIMATE 690). Thesis/Master of Science
Prerequisite: Permission of instructor; graduate standing. (2-6 credits)
Provides credit for research and writing of a Masters Thesis under direction of a faculty member. CourseProfile (ATLAS)

700 Level Courses

CLIMATE 701 (SPACE 701). Special Problems in Climate and Space Sciences
Prerequisite: permission of instructor.
Supervised analysis of selected problems in various areas of climate and space sciences. CourseProfile (ATLAS)

CLIMATE 747 (SPACE 747). CLaSP Student Seminar
Prerequisite: none. (1 credit)
Students take turns presenting short research seminars (20 minutes) and/or short talks introducing upcoming speakers in CLIMATE/SPACE 749. Some class time will also be devoted to discussions of effective oral and poster presentations and professional ethics. CourseProfile (ATLAS)

CLIMATE 749 (SPACE 749). CLaSP Seminar
Prerequisite: none. (1 credit)
Presentations from UM researchers and outside speakers about current research results, covering a broad range of topics in climate, atmosphere and space science. In this class students take turns serving as seminar chair. Questions from students will be handled before those from faculty. Conditions for credit are participation in this seminar and the completion of a short paper in which each student follows up on one talk given as part of this seminar series. CourseProfile (ATLAS)

SPACE 701 (CLIMATE 701). Special Problems in Meteorology and Oceanography
Prerequisite: permission of instructor.
Supervised analysis of selected problems in various areas of climate and space sciences. CourseProfile (ATLAS)

900 Level Courses

CLIMATE 990 (SPACE 990). Dissertation/Pre-Candidate
(2-8 credits); (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

SPACE 990 (CLIMATE 990). Dissertation/Pre-Candidate (2-8 credits); (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

CLIMATE 995 (SPACE 995). Dissertation/Candidate Graduate School
Prerequisite: authorization for admission as a doctoral candidate. (8 credits); (4 credits)
Cancellation for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

SPACE 995 (CLIMATE 995). Dissertation/Candidate Graduate School
Prerequisite: authorization for admission as a doctoral candidate. (8 credits); (4 credits)
Cancellation for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)
Electrical Engineering
& Computer Science
Overview

The expanding roles of electrical engineers, computer engineers, and computer scientists in today’s society reflect the variety and scope of these exciting professions. In recognition of the distinct qualifications required of engineers and scientists entering these fields, the Electrical Engineering and Computer Science department offers undergraduate programs in the following five areas: an electrical engineering program leading to a Bachelor of Science in Engineering (Electrical Engineering) – B.S.E. (E.E.); a computer engineering program leading to a Bachelor of Science in Engineering (Computer Engineering) – B.S.E. (C.E.); a computer science program leading to a Bachelor of Science in Engineering (Computer Science) – B.S.E. (C.S.) offered through the College of Engineering; a data science program leading to a Bachelor of Science in Engineering (Data Science) – B.S.E (D.S.); or a Bachelor of Arts or Bachelor of Science degree offered through the College of LS&A. (Please consult the LS&A Bulletin for information about completing a computer science or data science degree through LS&A. LS&A also offers a Bachelor of Science degree in Data Science through the Department of Statistics.)

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

Department Administration

Interim Department Chair, CSE Division
Peter Chen, Arthur F. Thurnau Professor
3713 Bob & Betty Beyster Building

Department Chair, ECE Division
Mingyan Liu, Peter and Evelyn Fuss Chair of Electrical and Computer Engineering
3401 Electrical Engineering & Computer Science Building

For more specific information on contacting people, go to our Contacts page.

Mission Statements

Computer Engineering

Mission

To provide a solid technical foundation that prepares students for a career that can adapt to rapidly changing technology in computer engineering.
Goals
To educate students with a broad and in-depth knowledge of computing systems, and to develop leaders in this field.

Objectives
• Graduates should be able to apply the technical skills necessary to design and implement low level computer systems and applications.
• Graduates should have the theoretical and practical skills needed for advanced graduate education.
• Graduates should be able to work effectively on teams, to communicate in written and oral form, to practice life-long learning, and to develop the professional responsibility needed for successful technical leadership positions.

Outcomes
The outcome we desire is that our graduates demonstrate:
• An ability to apply knowledge of mathematics, science, and engineering.
• An ability to design and conduct experiments, as well as to analyze and interpret data.
• An ability to design, implement, test, and evaluate a computer system, component, or algorithm to meet desired needs.
• An ability to function on multi-disciplinary teams.
• An ability to identify, formulate, and solve engineering problems.
• An understanding of professional and ethical responsibility.
• An ability to communicate effectively.
• The broad education necessary to understand the impact of computer engineering solutions in a global and societal context.
• A recognition of the need for an ability to engage in life-long learning.
• A knowledge of contemporary issues.
• An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
• A knowledge of probability and statistics, including applications appropriate to computer engineering.
• A knowledge of mathematics through differential and integral calculus, basic sciences, and engineering sciences necessary to analyze and design complex systems containing hardware and software components, as appropriate to program objectives.
• A knowledge of discrete mathematics.
Computer Science

Mission

To provide each student with a solid foundation in the scientific, engineering, and societal aspects of computing that prepares the student for a career that can advance the creation and application of computing technologies for the benefit of society.

Goals

To educate students with core knowledge of the software, hardware, and theory of computing; to give each student in-depth knowledge in one or more computing areas; and to develop leaders in this field.

Objectives

- To provide the necessary foundation in the principles and methods of computer science while preparing students for a broad range of responsible technical positions in industry and/or advanced graduate education.
- To provide the technical skills necessary to design and implement computer systems and applications, to conduct open-ended problem solving, and apply critical thinking.
- To provide an opportunity to work effectively on teams, to communicate in written and oral form, and to develop an appreciation of ethics and social awareness needed to prepare graduates for successful careers and leadership positions.

Outcomes

The outcome we desire is that our graduates demonstrate:

- An ability to apply knowledge of computing and mathematics appropriate to the program’s student outcomes and to the discipline
- An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution
- An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs
- An ability to function effectively on teams to accomplish a common goal
- An understanding of professional, ethical, legal, security and social issues and responsibilities
- An ability to communicate effectively with a range of audiences
- An ability to analyze the local and global impact of computing on individuals, organizations, and society
- Recognition of the need for and an ability to engage in continuing professional development
- An ability to use current techniques, skills, and tools necessary for computing practice.
• An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices.

• An ability to apply design and development principles in the construction of software systems of varying complexity.

**Data Science**

**Mission**

To provide each student with a solid foundation in techniques for deriving insights from data that may be complex, heterogeneous, voluminous, and rapidly changing.

**Goals**

To produce students with intellectual understanding of both statistical and computing principles for exploring methods and algorithms related to data science so as to enable knowledge creation and decision-making in various application domains.

**Objectives**

• To provide the necessary foundation in the principles and methods of data science while preparing students for a broad range of responsible technical positions in industry and/or advanced graduate education.

• To provide the technical skills necessary to ingest, curate, manage, query, analyze, and transform data.

• To provide an opportunity to communicate in written and oral form, to develop an appreciation of ethics, security, and privacy in the digital world, and to prepare graduates for successful careers and leadership positions.

**Outcomes**

The outcome we desire is that our graduates demonstrate:

• An ability to apply knowledge of mathematics, science, and engineering to problem solving.

• Knowledge of probability and statistics, including applications appropriate to data science.

• An ability to design and conduct experiments, as well as to analyze and interpret data.

• An ability to select ways of storing and analyzing data to meet desired needs, both in memory and on persistent storage.

• An ability to design and implement automated or semi-automated methods to help curate, query, and transform data.

• An ability to apply machine learning and statistical techniques to help analyze large datasets and to create prediction models or decision models.

• An ability to analyze data in the context of an application domain.

• An understanding of professional and ethical responsibility.
• An ability to communicate effectively.
• The broad education necessary to understand the impact of data science solutions in a global and societal context

**Electrical Engineering**

**Mission**

To provide an outstanding education for engineers in electrical engineering and to develop future leaders.

**Goals**

To provide students with the education for a rewarding and successful career.

**Objectives**

- Graduates should be prepared for entry-level engineering jobs, for graduate school, or for entrepreneurial activities based on their rigorous education in the fundamentals and applications of electrical engineering, including laboratory and design work.
- Graduates should be able to pursue a variety of careers, based on a curriculum that allows for a balance between a deep education in one area and a broad education in several areas.
- Graduates should be able to work effectively on diverse teams, to communicate in written and oral form, to practice life-long learning, and to develop the professional skills and ethics needed for successful leadership positions.

**Outcomes**

The outcome that we desire is that our graduates demonstrate:

- An ability to apply knowledge of mathematics, science, and engineering.
- An ability to design and conduct experiments, as well as to analyze and interpret data.
- An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- An ability to function on multi-disciplinary teams.
- An ability to identify, formulate, and solve engineering problems.
- An understanding of professional and ethical responsibility.
- An ability to communicate effectively.
- The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
- A recognition of the need for an ability to engage in life-long learning.
- A knowledge of contemporary issues.
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
Enrollment and Graduation Data

Computer Engineering

The University Registrar publishes the number of students enrolled annually in this program and the number of degrees granted by this program each term.

Computer Science Engineering

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

Data Science Engineering

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

Electrical Engineering

The University Registrar publishes the number of students enrolled annually in this program and the number of degrees granted by this program each term.

Undergraduate

Degree Program

Requirements

Candidates for the Bachelor of Science in Engineering (Computer Engineering) – B.S.E. (C.E.), the Bachelor of Science in Engineering degree (Computer Science) – B.S.E. (C.S.), the Bachelor of Science in Engineering (Data Science) – B.S.E. (D.S.) and Bachelor of Science in Engineering (Electrical Engineering) – B.S.E. (E.E.) must complete the respective degree requirements. The following Sample Schedules are examples that lead to graduation in eight terms. Candidates for the Bachelor of Science or Bachelor of Arts degree in Computer Science through the College of Literature, Science, and the Arts should consult the LS&A Bulletin for degree requirements.

C- Rule

Among science, engineering and mathematics courses, a grade of C- or below is considered unsatisfactory.

Repeat Policy

Students are limited to attempting each of the three 200-level courses (EECS 203, EECS 280, EECS 281) at most twice. An attempt includes, but is not limited to, a notation of any letter grade (A-F), withdraw (W), pass/fail (P/F), transfer (T), or incomplete (I) posted on the U-M transcript.
Declaration Requirements

The EECS Department follows the College of Engineering rules for Program Selection (i.e., Declaration). For more information see: “Academic Rules,” then the “Registration, Grading Options and Program Selection” section of the College Bulletin.

Sample Schedules

B.S.E. in Computer Engineering

The Computer Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. Please see the PDF version of the sample schedule. Additional information can be found on the department advising website, https://www.eecs.umich.edu/eecs/undergraduate/.

B.S.E. in Computer Science

The Computer Science program is accredited by the Computing Accreditation Commission of ABET, http://www.abet.org. Please see the PDF version of the sample schedule. Additional information can be found on the department advising website, https://www.eecs.umich.edu/eecs/undergraduate/.

B.S.E. in Data Science

*The Data Science program is not an ABET accredited program. Please see the PDF version of the sample schedule. Additional information can be found on the department advising website, https://www.eecs.umich.edu/eecs/undergraduate/*.

B.S.E. in Electrical Engineering

The Computer Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. Please see the PDF version of the sample schedule. Additional information can be found on the department advising website, https://www.eecs.umich.edu/eecs/academics/academics.html.

Concentrations

Computer Engineering

The program in Computer Engineering provides each student with a broad and well-integrated background in the concepts and methodologies that are needed for the analysis, design, and utilization of information processing systems. Although such systems are often popularly called “computers,” they involve a far wider range of disciplines than merely computation, and the Computer Engineering Program is correspondingly broad. A set of required technical courses (along with the college-wide requirements) gives the essential material in circuits, digital logic, discrete mathematics, computer programming, data structures, signals and systems, and other topics. Following completion of this work, the student can select courses in a wide range of subject areas. These include operating systems, programming languages and compilers, computer architecture, microprocessor-based systems, computer aided
design and VLSI, digital signal processing, and computer networking, among others. A broad selection from several areas is recommended for most undergraduate students. Specialization in particular areas is more typical of graduate programs of study.

**Computer Science**

Computer scientists are experts on the theory and practice of computation, including the fundamental capabilities and limitations of computation and how computational thinking can be practically applied. A computer scientist understands how to design and analyze algorithms, how to retrieve, transform, and restore information efficiently, how computers work to execute algorithms, and how to develop software systems that solve complex problems. Specialists within computer science might have expertise in developing software applications, designing computer hardware, protecting computer systems against attacks, developing algorithms, analyzing large data sets, and many other current and emerging possibilities.

The computer science (CS) program at the University of Michigan is available to students in both the Colleges of Engineering and of Literature, Science, and the Arts. The program requires students to have a solid foundation in computer software, hardware, and theory, but also gives a student ample opportunity to take advanced electives in areas of computer science such as databases, architecture, networks, artificial intelligence, and graphics, or in emerging interdisciplinary areas such as electronic commerce, web information systems, and computer game design.

**Data Science**

Huge amounts of data are being collected in all areas, made possible by rapid technological advances over the last few decades. This is further enabling the use of data-driven approaches to fundamentally transform the way corporations do business and is also leading to new discoveries in science and engineering. Data Science affects research and applications in many domains, including education, biological sciences, medical informatics, engineering, healthcare, social sciences, and the humanities. It is a rapidly growing field providing students with exciting career paths, and opportunities for advanced study.

The Data Science major gives students a foundation in aspects of computer science, statistics, and mathematics relevant for analyzing and manipulating voluminous or complex data. Students majoring in Data Science will learn computer programming, statistical analysis and data management, and will learn to think critically about the process of understanding data. Students will also take a capstone experience course that aims to synthesize the skills and knowledge learned in the various disciplines that encompass data science. The Data Science major is a rigorous program that covers the practical use of Data Science methods as well as the theoretical properties underpinning the performance of the methods and algorithms.

The Data Science major is open to students in the Colleges of LSA and Engineering. The Data Science program for the College of Engineering is administered by the CSE Division in the Department of Electrical Engineering and Computer Science. The LSA program is administered by the LSA Department of Statistics.
Electrical Engineering

The Electrical Engineering program provides students with a fundamental background in the basic theoretical concepts and technological principles of modern electrical engineering. A flexible curriculum allows students to emphasize a wide variety of subject areas within the field, including: analog and digital circuits, communication systems, control systems, electromagnetics, integrated circuit (microprocessor) design, signal processing, microelectromechanical devices, solid state electronics, and optics and photonics.

As seen from the list of subject areas, a degree in electrical engineering can lead to a wide range of work opportunities. Automotive applications include engine control processors, sensors to trigger airbags or activate antilock brake systems, development of sophisticated audio systems, and the systems that power electric vehicles. Electrical engineers work in the wireless communications field, including mobile phone systems and global positioning systems. Electrical engineers also work in remote sensing to infer characteristics of a region of the earth from the air or from space to study the environment and climate change. They design, manufacture, test and market the microprocessor, analog and RF integrated circuits from which computers, digital movie and still cameras, the internet, communication systems, and many other modern conveniences are made. Electrical engineers develop signal processing algorithms and hardware for multimedia devices and develop control algorithms and electronics for mechanical systems such as automobiles, robotics, planes and spacecraft. They embed microprocessors in everything from entertainment gadgets to industrial plants. Electrical engineers develop optical fiber communication systems and laser technology for applications ranging from astrophysics to eye surgery. Electrical engineers use semiconductor fabrication technology to make high-efficiency solar cells, light emitting diodes for lighting, and miniature machines called microelectromechanical devices. The signal processing algorithms, optical devices, and miniature systems invented and developed by electrical engineers are providing breakthrough technologies in the biomedical world for health and wellness and the diagnosis and treatment of diseases. A common effort of electrical engineers is to make components smaller, faster, more energy efficient and less costly.

Sequential Undergraduate/Graduate Study (SUGS)

BSE or BS in one of the EECS programs or Computer Science/MSE or MS in one of the Electrical Engineering and Computer Science (EECS) Programs

There are two separate SUGS programs available through Rackham open to Electrical Engineering and Computer Science undergraduates (depending on major/minor, etc.) who have completed 85 or more credit hours with a cumulative GPA of at least 3.5 (ECE) or at least 3.6 (CSE). Please see the individual program options and contact the respective CSE or ECE Graduate Program Coordinator for more complete program information.
BSE in Electrical Engineering/MS Biomedical Engineering

This SUGS program is open to all undergraduate students from Electrical Engineering who have achieved senior standing (85 credit hours or more) and have an overall cumulative GPA of 3.2 or higher. Please contact the Department of Biomedical Engineering for more complete program information.

Graduate

Graduate Degrees in Computer Science and Engineering:
- Master of Science (M.S.) in Computer Science and Engineering
- Master of Science in Engineering (M.S.E.) in Computer Science and Engineering
- Doctor of Philosophy (Ph.D.) in Computer Science and Engineering
- Master of Science (M.S.) in Data Science

Graduate Degrees in Electrical & Computer Engineering:
- Master of Science (M.S.) in Electrical & Computer Engineering
- Master of Science in Engineering (M.S.E.) in Electrical & Computer Engineering
- Master of Engineering (MEng) in Electrical & Computer Engineering
- Doctor of Philosophy (Ph.D.) in Electrical & Computer Engineering
- Graduate Certificate for Data Science
- Graduate Certificate for Plasma Science and Engineering

Electrical Engineering and Computer Science (EECS) is one of the highest-ranking EECS departments in the country, and many of the faculty are recognized as leaders in their field. Please review Degree information in both divisions.

Master of Science / Master of Science in Engineering

The M.S. (Master's of Science) and M.S.E. (Master's of Science in Engineering) degrees differ mainly in name. The degree requirements are the same. Students with a bachelor’s degree in engineering can elect either degree. Students without an engineering bachelor’s degree are eligible only for the M.S. The principal requirements for the specific M.S. and M.S.E. degrees are listed below. (A more complete statement on master’s degree requirements is available on the Web: http://www.eecs.umich.edu/eecs/graduate/index.html.)

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

A student must satisfy the regulations of the Rackham School of Graduate Studies, the College of Engineering, and the regulations as specified by the program brochure(s) and the program office.

A student must earn at least 30 credit hours of graduate level coursework, of which at least 24 hours must be technical courses, at least 15 hours must be CSE coursework at the 500 level or higher (excluding credit hours earned in individual study, research or seminar courses). The student must also satisfy course requirements in “breadth” areas.
of software, hardware, artificial intelligence, and theory. A maximum of six credit hours of individual study, research and seminar courses will be accepted toward the master's degree. The VLSI concentration has slightly different course requirements; please refer to the CSE Brochure available on the Web for details.

The program requires that the grade point average received in CSE coursework must be at least 3.0 (based on Rackham's 4.0 scale). An individual course grade of B- or better is required for the credit hours received in any course to be counted towards any master's degree requirement. A master's thesis is optional. Credit hours transferred may be applied to meet any master's degree requirement except the 15 credit hours of 500 level CSE coursework required. (Rackham specifies limitations to the circumstances under which credits may be transferred. See the Rackham Student Handbook.) Courses of an insufficiently advanced level, or which substantially duplicate in level and/or content courses already completed by the student, may not be counted as meeting any master's degree requirements.

**M.S. and M.S.E. in Electrical & Computer Engineering**

The Master's Program in Electrical & Computer Engineering covers topics such as Applied Electromagnetics & RF Circuits, Computer Vision, Control Systems, Embedded Systems, Integrated Circuits & VLSI, MEMS & Microsystems, Network, Communication, & Information Systems, Optics & Photonics, Power & Energy, Robotics, Signal and Image Processing & Machine Learning, and Solid State & Nanotechnology. A student must earn at least 30 credit hours of graduate-level coursework, of which at least 24 credit hours must be in technical courses, at least 12 credit hours must be ECE coursework at the 500 level or higher (excluding credit hours earned in individual study, research, or seminar courses, other departments or universities), and 9 credit hours from an ECE major area including at least 6 at the 500 level or above, and at least 6 credit hours in courses outside of ECE. A maximum of 3 credit hours of S/U courses that are not directed study will be accepted toward the degree. At most 6 credit hours of directed study will be accepted. Course grades must be “B-” or better in order to be counted towards any requirements. A grade point average of “B” or higher is required overall. A master's thesis is optional.

**MEng in Electrical & Computer Engineering**

The Master of Engineering (MEng) degree in Electrical and Computer Engineering is designed to serve students pursuing a terminal, professional Master's degree. The degree is offered with a concentration area in either Data Science and Machine Learning (DS/ML) or Autonomous systems (AS).

The MEng degree, which is distinct from the Master of Science (MS) program and from the M.S. degree in data science, is specially designed for students who plan to enter industry after graduation and who have already decided their specialty. The program is highly structured, emphasizes rigorous theory, practical training, engineering projects, industrial skills, communications, project management, leadership, and entrepreneurial
training. The curriculum is aligned with emerging application areas of high workforce demand.

The ECE MEng degree program is a 26-credit program with the following components:

1. At least 12 credits in technical courses, of which at least 9 from a set of core courses for a selected MEng concentration; the rest from a set of approved non-core courses.
2. At least 4 credits in project and design courses in the same concentration.
3. At least 4 and up to 6 credits in ENTR courses; these are in the areas of entrepreneurship, leadership, communication and project management. This requirement may be waived by the MEng program director or the cognizant faculty, in cases such as continuing education and other warranted circumstances.
4. An optional summer internship, which can count up to 6 credits, corresponding to a 12-week full-time internship.

**Doctor of Philosophy**

*Ph.D. in Computer Science and Engineering*

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad field of knowledge. A part of the work consists of regularly scheduled graduate courses of instruction in the chosen field and in such cognate subjects as may be required by the committee. In addition, the student must pursue independent investigation in a subdivision of the selected field and must present the result of the investigation in the form of a dissertation.

A student becomes an applicant for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted in a field of specialization. Candidacy is achieved when the student demonstrates competence in her/his broad field of knowledge through completion of a prescribed set of courses and passing a comprehensive examination.

In most areas, a student must complete required coursework, pass a comprehensive examination and any other program requirements and be recommended for candidacy for the doctorate. A special doctoral committee is appointed for each applicant to supervise the work of the student both as to election of courses and in preparation of the dissertation.

Requirements regarding foreign language and non-technical courses are left to individual departments or programs and to the Graduate School. A prospective doctoral student should consult the program advisor regarding specific details.
A pamphlet that describes the general procedure leading to the doctorate is available in the Graduate School office, 1004 Rackham Building, upon request.

**Ph.D. in Electrical & Computer Engineering**


A student entering the Ph.D. without a relevant Master’s degree, must earn at least 36 credit hours of graduate-level coursework, of which at least 30 credit hours must be in technical courses, at least 12 credit hours must be ECE coursework at the 500 level or higher (excluding credit hours earned in individual study, research, or seminar courses, other departments or universities), and 9 credit hours from an ECE major area including at least 6 at the 500 level or above, and at least 6 credit hours in courses outside of ECE. A maximum of 3 credit hours of S/U courses that are not directed study will be accepted toward the degree. At most 6 credit hours of directed study will be accepted.

A student entering the Ph.D. with a relevant Master’s degree must earn at least 18 credits, including at least 6 technical credit hours, 6 cognate credit hours, and 6 elective credit hours.

Course grades must be “B-” or better in order to be counted towards any requirements. A grade point average of “B” or higher is required overall. In addition, students must complete the following milestones: qualification exam, thesis proposal, dissertation, and dissertation defense. There is an annual progress report which students must achieve satisfactory progress as determined by the research advisor in order to continue in the program.

Please refer to the ECE Graduate Program manual for details.

**Graduate Certificate for Data Science**

The University of Michigan Graduate Data Science Certificate Program provides graduate science, technology and skills training for data scientists. The program emphasizes the practice of modeling using modern technology to handle large, incongruent, and heterogeneous collections of data. The Graduate Certificate for Data Science is issued by the Rackham Graduate School. The Program provides interactive data-centered training and involves 9 credits of courses and 3 credits of experiential training that require a written report on data analytics. Michigan Institute for Data Science (MIDAS) faculty from different disciplines provide student mentorship and curriculum advising. MIDAS offers merit-based top-off scholarships for graduate students enrolled in the Certificate program. Completion of the program is expected in 2-4 semesters. The Data Science Certificate program aims to provide core experiences in:
• (Modeling) Understanding of core Data Science principles, assumptions & applications
• (Technology) Data management, computation, information extraction & analytics
• (Practice) Hands-on experience with modeling tools and technology using real data

Who is eligible?
University of Michigan graduate students from any field are eligible to enroll.

Program Requirements

There are three fundamental requirements for earning a Graduate Data Science Certificate Program.

1. Nine graduate credit hours of coursework in approved courses. These courses are designated as core and elective Methods, Technology or Applications. At most one course may be double-counted with the core graduate degree program (up to 3 credits). It is recommended, but not required, that courses outside the main graduate program of study be selected to broaden the student data-science experiences (e.g., statistics students may take engineering courses, social-science students may take outside statistics and application courses, etc.).

2. A Data Science related experience (3 credit semester equivalent, over 160 hours for work). This can take the form of non-credit activity like an internship, practicum, or professional project equivalent to a three credit-hour course, or additional coursework of at least three credits from the approved course list. (This course may be double-counted with another Rackham degree program.) To satisfy this “Plus Requirement” with a data-related experience, students will need to have their supervisor or mentor sign the verification form certifying that the student spent sufficient time working on a data-intense project during that practicum. Alternatively, if allowed and approved by the mentor, students may complete and submit to the DS Certificate Program Chair a report (2-6 pages) describing their experience and results, which will be evaluated to ensure the project demonstrates Data Science content, relevance and applications.

3. Regular attendance of the MIDAS Seminar Series, which brings nationally recognized data scientists to U-M, is required. One semester (1-credit) enrollment in EECS 409 (MIDAS Seminar) is required (could count towards the 9 didactic credits). This colloquial training will expose students to current DS developments beyond the boundaries of their own discipline. Students will be required to attend 75% of all seminars (attendance will be taken) to complete the requirement. Viewing archived past MIDAS seminars counts.
Program Chair

Associate Professor Ivo Dinov, https://www.umich.edu/~dinov

The complete Data Science Certificate Program details are available online at https://midas.umich.edu/certificate
Engineering
Education
Research
The EER Ph.D. is a typical research-based doctoral degree. It provides essential coursework and other learning experiences that will prepare students to publish in top tier engineering education and education journals, compete for federal grants and contracts, and enter into multiple career paths. Students who are admitted to the EER Ph.D. program will be assigned an EER faculty advisor, who is a member of the EER core faculty, or two EER faculty co-advisors (one of whom must be a member of the EER core faculty). The EER faculty advisor is intended to serve as the primary academic and research advisor.

### Course and credit requirements for EER Ph.D.

<table>
<thead>
<tr>
<th>Category</th>
<th># courses</th>
<th># credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Education Core</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Research Methods Core</td>
<td>4</td>
<td>12 to 20</td>
</tr>
<tr>
<td>Specialization Electives</td>
<td>5</td>
<td>Up to 15</td>
</tr>
<tr>
<td>Immersive Learning Experience</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

May include up to 6 credits of EER 690: Graduate Independent/Directed Studies and up to 3 credits of EER 598: Special Topics in EER.

A grade of B- or better to count for credit towards the degree. The curriculum includes an M.S. degree in EER (30 credits) typically awarded within the first two years.
EER Courses

- EER 601: Foundations of Engineering Education Research (3 credits, to be offered every fall term)
- EER 602: Introduction to Theoretical Frameworks (3 credits, to be offered alternate winter terms)
- EER 610: Immersive Learning Experience
- Research methods core: 4 courses
- Specialization electives: 3 or more courses

Master’s Program

The EER M.S. Program provides foundational knowledge of EER topics, theories, and research methods as well as a specialization appropriate to students’ intended career paths. Students may earn the M.S. degree in the following ways. First, students may apply for and be admitted to the EER Program to earn a stand-alone EER M.S. degree. Second, students admitted to the Ph.D. program will be eligible to add the master’s degree after successful completion of the 30 credit hours of master’s degree coursework (typically within two years). The M.S. degree requires 30 credits of coursework, (10 courses) as shown in the table below.

Course and credit requirements for EER M.S.

<table>
<thead>
<tr>
<th>Category</th>
<th># courses</th>
<th># credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Education Core</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>
Admissions

Applicants to the EER program must have already earned both B.S. and M.S. degrees (or equivalent) in a traditional engineering discipline. A student may complete an M.S. degree through the Sequential Undergraduate/Graduate Studies (SUGS) program and qualify for admission to the EER graduate program. Admission to the EER graduate program is done annually based on a formal online application submitted to the Rackham Graduate School.

Application materials include:

- Completed online application form at Rackham Graduate School
- Statement of Purpose
- Academic Statement
- 3 letters of recommendation
- GRE Scores will not be accepted for any student applying for Fall 2021 admission
- TOEFL – for non-native English speaker
- Transcripts
The University of Michigan’s engineering education program follows a unique model. The Engineering Education Research (EER) faculty are embedded within the traditional engineering departments, while the graduate students are admitted to a college-wide program and are not affiliated with a specific department. This allows the EER faculty and their research to be well-integrated with the traditional engineering disciplines, provides students a better opportunity for research, and helps raise the profile of EER by diffusing the fruits of the scholarly work through the College of Engineering.

Engineering Education Research Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: https://bulletin.engin.umich.edu/courses/course-info/

300 Level Courses

EER 390. Undergraduate Independent/Directed Study
Prerequisite: Sophomore or junior standing. (1-4 credits)
Opportunity for undergraduate students to work on research projects under the supervision of an engineering education research faculty member. May be elected for 1-4 credits (approximately 4 hours/week for each credit). CourseProfile (ATLAS)

400 Level Courses

EER 490. Undergraduate Advanced Independent/Directed Study
Prerequisite: Senior Standing. (1-4 credits)
Opportunity for undergraduate students to work on advanced research projects under the supervision of an engineering education research faculty member. Project report submitted at the
EER 498. Special Topics in Engineering Education Research
Advisory Prerequisite: permission from instructor. (1-4 credits)  
Minimum Grade Requirement: C  
Topics of current interest in engineering education research, selected by the faculty. lecture, seminar or laboratory.  

500 Level Courses

EER 598. Special Topics in Engineering Education Research
Advisory Prerequisite: permission from instructor. (1-4 credits)  
Minimum Grade Requirement: B-  
Topics of current interest in engineering education research. lecture, seminar or laboratory. Can be taken more than once for credit.  

600 Level Courses

EER 601. Foundation of Engineering Education Research  
Prerequisite: None. (3 credits)  
Introduction to the field of engineering education research (EER); the conduct of educational research and its application to engineering education; current literature to the use of theoretical and conceptual frameworks to guide EER; and professional development opportunities in EER.  

EER 602. Theoretical and Conceptual Frameworks in Engineering Education Research  
Prerequisite: None. (3 credits)  
In-depth examination of theories from education, psychology, and other disciplines that are relevant to EER with a focus on how the theories apply to EER, how they can guide research, and how they advance knowledge and practice.  

EER 603. Research Design in Engineering Education Research  
Prerequisite: EER 601. (3 credits)  
Study of assessment, evaluation, and research in engineering education; overview of research design approaches in quantitative, and mixed methods research (e.g., sampling, experimental and quasi-experimental designs, inductive analysis approaches), instrument development, measurement and testing, validity, and other related topics.  

EER 610. Practicum – Immersive Learning Experience  
Enforced Prerequisite: EER 601 and EER 602. Minimum grade requirement of “C”. (3 credits)  
EER 610 enables students to develop a robust skill set in applying knowledge acquired from coursework to practical needs or real-world problems in engineering education. Two basic types of Immersive Learning Experiences are possible: (1) teaching apprenticeships and (2) internships.  

EER 690. Graduate Independent/Directed Study  
Prerequisite: Graduate Standing. (1-4 credits)  
Opportunity for graduate students to work on research projects under the supervision of an engineering education research faculty member. Project reports submitted at end of term; may be elected for 1-4 credits (approximately 4 hours/week for each credit).  

CourseProfile (ATLAS)
900 Level Courses

EER 990. Dissertation Research/Pre-Candidate
Advisory Prerequisite: Election for dissertation work by doctoral student not yet admitted as a candidate. (1-8 credits)
Election for dissertation work by doctoral student not yet admitted to status as candidate, typically after all coursework is complete. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

EER 995. Dissertation Research/Candidate
Prerequisite: Standing as EER Doctoral Candidate. (4-8 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

EER 998. Curriculum Practical Project
Prerequisite: None. (1 credit)
Practical work experience related to graduate student’s field of study in consultation with the student’s department/program, cognizant faculty, and the Engineering Career Resource Center. CourseProfile (ATLAS)
Engineering
Physics
Overview

Basic physics is an integral part of every engineering curriculum. However, the sophistication of many areas of engineering, coupled with the staggering rate of technological advance, has created a need for engineers with much stronger backgrounds in math and physics—people who can work in an engineering environment and who are capable of applying advanced physics concepts to bring innovations to the marketplace. For example, the development of the computer closely followed the invention of the transistor. Consider the number of other physical phenomena (lasers, nuclear reactors, nuclear magnetic resonance, particle accelerators, etc.) that have been developed by engineers into modern technologies.

Engineering Physics is particularly attractive to those students who may attend graduate school, even if they have not yet decided on a particular field. An advanced physics and mathematics background coupled with an engineering curriculum, is excellent preparation for most graduate engineering programs and for traditional physics or applied physics programs.

Engineering Physics meets the stated needs by providing a thorough curriculum in basic and advanced engineering courses combined with sufficient physics and mathematics to be equivalent to a traditional degree in physics. A unique feature of the curriculum is the elective sequence of engineering courses that the student elects in a specialized field of engineering. This sequence of courses is chosen by the student (with the advisor’s input and approval) in any field of interest, such as microprocessor design, plasma processing, electro-optics, radiological health, computational methods or bioengineering, to name just a few. With 42 credit hours of electives in math, engineering and physics, the student has a high degree of flexibility and opportunity for exploring or specializing in fields of their interest. Many Engineering Physics students also take advantage of the extensive research opportunities on campus, both in engineering and in science departments.

The Engineering Physics degree program is administered by the Nuclear Engineering and Radiological Sciences Department.

Program Administration

Faculty Program Advisors

Michael Atzmon
2933 Cooley Laboratory

Carolyn Kuranz
2911 Cooley Laboratory

Undergraduate Program Manager

Michelle Sonderman
1919 Cooley Laboratory

For more specific information on contacting people – go to our Contacts page.
Entrepreneurship
Overview

The Center for Entrepreneurship’s academic and co-curricular programs support students’ growth as entrepreneurs and innovative thinkers by offering exciting opportunities to create value, challenge the status quo, and develop new career possibilities. Students from across the University and the College of Engineering engage in our immersive curricular community and collaborate to turn their ideas into tangible projects.

The CFE’s classes demand active participation in learning multiple skill sets and perspectives. We teach students how to identify challenges and facilitate hands-on practice in developing solutions that are scalable and impactful.

ENTR courses at the CFE cover a wide range of topics, all taught by real entrepreneurs who teach from experience.

Undergraduate Programs

CFE courses are open to all students from every school and college across the University.

For College of Engineering students, ENTR courses can satisfy up to 4 Professional or Creative Development (PCDC) credits towards the College’s Intellectual Breadth requirement.

ENTR courses also count toward the University’s 15-credit Minor in Entrepreneurship: http://innovateblue.umich.edu/academics/minor-in-entrepreneurship/

Graduate Programs

Graduate students from all schools and colleges are able to enroll in ENTR courses.

Degree-seeking master’s, Ph.D., and professional students can also apply for the 12-credit Certificate in Innovation and Entrepreneurship. Learn more here: https://cfe.umich.edu/certificate/

Co-Curricular Programs

The CFE offers a variety of opportunities for students to build entrepreneurial skills and experience both inside and outside the classroom. From startup treks to startup competitions, advising, study abroad, mentoring, and more, there is something for everyone. Interested in learning more? Visit us at https://cfe.umich.edu/ or email entrepreneurship@umich.edu.

Contacts

CFE Website: https://cfe.umich.edu/

General email: entrepreneurship@umich.edu

CFE Staff: https://cfe.umich.edu/team/staff/
Industrial & Operations Engineering
Industrial and Operations Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: [https://bulletin.engin.umich.edu/courses/course-info/](https://bulletin.engin.umich.edu/courses/course-info/)

200 Level Courses

**IOE 201. Economic Decision Making**  
*Prerequisite: ENGR 100 and ENGR 101. (2 credits) (7-week course)*  
Overview of business operations, valuation and accounting principles. Time value of money and net present values. Practical team project experience. [CourseProfile (ATLAS)]

**IOE 202. Operations Modeling**  
*Prerequisite: ENGR 100 and ENGR 101. (2 credits) (7-week course)*  
Process of mathematically modeling operational decisions including the role of uncertainty in decision-making. Basic tools for solving the resulting models, particularly mathematical programs, statistical models and queueing models. Cases may come from manufacturing and service operations and ergonomics. [CourseProfile (ATLAS)]

**IOE 265. Probability and Statistics for Engineers**  
*Prerequisite: Math 116 and ENGR 101, Minimum grade of “C-” required for enforced prerequisite. (3 credits)*  
Graphical Representation of Data; Axioms of Probability; Conditioning, Bayes Theorem; Discrete Distributions (Geometric, Binomial, Poisson); Continuous Distributions (Normal Exponential, Weibull), Covariance and Correlation. Point and Interval Estimation, Likelihood Functions, Test of Hypotheses for Means, Variances and Proportions for One and Two Populations. [CourseProfile (ATLAS)]

300 Level Courses

**IOE 310. Optimization and Computational Methods**  
*Prerequisite: Math 214, IOE 202 and ENGR 101. Minimum grade of “C-” required for enforced prerequisite. (3 credits)*  
Introduction to deterministic optimization models and computational algorithms with emphasis on linear and integer programming; simplex and branch-and-bound algorithms; duality, complementary slackness, and sensitivity analysis. Emphasis on decision making for real-world applications from transportation, healthcare, and other industrial domains. [CourseProfile (ATLAS)]

**IOE 316. Introduction to Markov Processes**  
*Prerequisite: IOE 265 and Math 214. Minimum grade of “C-” required for enforced prerequisite. (3 credits)*  
Introduction to discrete Markov Chains and continuous Markov processes, including transient and limiting behavior. Introduction to Markov Decision Processes. The Poisson/Exponential process. Applications to reliability, maintenance, inventory, production, queues and other engineering problems. [CourseProfile (ATLAS)]

**IOE 333. Human Factors and Ergonomics**  
*Advised Prerequisite: Preceded or accompanied by IOE 265. (3 credits)*
Introduction to human sensory, decision, control, and motor systems in the context of visual, auditory, cognitive and manual task evaluation and design. Problems with computer displays, illumination, noise, eye-hand coordination as well as repetitive and high physical effort tasks are presented. Workplace and vehicle design strategies used to resolve these are discussed. 

IOE 334. Ergonomics Lab  
**Prerequisite:** Preceded or accompanied by IOE 333. (1 credit)  
Principles of measurement and prediction of human performance in man-machine systems. Laboratory experiments investigating human capabilities of vision, hearing, information processing, memory, motor processes, strength and endurance.  

IOE 366. Introduction to Engineering Data Analytics  
**Prerequisite:** IOE 265 and Math 214, C- or better. (3 credits)  
Introduction to data analysis methods and statistical tools, linear regression and correlation, multiple linear regression, stepwise selection, nonlinear regression, logistic regression, analysis of variance, introduction to design of experiments.  

IOE 373. Data Analytics Tools and Techniques  
**Prerequisite:** ENGR 101. Minimum grade of C- for enforced prerequisites (4 credits)  
Introduction to the computing tools necessary for data, business, and engineering analytics. Emphasis on data cleansing, manipulation, and preparation for visualization, as well as basic inferential statistical analyses and predictive analytics using Python.  

**400 Level Courses**  

IOE 410. Advanced Optimization and Computational Methods  
**Prerequisite:** IOE 310 or graduate standing. Minimum grade of C- required for enforced prerequisite. (3 credits)  
Algorithms and computational methods for solving structured large-scale optimization models. Efficient algorithms for network optimization problems, basics of dynamic programming and convex programming, and advanced topics in linear and integer programming. Applications, including routing, scheduling, and inventory problems.  

IOE 412. Constraint Programming  
**Prerequisite:** IOE 310 or graduate standing. Minimum grade of C- required for enforced prerequisite. (3 credits)  
This course is an introduction to constraint programming, one of the main paradigms for solving hard combinatorial optimization problems. The class covers the foundation of constraint programming, its modeling and search techniques, and its applications in resource allocations, scheduling, and routing.  

IOE 413. Optimization Modeling in Health Care  
**Prerequisite:** IOE 265 and IOE 310 or equivalent. (3 credits)  
Introduction to optimization modeling in health care. Linear and integer programming models are developed for problems in health and medicine. Problems considered may include breast cancer diagnosis, radiotherapy treatment planning, fracture fixation planning and others as selected by the instructor. Emphasis is placed on model formulation, verification, validation and uncertainty quantification.  

IOE 416. Queueing Systems  
**Prerequisite:** IOE 316. (2 credits) (7-week course)  
Introduction to queueing processes and their applications. The M/M/s and M/G/1 queues. Queue
length, waiting time, busy period. Examples from production, transportation, communication and public service. CourseProfile (ATLAS)

**IOE 419. Service Operations Management**  
*Prerequisite: IOE 310 and IOE 316 or equivalent. (3 credits)*  
Introduction to optimization, queueing, and spreadsheet-based simulation modeling applications in the service industries. Topics covered will include facility location modeling, short-term workforce management, long-term workforce planning, resource allocation, inventory applications in service systems, customer scheduling, call center design and vehicle routing. CourseProfile (ATLAS)

**IOE 421. Work Organizations**  
*Prerequisite: IOE 201, 202 and Senior Standing. (3 credits)*  
Applications of organizational theory to the analysis and design of work organizations is taught through lectures, projects in real organizations, experiential exercises and case studies. Topics include: open-systems theory, organizational structure, culture and power. A change strategy: current state analysis, future state vision and strategies for organizational transformation. CourseProfile (ATLAS)

**IOE 422. Entrepreneurship**  
*Prerequisite: Senior Standing. Not for graduate credit. (3 credits)*  
Engineering students will explore the dynamics of turning an innovative idea into a commercial venture in an increasingly global economy. Creating a business plan originating in an international setting will: challenge students to innovate; manage risk, stress and failure; confront ethical problems; question cultural assumptions; and closely simulate the realities of life as an entrepreneur. CourseProfile (ATLAS)

**IOE 424. Practicum in Production and Service Systems**  
*Prerequisite: Senior Standing, IOE undergraduates only. Not for graduate credit. (4 credits)*  
Student teams will work with an organization on an Industrial and Operations Engineering design project with potential benefit to the organization and the students. The final report should demonstrate a mastery of the established technical communication skills. The report will be reviewed and edited to achieve this outcome. CourseProfile (ATLAS)

**IOE 425 (MFG 426). Lean Manufacturing and Services (MFG 426)**  
*Prerequisite: Senior Standing. (2 credits) (7-week course)*  
Review of philosophies, systems, and practices utilized by world-class manufacturers and service organizations focusing on “lean management,” including material and information flow, in-process quality assurance, standardized work, continuous improvement, visual management and lean leadership. Practical examples and in-class exercises bring concepts to life. CourseProfile (ATLAS)

**IOE 430. Global Cultural Systems Engineering**  
*Prerequisite: IOE 333 and IOE 366 or graduate standing. (3 credits)*  
Selected topics of systems engineering are examined from the global cultural perspective. Topics include global cultural issues of design, marketing and communication; engineering aesthetics and ethics; individual and aggregated behavioral decision making; social networking and online communities; research and evaluation methods; applications in many systems engineering. CourseProfile (ATLAS)

**IOE 434. Human Error and Complex System Failures**  
*Prerequisite: IOE 333 or IOE 536 or Permission of Instructor. (3 credits)*  
Introduction to a new systems-oriented approach to safety management and the analysis of complex system failures. The course covers a wide range of factors contributing to system failures: human perceptual and cognitive abilities and limitations, the design of modern technologies and interfaces, and biases in accident investigation and error analysis. Recent concepts in the area of high reliability organizations and resilience engineering are reviewed. Students perform systems analysis of actual
mishaps and disasters in various domains, including various modes of transportation, process control and health care. **CourseProfile (ATLAS)**

**IOE 436. Human Factors in Computer Systems**  
*Prerequisite: IOE 333. (3 credits)*  
This course discusses how to design and evaluate computer systems for ease of use. Topics to be covered include keyboards and how people type, vision and video display design, human body size and computer furniture, regulations concerning working conditions, software issues, methods for studying user performance, documentation and information systems of the future. **CourseProfile (ATLAS)**

**IOE 437. Automotive Human Factors**  
*Prerequisite: Senior Standing and IOE 333/334 or Graduate Standing. (3 credits)*  
This course provides an overview of human factors and driving to help engineers design motor vehicles that are safe and easy to use and to provide basic knowledge for those interested in conducting automotive human factors/ergonomics research. The focus is on the total vehicle (all aspects of vehicle design) and for an international market. Key topics include design guidelines, crash investigation and statistics, driving performance measures, vehicle dynamics, occupant packaging and driver vision. **CourseProfile (ATLAS)**

**IOE 438. Occupational Safety Management**  
*Prerequisite: Enforced: IOE 333 or senior or graduate standing. (2 credits) (7-week course)*  
Survey of occupational safety management methods, theories and activities. Topics include: history of safety engineering, management, and worker compensation; collection and critical analysis of accident data; safety standards, regulations and regulatory agencies; theories of self-protective behavior and accident prevention; and analysis of safety program effectiveness. **CourseProfile (ATLAS)**

**IOE 440 (MFG 440). Operations Analysis and Management**  
*Prerequisite: Enforced: IOE 310 and 316 or graduate standing. No credit granted for students who have credit for TO 605. (3 credits).*  
Principles and models for analyzing, engineering and managing manufacturing and service operations as well as supply chains. Emphasis on capacity management; queueing models of operational dynamics (including cycle time, work-in-progress, inventory, throughput and variability); operational flexibility; the math and physics of lean enterprises. **CourseProfile (ATLAS)**

**IOE 441 (MFG 441). Production and Inventory Control**  
*Prerequisite: IOE 310 and 366 (C- or better); or graduate standing. (3 credits)*  
Basic models and techniques for managing inventory systems and for planning production. Topics include deterministic and probabilistic inventory models; production planning and scheduling; and introduction to factory physics. **CourseProfile (ATLAS)**

**IOE 447 (MFG 447). Facility Planning**  
*Prerequisite: IOE 310, IOE 316. (3 credits)*  

**IOE 449 (MFG 449). Material Handling Systems**  
*Prerequisite: IOE 310, IOE 316 with minimum grade of “C-” for enforced prerequisites or Graduate standing. (3 credits)*  
Review of material handling equipment used in warehousing and manufacturing. Analytic models and algorithms to design and analyze the performance of discrete-flow manual and automated storage/retrieval systems, order picking centers, automated guided vehicle systems, conveyor loops, and lean manufacturing driven milkrun systems and call systems. **CourseProfile (ATLAS)**
IOE 452 (MFG 455). Corporate Finance
Prerequisite: IOE 201, IOE 310, IOE 366. (3 credits)
The goal of this course is to introduce a basic understanding of financial management. The course develops fundamental models of valuation and investment from first principles and applies them to problems of corporate and individual decision-making. The topics of discussion will include the net present valuation, optimal portfolio selection, risk and investment analysis, issuing securities, capital structure with debt financing and real options. CourseProfile (ATLAS)

IOE 453 (MFG 456). Derivative Instruments
Prerequisite: IOE 201, IOE 310, IOE 366. (3 credits, no credit granted for students who have credit for MATH 423)
The main objectives of the course are first, to provide the students with a thorough understanding of the theory of pricing derivatives in the absence of arbitrage, and second, to develop the mathematical and numerical tools necessary to calculate derivative security prices. We begin by exploring the implications of the absence of static arbitrage. We study, for instance, forward and futures contracts. We proceed to develop the implications of no arbitrage in dynamic trading models: the binomial and Black-Scholes models. The theory is applied to hedging and risk management. CourseProfile (ATLAS)

IOE 460. Decision Analysis and Bounded Rationality
Prerequisite: IOE 265, IOE 310 with minimum grade of “C-” for enforced prerequisites. (3 credits)
This course provides a rigorous introduction to prescriptive decision analysis and more descriptive bounded rationality models. The course starts from the classic axioms of rational choice and covers single-attribute and multi-attribute utility theory, decision trees, the value of information in a decision analytic context, and expert elicitation of both probabilities and utility functions. It then introduces bounded rationality and covers some of the main classes of bounded rationality and how they can be modeled. CourseProfile (ATLAS)

IOE 461. Quality Engineering Principles and Analysis
Prerequisite: IOE 366. (3 credits)
This course provides students with the analytical and management tools necessary to solve manufacturing quality problems and implement effective quality systems. Topics include voice of the customer analysis, the Six Sigma problem solving methodology, process capability analysis, measurement system analysis, design of experiments, statistical process control, failure mode and effects analysis, quality function deployment and reliability analysis.

IOE 463 (MFG 463). Measurement and Design of Work
Prerequisite: IOE 333 or MECHENG 395 or BIOMEDE 231 and IOE 265 or Stats 412. (3 credits)
Design of lean manufacturing systems requires knowledge and skills for describing manual work, identifying value and non-value added work elements, designing efficient work equipment and methods, preventing fatigue and related worker health problems and predicting work performance.

IOE 465. Design of Experiments.
Prerequisite: IOE 366; C- or better or graduate standing. (3 credits)
Linear models, Multi-colinarity and Robust Regression, Comparative Experiments, Randomized Blocks and Latin Squares, Factorial Designs, Confounding, Mixed Level Fractional Factorials, Random and Mixed Models, Nesting and Split Plots, Response Surface Methods, Taguchi Contributions to Experimental Design.

IOE 466 (MFG 466). Statistical Quality Control
Prerequisite: IOE 366 or Stats 401 or graduate standing. (3 credits)
Quality Improvement Philosophies; Modeling Process Quality, Statistical Process Control, Control Charts for Variables and Attributes, CUSUM and EWMA, Short Production Runs, Multivariate Quality Control, Auto Correlation, Engineering Process Control, Economic Design of Charts, Fill Control,
Pre-control, Adaptive Schemes, Process Capability, Specifications and Tolerances, Gage Capability Studies, Acceptance Sampling by Attributes and Variables, International Quality Standards. [CourseProfile (ATLAS)]

**IOE 474. Simulation**  
*Prerequisite: IOE 316, IOE 366, IOE 373. (4 credits)*  
Simulation of complex discrete-event systems with applications in industrial and service organizations. Course topics include modeling and programming simulations in one or more high-level computer packages such as ProModel or GPSS/H; input distribution modeling; generating random numbers; statistical analysis of simulation output data. The course will contain a team simulation project. [CourseProfile (ATLAS)]

**IOE 481. Practicum in Hospital Systems**  
*Prerequisite: Senior Standing, IOE undergraduates only; Not for graduate credit. (4 credits)*  
Student team projects in hospital systems. Projects will be offered from areas of industrial and operations engineering, including work measurement and control, systems and procedures, management, organization and information systems. Lectures will deal with the hospital setting and project methodologies. The final report should demonstrate a mastery of the established technical communication skills. The report will be reviewed and edited to achieve the outcome. [CourseProfile (ATLAS)]

**IOE 490. Undergraduate Directed Study, Research, and Special Problems**  
*Prerequisite: permission of instructor, not for graduate credit; maximum 4 credit hours per term. (2-4 credits)*  
Individual or group study, design, or laboratory research in a field of interest to the student or group. Topics may be chosen from any area of industrial and operations engineering. Student(s) must register for the individual section number of the instructor/advisor. [CourseProfile (ATLAS)]

**IOE 491. Special Topics in Industrial and Operations Engineering**  
*(to be arranged)*  
Selected topics of current interest in industrial and operations engineering. [CourseProfile (ATLAS)]

**IOE 499. Senior Design Projects**  
*Prerequisite: senior standing, permission of advisor. (4 credits)*  
Selected design projects in industrial and operations engineering to be conducted for project sponsors. The final report submitted by the students should demonstrate a mastery of the established communication skills. The final project report will be reviewed to achieve this outcome. [CourseProfile (ATLAS)]

### 500 Level Courses

**IOE 506 (Math 506). Stochastic Analysis for Finance**  
*Prerequisite: graduate standing or permission of advisor. (3 credits)*  
The aim of this course is to teach the probabilistic techniques and concepts from the theory of stochastic processes required to understand the widely used financial models. In particular concepts such as martingales, stochastic integration/calculus, which are essential in computing the prices of derivative contracts, will be discussed. Pricing in complete/incomplete markets (in discrete/continuous time) will be the focus of this course as well as some exposition of the mathematical tools that will be used such as Brownian motion, Levy processes and Markov processes. [CourseProfile (ATLAS)]
IOE 510 (Math 561) (OMS 518). Linear Programming I
Prerequisite: Math 217, Math 417, or Math 419. (3 credits)
Formulation of problems from the private and public sectors using the mathematical model of linear programming. Development of the simplex algorithm; duality theory and economic interpretations. Postoptimality (sensitivity) analysis application and interpretations. Introduction to transportation and assignment problems; special purpose algorithms and advanced computational techniques. Students have opportunities to formulate and solve models developed from more complex case studies and to use various computer programs. CourseProfile (ATLAS)

IOE 511 (Math 562). Continuous Optimization Methods
Prerequisite: Math 217, Math 417 or Math 419. (3 credits)
Survey of continuous optimization problems. Unconstrained optimization problems: unidirectional search techniques; gradient, conjugate direction, quasi-Newton methods. Introduction to constrained optimization using techniques of unconstrained optimization through penalty transformations, augmented Lagrangians and others. Discussion of computer programs for various algorithms. CourseProfile (ATLAS)

IOE 512. Dynamic Programming
Prerequisite: IOE 510, IOE 316. (3 credits)
The techniques of recursive optimization and their use in solving multistage decision problems, applications to various types of problems, including an introduction to Markov decision processes. CourseProfile (ATLAS)

Prerequisite: IOE 316 or IOE 315 and IOE 310 or IOE 510 and IOE366 or IOE 474 and graduate standing or permission of instructor. (3 credits)
This course provides an overview of the role of operations research in healthcare. It surveys and evaluates research done in this field and addresses some of the key technical issues encountered when developing healthcare operations research models. Insights will be shared about carrying out collaborative research with healthcare professionals. CourseProfile (ATLAS)

IOE 515. Stochastic Processes
Prerequisite: IOE 316 or Stats 310. (3 credits)
Introduction to non-measure theoretic stochastic processes. Poisson processes, renewal processes and discrete time Markov chains. Applications in queueing systems, reliability, and inventory control. CourseProfile (ATLAS)

IOE 516. Stochastic Processes II
Prerequisite: IOE 515. (3 credits)
This course emphasizes the use of Markov Chains in theory and practice. General knowledge of probability theory and stochastic processes is assumed. Applications may include equipment replacement, queueing systems and production systems. Methodologies covered include invariant measures and stationary distributions for both the discrete and continuous cases. CourseProfile (ATLAS)

IOE 517. Game Theory and Operations Applications
Advisory prerequisite: Undergraduate level courses in optimization and probability theory. (3 credits)
Topics covered include static games, Stackelberg games, dynamic games; games with complete information, incomplete information, and asymmetric information; Nash equilibrium, Bayesian-Nash equilibrium, subgame perfect equilibrium, and perfect Bayesian equilibrium. Applications include auctions, supplier and retailer competition, sourcing selection, supply chain management and coordination, and salesforce incentive mechanism design. CourseProfile (ATLAS)
IOE 518. Introduction to Integer Programming  
*Prerequisite: IOE 510. (1.5 credits) (7-week course)*  
Introduction to optimization problems that fall within the framework of Integer Programming, and an overview of concepts and classical methods for their analysis and solution. Integer programming formulations, relaxations, duality and bounds, branch-and-bound and cutting plane algorithms, heuristic solution methods. [CourseProfile (ATLAS)]

IOE 522. Theories of Administration  
*Prerequisite: IOE 421. (3 credits)*  
Provide insight into leading theories concerning the administration of research and industrial organizations. Treat the concepts needed for describing, assessing and diagnosing organizations; processes of organizational communication, motivation, and conflict management; adaptation of organization systems to the requirements of work and information technologies. [CourseProfile (ATLAS)]

IOE 525. Lean Principles and Scientific Thinking in Organizations  
*Advisory Prerequisites: IOE 425. Minimum grade of “C-“.*  
This course will focus on the application of lean principles and scientific thinking methods to continuously improve the use of machines, materials, and methods in manufacturing and service industries. Students are taught a way of approaching challenging goals through kata (practice routines) to iteratively improve processes. Classroom lectures are reinforced by projects in the field. [CourseProfile (ATLAS)]

IOE 533 (MFG 535). Human Motor Behavior and Engineering Systems  
*Prerequisite: IOE 333 and IOE 366. (3 credits)*  
This course is designed to provide a basic perspective of the major processes of human motor behavior. Emphasis will be placed on understanding motor control and man-(machine)-environment interaction. Information processing will be presented and linked to motor behavior. Application of theories to the design of the workplace, controls and tools will be underlined and illustrated by substantial examples. [CourseProfile (ATLAS)]

IOE 534 (BIOMEDE 534) (MFG 534). Occupational Biomechanics  
*Prerequisite: IOE 333, IOE 334, or IOE 433. (3 credits)*  
Anatomical and physiological concepts are introduced to understand and predict human motor capabilities, with particular emphasis on the evaluation and design of manual activities in various occupations. Quantitative models are developed to explain (1) muscle strength performance; (2) cumulative and acute musculoskeletal injury; (3) physical fatigue; and (4) human motion control. [CourseProfile (ATLAS)]

IOE 536. Cognitive Ergonomics and Human System Integration  
*Advisory prerequisite: IOE 333. (3 credits)*  
Theories and concepts of human information processing are introduced to analyze human perceptual and cognitive performance in human machine information systems such as intelligent transportation and manufacturing systems. Conceptual and quantitative models, interface design techniques and research and evaluation methods are presented. Samples of on-going research are also discussed. [CourseProfile (ATLAS)]

IOE 537. Ergonomics for Inclusive Design  
*Advised prerequisites: Introductory course in ergonomics; introductory course in statistics; graduate standing or permission of instructor. (3 credits)*  
Population aging, obesity and disability prevalence has increased the profile of inclusive design as an approach to accommodating the broad spectrum of human physical, perceptual and cognitive abilities. This course is a graduate-level study of contemporary ergonomics research methods for examining human performance variability associated with aging, disability and health-related factors and its relevance to inclusive systems engineering and design. [CourseProfile (ATLAS)]
IOE 539 (MFG 539). Safety Engineering Methods
Prerequisite: IOE 265 or Biostat 503. (3 credits)
Recognition, evaluation and control of generic safety hazards (confined spaces, electricity, fire, mechanical energy, etc.) found in contemporary workplaces, using case studies from manufacturing, transportation and power generation. Students perform an interdisciplinary team project using systems safety engineering methods to redesign a work station, manufacturing process, or consumer product. CourseProfile (ATLAS)

IOE 541. Optimization Methods in Supply Chain
Advisory Prerequisite: IOE 310, IOE 316 or permission of instructor. (3 credits)
Introductory graduate course on optimization methods in supply chain management. Topics include forecasting and demand models, deterministic and stochastic inventory models, multi-echelon inventory models, facility location models, process flexibility, supply chain contracts, and joint learning and optimization methods in supply chain models. CourseProfile (ATLAS)

IOE 543 (MFG 543). Scheduling
Prerequisite: IOE 316, IOE 310. (3 credits)
The problem of scheduling several tasks over time, including the topics of measures of performance, single-machine sequencing, flow shop scheduling, the job shop problem and priority dispatching. Integer programming, dynamic programming and heuristic approaches to various problems are presented. CourseProfile (ATLAS)

IOE 545 (MFG 545). Stochastic Networks and Operations
Prerequisite: IOE 515 or EECS 501. (3 credits)
Introduction to queueing networks and their use in modeling and analysis of operational systems. Methodological topics include regenerative processes, Markov processes, embedding, reversibility, quasi-reversibility, approximations for open and closed networks, intro to control of Markov queueing systems. Application of these stochastic models and the “physics” of flow operations with emphasis on services, healthcare, and production. CourseProfile (ATLAS)

IOE 547 (MFG 547). Supply Chain Facilities
Prerequisite: IOE 265 or equivalent, IOE 310 or equivalent with minimum grade of “C-” for enforced prerequisites or Graduate standing. (3 credits)
A global supply network consists of “arcs” (transportation) and “nodes” (facilities) such as container terminals, crossdocks, distribution centers, consolidation centers, railway yards, and airfreight terminals. In this course we cover the basic functions and configuration of the above facilities, and we develop analytic design and performance evaluation models for them. CourseProfile (ATLAS)

IOE 548. Integrated Product Development
Prerequisite: Graduate Standing; Permission of Tauber Institute. (3 credits)
This is a Tauber Institute-sponsored graduate elective. Students form teams of four/five, each with mixed disciplinary backgrounds spanning business, engineering and art/architecture. A product category is announced, and each team acts as an independent firm competing in that product market against other teams while working independently through an integrated exercise of market research, product design, product development and manufacture, pricing, demand forecasting and inventory control. Market share of each team is determined through both a web-based competition and a physical trade show. CourseProfile (ATLAS)

IOE 549 (MFG 549). Plant Flow Systems
Prerequisite: IOE 310, IOE 416. (3 credits)
Analytical models for the design and throughput performance evaluation of material handling systems used in discrete parts flow production facilities. Analysis of design and control issues for manual and automated handling systems including lift trucks, micro-load automatic storage/retrieval systems and automated guided vehicle systems. CourseProfile (ATLAS)
IOE 551. Benchmarking, Productivity Analysis and Performance Measurement  
*Prerequisite: IOE 510. (3 credits)*  
Introduction to quality engineering techniques commonly used for performance measurement, productivity analysis, and identification of best practice. Topics include balanced scorecard, activity-based costing/management, benchmarking, quality function deployment and data envelopment analysis (DEA). Significant focus of the course is on the application of DEA for identification of best practice.  
CourseProfile (ATLAS)

IOE 552. Financial Engineering I  
*Prerequisite: IOE 453 or Math 423 or Fin 580 or Fin 618 or Fin 855. Minimum grade required for enforced prerequisites is C-. (3 credits)*  
Theory and applications of financial engineering. Designing, structuring and pricing financial engineering products (including options, swaps and other derivative securities) and their applications to financial and investment risk management. Mathematical methodology that forms the basis of financial engineering, applied stochastic processes and numerical methods in particular.  
CourseProfile (ATLAS)

IOE 553. Financial Engineering II  
*Prerequisite: IOE 552 or Math 542. Minimum grade required for enforced prerequisites is C-. (3 credits)*  
Advanced issues in financial engineering: stochastic interest rate modeling and fixed income markets, derivative trading and arbitrage, international finance, risk management methodologies including Value-at-Risk and credit risk. Multivariate stochastic calculus methodology in finance: multivariate Ito's lemma, Ito's stochastic integrals, the Feynman-Kac theorem and Girsanov's theorem.  
CourseProfile (ATLAS)

IOE 560 (Stats 550) (TO 603). Bayesian Data Analysis  
*Advised Prerequisite: IOE 366 or Statistics 600 or permission of instructor. (3 credits)*  
Practical inferential methods from data based on probability models; formulation of statistical decision problems; risk functions, admissibility; credible intervals; conjugate priors; simulation analysis; posterior sampler design; sampler diagnostics; Bayesian regression; model criticism; hierarchical models, hierarchical regression.  
CourseProfile (ATLAS)

IOE 561 (ISD 523). Risk Analysis I  
*Advised Prerequisite: Graduate level introductory probability course or permission of instructor. (3 credits)*  
This course provides a graduate-level introduction to the interdisciplinary field and methods of risk analysis. The course covers the foundations of the field – the meaning of risk and uncertainty; risk perception, communication and governance; semi-quantitative risk analysis methods; fault trees and event trees; Bayesian belief networks; probability elicitation. It also covers more domain-specific analysis methods from project risk management; terrorism risk analysis, infrastructure risk analysis, and environmental health and safety risk assessment. The focus is on providing a strong foundation for both further study and practice in the field of risk analysis.  
CourseProfile (ATLAS)

IOE 562 (Stats 535). Reliability  
*Prerequisite: IOE 316 and IOE 366 or Stats 425 and Stats 426. (3 credits)*  
Reliability concepts and methodology for modeling, assessing and improving product reliability: common models for component and system reliability; analysis of field and warranty data; component reliability inference; repairable systems; accelerated stress testing for reliability assessment; reliability improvement through experimental design.  
CourseProfile (ATLAS)

IOE 563. Advanced Work Design: Volunteer Work  
*Advisory Prerequisite: IOE 463 with a grade of C- or above or graduate standing. (3 credits)*  
Reliability concepts and methodology for modeling, assessing and improving product reliability: common models for component and system reliability; analysis of field and warranty data;
component reliability inference; repairable systems; accelerated stress testing for reliability assessment; reliability improvement through experimental design.  

**IOE 565 (MFG 561). Time Series Modeling, Analysis, Forecasting**  
*Prerequisite: IOE 366 or MECHENG 401. (3 credits)*  
Volunteers provide valuable services that benefit all segments of society. Design of effective volunteer work must consider extreme age, education and physical ability variations of volunteers, work settings and available tools. This course examines published studies of volunteer work, the application of ergonomic and work design tools and a first-hand volunteer experience.  

**IOE 568. Statistical Learning & Applications in Quality Engineering**  
*Prerequisite: IOE 466 or STATS 500. (3 credits)*  
Statistical learning and data transformation methods to advance quality control techniques for variation reduction. Focus on feature extraction of waveform signals, change point detection for system monitoring, data pattern recognition for fault diagnosis and Bayes/reinforcement learning for decision making.  

**IOE 570 (Stats 570) Experimental Design**  
*Prerequisite: Stats 500 or background in regression (3 credits)*  
Basic design principles, review of analysis of variance, block designs, two-level and three-level factorial and fractional factorial experiments, designs with complex aliasing, data analysis techniques and case studies, basic response surface methodology, variation reduction and introductory robust parameter designs.  

**IOE 574. Simulation Design and Analysis**  
*Advised Prerequisite: IOE 515. (3 credits)*  

**IOE 583 (MECHENG 583) (MFG 583) (EECS 566). Scientific Basis for Reconfigurable Manufacturing**  
*Prerequisite: Graduate Standing or permission of instructor. (3 credits)*  
Principles of reconfigurable manufacturing systems (RMS). Students will be introduced to fundamental theories applicable to RMS synthesis and analysis. Concepts of customization, integrability, modularity, diagnosability and convertibility. Reconfiguration design theory, life-cycle economics, open-architecture principles, controller configuration, system reliability, multi-sensor monitoring and stream of variations. Term projects.  

**IOE 588 (MECHENG 588) (MFG 588). Assembly Modeling for Design and Manufacturing**  
*Prerequisite: MECHENG 381 and MECHENG 401 or equivalent. (3 credits)*  

**IOE 590. Masters Directed Study, Research, and Special Problems**  
*Prerequisite: Graduate standing and permission of instructor. (2-4 credits)*  
Individual or group study, design or laboratory research in a field of interest to the student or group. Topics may be chosen from any area of industrial and operations engineering. Student(s) must register for the section number of the instructor/advisor. Maximum of six credits of IOE 590/593 may be counted toward the IOE Masters Degree.
IOE 591. Special Topics  
*Prerequisite: permission of instructor. (to be arranged)*  
Selected topics of current interest in industrial and operations engineering. [CourseProfile (ATLAS)](ATLAS)  

IOE 593. Ergonomics Professional Project  
*Prerequisite: Graduate Standing, permission of instructor. (2-4 credits)*  
Students work as part of a team within a production or service organization on a design project that emphasizes the application of ergonomic principles to enhance the safety, productivity, and/or quality aspects of a human-machine system. Student(s) must register for the section number of the instructor/advisor. A maximum of six credits of IOE 590/593 may be counted toward the IOE Masters Degree. [CourseProfile (ATLAS)](ATLAS)

### 600 Level Courses

**IOE 600 (EECS 600). Function Space Methods in System Theory**  
*Prerequisite: EECS 400 or Math 419. (3 credits)*  
Introduction to the description and analysis of systems using function analytic methods. Metric spaces, normed linear spaces, Hilbert spaces, resolution spaces. Emphasis on using these concepts in systems problems. [CourseProfile (ATLAS)](ATLAS)

**IOE 610 (Math 660). Linear Programming II**  
*Prerequisite: IOE 510 (Math 561). (3 credits)*  

**IOE 611 (Math 663). Nonlinear Programming**  
*Prerequisite: IOE 510 (Math 561). (3 credits)*  
Modeling, theorems of alternatives, convex sets, convex and generalized convex functions, convex inequality systems, necessary and sufficient optimality conditions, duality theory, algorithms for quadratic programming, linear complementary problems and fixed point computing. Methods of direct search, Newton and Quasi-Newton, gradient projection, feasible direction, reduced gradient; solution methods for nonlinear equations. [CourseProfile (ATLAS)](ATLAS)

**IOE 612. Network Flows**  
*Prerequisite: IOE 510 (Math 561). (3 credits)*  

**IOE 613. Infrastructure Optimization**  
*Advisory prerequisite: Linear Programming. (3 credits)*  
This class describes how to solve complex infrastructure problems using mathematical optimization. The methodologies include mixed-integer programming and convex optimization, Benders decomposition, Column Generation, and constraint programming. The class considers transportation, electrical and gas networks and applications such evacuation planning, optimal power flows, and real-time routing and dispatching. [CourseProfile (ATLAS)](ATLAS)
IOE 614. Integer Programming  
*Prerequisite: IOE 510 (Math 561). (3 credits)*
Modeling with integer variables, total unimodularity, cutting plane approaches, branch-and-bound methods, Lagrangian relaxation, Bender's decomposition, the knapsack and other special problems. CourseProfile (ATLAS)

IOE 615. Advanced Stochastic Processes  
*Prerequisite: IOE 515 and Math 451. (3 credits)*
Designed for students planning to do research on stochastic models in operations research (e.g., queueing systems, stochastic scheduling, financial models, simulation, etc.) Topics covered include Martingales, Brownian motion, diffusion processes, limit theorems, and coupling. CourseProfile (ATLAS)

IOE 616. Queueing Theory  
*Prerequisite: IOE 515. (3 credits)*
Theoretical foundations, models and techniques of queueing theory. Rigorous treatment of elementary through advanced queueing systems and queueing networks. Topics include Markov Renewal and Semi-Regenerative Processes. CourseProfile (ATLAS)

IOE 618. Stochastic Optimization  
*Advised Prerequisite: IOE 510 and C++/JAVA/MATLAB/AMPLD Coding Skills or permission of instructor. (3 credits)*
Planning and operational decisions are often made in uncertain environments, and optimization is a powerful decision support tool in this context. Models, theories, algorithms, and applications of optimization under uncertainty. The topics include stochastic programming, chance and risk constraints, robust optimization, and Benders decomposition. CourseProfile (ATLAS)

IOE 623 (Math 623). Computational Finance  
*Prerequisite: Math 316 and Math 425/525 or IOE 552. (3 credits)*
This is a course in computational methods in finance and financial modeling. Particular emphasis will be put on interest rate models and interest rate derivatives. The specific topics include: Black-Scholes theory, no arbitrage and complete markets theory, term structure models: Hull and White models and Heath Jarrow Morton models, the stochastic differential equations and martingale approach: multinomial tree and Monte Carlo methods, the partial differential equations approach: finite difference methods. CourseProfile (ATLAS)

IOE 635 (BIOMEDE 635). Laboratory in Biomechanics and Physiology of Work  
*Prerequisite: IOE 534 (BIOMEDE 534). (2 credits)*
This laboratory is offered in conjunction with the Occupational Biomechanics lecture course (IOE 534) to enable students to examine experimentally (1) musculoskeletal reactions to volitional acts; (2) the use of electromyography (EMGs) to evaluate muscle function and fatigue; (3) biomechanical models; (4) motion analysis system; and (5) musculoskeletal reactions to vibrations. CourseProfile (ATLAS)

IOE 640. Mathematical Modeling of Operational Systems  
*Prerequisite: IOE 510, IOE 515. (3 credits)*
The art and science of developing, using and explicating mathematical models, presented in a studio/workshop environment. Structuring of a variety of operational “situations” so they can be reasonably represented by a mathematical model. Extensive class discussion and out-of-class investigation of potential mathematical approaches to each situation. Incorporation of data analysis. CourseProfile (ATLAS)

IOE 641. Supply Chain Management  
*Prerequisite: IOE 510, IOE 515 and IOE 541. (3 credits)*
Structural analyses of production and inventory systems. Review of issues in supply chain management. Topics include inventory systems with stochastic lead time, multi-echelon supply
systems, and coordination of material flows, information flows and financial flows in a supply chain. [CourseProfile (ATLAS)]

**IOE 691. Special Topics**
*Prerequisite: permission of instructor. (to be arranged)*
Selected topics of current interest in industrial and operations engineering. [CourseProfile (ATLAS)]

## 700 Level Courses

**IOE 712. Infinite Horizon Optimization**
*Prerequisite: IOE 512. (3 credits)*
A seminar on optimization problems with an infinite time horizon. Topics include topological properties, optimality definitions, decision/forecast horizons, regenerative models and stopping rules. Applications discussed include capacity expansion, equipment replacement and production/inventory control. [CourseProfile (ATLAS)]

## 800 Level Courses

**IOE 800. First-Year Doctoral Seminar**
*Prerequisite: permission of instructor. (1 credit)*
Presentation by IOE faculty members of current and future research activities within the department. Discussion of procedural, philosophical and professional aspects of doctoral studies in industrial and operations engineering. [CourseProfile (ATLAS)]

**IOE 801. First-Year Doctoral Directed Research**
*Advised Prerequisite: IOE Ph.D. pre-candidacy, permission of instructor. (1-3 credits) (Restricted by 1-3 credits per election.)*
A research project is performed on a topic of mutual interest to the student and advisor. A proposal is submitted and approved prior to the start of the term, and a final report is due on the last day of scheduled classes. The student registers for the section number of his/her advisor. [CourseProfile (ATLAS)]

**IOE 802. Written and Oral Academic Presentations**
*Prerequisite: IOE 800 and IOE 801. (2 credits)*
The Dissertation Proposal is used as a platform for developing written and oral presentation skills as students prepare for the IOE Preliminary exam. Topics and assignments include: key elements of NIH and NSF proposals, writing the dissertation proposal and preparing/delivering oral presentations. [CourseProfile (ATLAS)]

**IOE 813. Seminars in Healthcare Systems Engineering**
*Prerequisite: graduate standing or permission of instructor. (2 credits)*
Healthcare is critical to society and has a major impact on our economy. In this course, focused around weekly seminars by leading scholars in this important area, we provide a broad overview to ways systems engineering can improve the delivery of healthcare: decreasing costs, reducing error and developing innovations. [CourseProfile (ATLAS)]

**IOE 836. Seminar in Human Performance**
*Prerequisite: graduate standing. (1 credits)*
Case studies of research techniques used in the human performance and safety fields. Speakers actively engaged in research will discuss their methods and results. [CourseProfile (ATLAS)]
IOE 837. Interprofessional Perspectives in Occupational Health and Safety  
Prerequisite: graduate standing. (1 credit)  
This seminar provides an opportunity for graduate students interested in occupational health and safety engineering problems to become acquainted with various related contemporary research and professional activities, as presented by both staff and guest speakers. CourseProfile (ATLAS)

IOE 899. Seminar in Industrial and Operations Engineering  
Prerequisite: permission of instructor; not for master’s degree; mandatory satisfactory/unsatisfactory. (1 credit)  
Presentation by IOE faculty members and outside speakers on current and future research activities in industrial and operations engineering. CourseProfile (ATLAS)

900 Level Courses

IOE 990. Dissertation Research: Pre-Candidate  
Prerequisite: Completion of IOE Qualifying Exam and permission of instructor. (2-8 credits); (1-4 credits)  
Dissertation work by doctoral student who has passed the IOE Qualifying Exam with Pass or Conditional Pass, but is not yet admitted to candidacy. Student must register for the section number of the instructor/advisor. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

IOE 995. Dissertation Research: Candidate  
Prerequisite: Graduate School authorization for admission as a doctoral candidate and permission of the instructor. (8 credits); (4 credits)  
Dissertation research by a doctoral student who has been admitted to Candidacy. Student must register for the section number of the instructor/advisor. The defense of the dissertation (e.g., the final oral examination) must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)
Integrative Systems + Design Courses
Automotive Engineering Courses

400 Level Courses

AUTO 499. Special Topics in Automotive Engineering
Prerequisite: permission of instructor. (3 credits)
Selected topics pertinent to Automotive Engineering. CourseProfile (ATLAS)

500 Level Courses

AUTO 501. Integrated Vehicle Systems Design
Prerequisite: Graduate student or permission of instructor. (3 credits)
This course is intended to examine the process by which a first layout is developed for a new vehicle platform. The course will focus on the layout of the major space-defining vehicle subsystems required to arrive at a preliminary vehicle package drawing. The process followed will be based on systems engineering: requirements-to-design concepts-to-performance prediction-to-comparison to requirements-to-iteration. CourseProfile (ATLAS)

AUTO 503. Automotive Engineering Project
Prerequisite: Permission of the department. (3 credits)
As an essential component of the Master of Engineering in Automotive Engineering program, students are required to participate in a sponsored project in automotive engineering. The intent of this project course is to provide students with a capstone project experience where they can apply the knowledge and skills acquired to relevant automotive engineering problems. Each project must have a clearly defined problem or need and a solution methodology. The project must provide value-add to the sponsor. CourseProfile (ATLAS)

AUTO 512. Lean Program Engineering
Prerequisite: Graduate student or permission of the instructor. (3 credits)
This course provides an opportunity to acquire and demonstrate mastery of critical lean product design engineering disciplines within the context of an automotive vehicle program team. The course identifies and integrates engineering skills, tools, and processes required for successful automotive vehicle project planning and completion consistent with lean product development principles. CourseProfile (ATLAS)

AUTO 514 (ISD 514). Vehicle Crashworthiness and Occupant Protection
Advisor Prerequisite: Basic knowledge of finite element analysis. (3 credits)
General procedures and state-of-the-art tools to evaluate vehicle crash safety, apply fundamental principles to interpret injury mechanisms, safety concerns, and design benefits in different types of crashes, and assess safety systems using finite element crash simulations. CourseProfile (ATLAS)

AUTO 533 (MECHENG 433). Advanced Energy Solutions
Prerequisite: MECHENG 235. (3 credits)
Introduction to the challenges of power generation for a global society using the thermodynamics to understand basic principles and technology limitations. Covers current and future demands for
energy; methods of power generation including fossil fuel, solar, wind and nuclear; associated detrimental by-products; and advanced strategies to improve power densities, efficiencies and emissions. CourseProfile (ATLAS)

AUTO 542 (MECHENG 542). Vehicle Dynamics
Advisory Prerequisite: MECHENG 440 or 540. (3 credits)
This course focuses on the dynamics and control of road vehicles. Dynamical models of automobiles and trucks are constructed and analyzed. Controllers are designed for driver assistance and vehicle automation. Topics include: longitudinal vehicle dynamics; cruise control and adaptive cruise control; ride dynamics; passive and active suspension design; nonholonomic dynamics of rolling; kinematic and dynamic bicycle models of automobile steering; lane-keeping control; motion planning for automated vehicles, longitudinal and lateral tire models; vehicle handing with tires. CourseProfile (ATLAS)

AUTO 562 (ISD 562). Modeling Analysis of Vehicle Systems
Advised Prerequisite: MECHENG 350 & MECHENG 240. Basic thermo, MATLAB/Simulink, grad standing, trans func, freq. (3 credits)
Basic functionality of vehicle subsystems and domain specific modeling and analysis tools will be introduced. Propulsion system: Engine (breathing and thermodynamics), clutch, transmission and gears. Vehicle performance criteria, real world driving behavior, fuel economy and emission regulation. Braking systems & Vehicle Dynamics. CourseProfile (ATLAS)

AUTO 563. Dynamics and Controls of Automatic Transmissions
Prerequisite: Graduate student or permission of instructor. (3 credits)
Automatic transmission is a key element of automotive vehicles for improved driving comfort. This course will introduce the mechanisms, design and control of modern transmission systems. The emphasis will be on the dynamic analysis, and the application of modern control theories for the overall control design, analysis and synthesis problems. CourseProfile (ATLAS)

AUTO 566 (MECHENG 566). Modeling, Analysis, and Control of Hybrid Electric Vehicles
Prerequisite: MECHENG 438 and MECHENG 461 or equivalent is recommended. (3 credits)
Modeling, analysis and control of vehicles with electrified propulsion systems, including electric vehicles, hybrid vehicles, plug-in and fuel cell vehicles. Introduction of the concepts and technology, the state of the art development, energy conversion and storage options, modeling, analysis, system integration and basic principles of vehicle controls. CourseProfile (ATLAS)

AUTO 590. Study of Research in Selected AUTO topics.
Prerequisite: None. (1-3 credits)
Individualized study of specialized aspects/topics of Automotive Engineering. CourseProfile (ATLAS)

AUTO 599. Special Topics in Automotive Engineering
Prerequisite: Graduate standing or permission of instructor. (3 credits)
Selected topics pertinent to Automotive Engineering. CourseProfile (ATLAS)

Design Science Courses

500 Level Courses

DESCI 501. Analytical Product Design
Advised Prerequisite: Graduate standing. (3 credits)
The design of artifacts is addressed from the multidisciplinary perspective that includes engineering, art, psychology, marketing, and economics. Using a decision-making framework, emphasis is places on understanding basic quantitative methods employed by the different disciplines for making design
decisions, building mathematical models, and accounting for interdisciplinary interactions throughout the design and development process. Students work in teams to apply the methods on design project from concept generation to prototyping and design verification. CourseProfile (ATLAS)

**DESCI 502. Design Process Models**  
*Advised Prerequisite: DESCI 501 or Permission of Instructor. (3 credits)*  
Interaction and coordination of decisions based on multi-discipline design analyses is studied in the context of a newly developed artifact. Innovation and creativity are addressed as elements of the design process. Enterprise design decisions made on functionality and business criteria are analyzed within organizational, cultural and social models. Students propose and test novel analysis methods and design process models. CourseProfile (ATLAS)

**DESCI 590. Directed Design Research**  
*Prerequisite: Graduate Standing. (3-6 credits)*  
Students conduct independent practicum project integrating core design course material under direction of approved faculty or industrial mentor. CourseProfile (ATLAS)

**DESCI 599. Special Problems**  
*Prerequisite: Graduate Standing. (3 credits)*  
Special topics course for DESCI students. CourseProfile (ATLAS)

### 700 Level Courses

**DESCI 790. Design Science Colloquium**  
*Advised Prerequisite: Graduate Standing. (1-4 credits)*  
Topics on Design Science are presented by doctoral candidates and by invited speakers across campus and from outside the University. The aim of the colloquium is to aid in identifying appropriate dissertation topics. CourseProfile (ATLAS)

**DESCI 791. Design Science Seminar**  
*Prerequisite: Graduate Standing. (1-2 credits)*  
Topics on Design Science are presented by doctoral candidates with an emphasis on interdisciplinary scholarship and students’ own research projects. The aim of the seminar is to build community, discuss recent journal papers related to Design Science, and provide an opportunity for students to discuss their own research. CourseProfile (ATLAS)

### 900 Level Courses

**DESCI 990. Dissertation/Pre-candidate**  
*Advised Prerequisite: Permission of advisor. (1-8 credits)*  
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

**DESCI 995. Dissertation/Pre-candidate**  
*Advised Prerequisite: Graduate School authorization for admission as a doctoral candidate. (4-8 credits)*  
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)
Energy Systems Engineering Courses

500 Level Courses

Prerequisite: Graduate student or permission by instructor. (3 credits)
This course is intended to provide students with an understanding the critical issues in energy technologies. Researchers, industry leaders, entrepreneurs, and policymakers discuss technology, policy and economic drivers for sustainable global energy systems. Students complete homework assignments and a term paper on an energy-themed subject. CourseProfile (ATLAS)

ESENG 503. Energy Systems Engineering Project
Prerequisite: ESENG 501. (3 credits)
This required project course is intended to provide students with a relevant experience in energy systems. CourseProfile (ATLAS)

ESENG 505 (MECHENG 571). Energy Generation and Storage Using Modern Materials
Prerequisite: MECHENG 382 and MECHENG 335 or equivalents. (3 credits)
Energy and power densities previously unattainable in environmentally-friendly energy technologies have been achieved through use of novel materials. Insertion of new materials into power supplies has changed the landscape of options. Design strategies for power systems are described, in the context of growing global demand for power and energy. CourseProfile (ATLAS)

ESENG 532 (ISD 532, RCNSCI 419, PUBPOL 519). Sustainable Energy Systems
Advised Prerequisite: Senior standing, college level course in math, economics or physical science. (3 credits)
Examines the production and consumption of energy from a systems perspective. Students will examine sustainability by studying global and regional environmental impacts, economics, energy efficiency, consumption patterns and energy policy. The physics of energy and energy accounting methods are introduce, followed by the current energy system that encompasses resource extraction, conversion processes and end-uses. Responses to current challenges such as declining fossil fuels and climate change are then explored, including unconventional fossil fuels, carbon sequestration, emerging technologies (e.g., renewable sources: biomass, wind, and photovoltaics; fuel cells) and end-use efficiency/conservation. CourseProfile (ATLAS)

ESENG 590. Study or Research in ESENG Topics
Prerequisite: None. (1-3 credits)
Individualized study of specialized aspects/topics of Energy Systems Engineering. CourseProfile (ATLAS)

ESENG 599. Special Topics in Energy Systems Engineering
Prerequisite: Permission of instructor. (3 credits)
Selected topics pertinent to the Energy Systems Engineering program. CourseProfile (ATLAS)
Integrative Systems + Design Courses

500 Level Courses

ISD 503. Integrative Systems + Design Practicum
Prerequisite: Enforced: ISD 520. (3-9 credits)
The Practicum is a project course providing students with an integrative capstone experience where they apply knowledge and skills acquired from coursework to a complex engineering system design problem. Each project must have clearly defined goals and deliverables, and provide a solution methodology. A comprehensive project report is required at completion. CourseProfile (ATLAS)

ISD 514 (AUTO 514). Vehicle Crashworthiness and Occupant Protection
Advisor Prerequisite: Basic knowledge of finite element analysis. (3 credits)
General procedures and state-of-the-art tools to evaluate vehicle crash safety, apply fundamental principles to interpret injury mechanisms, safety concerns, and design benefits in different types of crashes, and assess safety systems using finite element crash simulations. CourseProfile (ATLAS)

ISD 520. Introduction to Systems Engineering
Prerequisite: Enforced: graduate student;. Advisory: background in multivariate calculus and statistics necessary. (3 credits)
Introduction to the systems engineering process used to create multidisciplinary solutions to complex problems with multiple, often conflicting objectives; application to large developmental programs from such diverse areas as civil engineering and transportation, space and missiles, ships and land vehicle systems. CourseProfile (ATLAS)

ISD 521. Development and Verification of Systems Design Requirements
Advised Prerequisite: Basic statistical distributions. (3 credits)
Requirements and contracts, systems and verification requirements, levels of confidence on verification requirements. Verification by inspection, demonstration, analysis, simulation, testing and similarity methods. Needs and development of mission requirements. Use case analysis. Balancing stakeholder requirements with feasibility and verifiability. Applications in automotive, aerospace, defense and software. CourseProfile (ATLAS)

ISD 522. Systems Engineering Architecture and Design
Advised Prerequisite: ISD 520, ISD 521, DESCI 501, DESCI 502. (3 credits)
Gain experience implementing lean systems engineering from systems architecting through systems embodiment. The class will be formed into product development teams of between 3-6 students to design a human powered enclosed vehicle. CourseProfile (ATLAS)

ISD 527 (MFG 527). Systems Engineering Architecture and Design
Advised Prerequisite: Basic statistical distribution & models, product development proc & des experiment (3 credits).
Methods and analysis tools for preventing quality and warranty concerns are explored. This course focuses on the Design for Six Sigma Quality methodology: IDDOV (Identify/Define, Design New System, Optimize, Validate). Using the IDDOV framework, this course examines tools and methods for identifying customer requirements, evaluating design concepts, and optimizing processes to meet quality objectives. CourseProfile (ATLAS)

ISD 528. Advanced Design for Manufacturability
Advised prerequisite: MECHENG 350. (3 credits)
The foci of this course are the study of systematic methods in product design that improve overall quality and cost and implementing these methods by redesigning a product and demonstrating the resulting improvements. The course covers conceptual design, design for economical production, Taguchi methods, design for assembly, product design using advanced polymeric materials and
composites, part consolidation, snap-fit assemblies, and novel applications. It is built around a team project that applies course lectures to a product redesign. Advanced concepts for enhancing manufacturability of products will be covered in certain lectures and homework assignments. [CourseProfile (ATLAS)]

**ISD 532 (ESENG 532, RCNSCI 419, PUBPOL 519). Sustainable Energy Systems**

*Advised Prerequisite: Senior standing, college level course in math, economics or physical science. (3 credits)*

Examines the production and consumption of energy from a systems perspective. Students will examine sustainability by studying global and regional environmental impacts, economics, energy efficiency, consumption patterns and energy policy. The physics of energy and energy accounting methods are introduce, followed by the current energy system that encompasses resource extraction, conversion processes and end-uses. Responses to current challenges such as declining fossil fuels and climate change are then explored, including unconventional fossil fuels, carbon sequestration, emerging technologies (e.g., renewable sources: biomass, wind, and photovoltaics; fuel cells) and end-use efficiency/conservation. [CourseProfile (ATLAS)]

**ISD 555 (MFG 555, MECHENG 555). Design Optimization**

*Advised Prerequisite: MATH 451 and MATH 217 or equivalent. (3 credits)*

Mathematical modeling of engineering design problems for optimization. Boundedness and monotonicity analysis of models. Differential optimization theory and selected numerical algorithms for continuous nonlinear models. Emphasis on the interaction between proper modeling and computation. Students propose design term projects from various disciplines and apply course methodology to optimize designs. [CourseProfile (ATLAS)]

**ISD 565 (MECHENG 565). Battery Systems and Control**

*Advised Prerequisite: ME 360 or equivalent. Advised Co-requisite: ME 461 or equivalent. (3 credits)*

Battery modeling, control and diagnostic methodologies associated to battery electric and battery hybrid electric vehicles. Emphasis on system-level modeling, model order reduction from micro-scale to macro-scale and surrogate models for load control, estimation, on-board identification and diagnostics for Lithium Ion batteries. [CourseProfile (ATLAS)]

**ISD 562 (AUTO 562). Modeling Analysis of Vehicle Systems**

*Advised Prerequisite: MECHENG 350 & MECHENG 240. Basic thermo, MATLAB/Simulink, grad standing, trans func, freq. (3 credits)*

Basic functionality of vehicle subsystems and domain specific modeling and analysis tools will be introduced. Propulsion system: Engine (breathing and thermodynamics), clutch, transmission and gears. Vehicle performance criteria, real world driving behavior, fuel economy and emission regulation. Braking systems & Vehicle Dynamics. [CourseProfile (ATLAS)]

**ISD 590. Directed Study and Research**

*Prerequisite: none. (1-3 credits)*

Individualized study of specialized topics in Integrative Systems + Design. [CourseProfile (ATLAS)]

**ISD 599. Special Topics in ISD**

*Prerequisite: See individual department requirements; permission of instructor. (1-4 credits)*

Special topics in Integrative Systems and Design. [CourseProfile (ATLAS)]
Manufacturing Courses

400 Level Courses

MFG 402 (MECHENG 401). Statistical Quality Control and Design
Prerequisite: Senior or graduate standing. (3 credits)

MFG 410 (NAVARCH 410). Marine Structures II
Prerequisite: NAVARCH 310. (4 credits)
Structural modeling and analysis techniques applied to ship and marine structural components. Equilibrium and energy methods applied to elastic beam theory; static bi-axial bending, torsion and buckling. Shear flow in multicell cross sections. Stiffened and composite plates. Plastic analysis of beams and plates. Structural limit states and introduction to structural reliability. CourseProfile (ATLAS)

MFG 426 (IOE 425). Manufacturing Strategies
Prerequisite: Senior standing. (2 credits)
Review of philosophies, systems, and practices utilized by world-class manufacturing and services organizations focusing on “lean management,” including material and information flow, in-process quality assurance, standardized work, continuous improvement, visual management, and learn leadership. Practical examples and in-class exercises bring concepts to life. CourseProfile (ATLAS)

MFG 440 (IOE 440). Operations Analysis and Management
Prerequisite: IOE 310 and 316 or graduate standing. No credit granted for students who have credit for TO 605. (3 credits)
Principles and models for analyzing, engineering, and managing manufacturing and service operations as well as supply chains. Emphasis on capacity management; queuing models of operational dynamics (including cycle time, work-in-progress, inventory, throughput, and variability); operational flexibility; the math and physics of lean enterprises. CourseProfile (ATLAS)

MFG 441 (IOE 441). Production and Inventory Control
Prerequisite: IOE 310, IOE 316. (3 credits)
Basic models and techniques for managing inventory systems and for planning production. Topics include deterministic and probabilistic inventory models; production planning and scheduling; and introduction to factory physics. CourseProfile (ATLAS)

MFG 447 (IOE 447). Facility Planning
Prerequisite: IOE 310, IOE 316. (3 credits)

MFG 452 (MECHENG 452). Design for Manufacturability
Prerequisite: MECHENG 350. (3 credits)
Study of systematic methods in product design which improve overall quality and cost. Methods include analysis of customer needs, function analysis, product architecture, material and process selection, design for assembly, robust design, and Taguchi methods. A course project to implement the methods by redesigning a product is required. CourseProfile (ATLAS)
MFG 453 (MECHENG 451). Properties of Advanced Materials for Design Engineers
Prerequisite: MECHENG 382. (3 credits)
Mechanical behavior and environmental degradation of polymeric-, metal-, and ceramic-matrix composites; manufacturability of advanced engineering materials; use of composite materials in novel engineering designs. CourseProfile (ATLAS)

MFG 455 (IOE 452). Corporate Finance
Prerequisite: IOE 201, IOE 310, IOE 366. (3 credits)
The goal of this course is to introduce a basic understanding of financial management. The course develops fundamental models of valuation and investment from first principles and applies them to problems of corporate and individual decision-making. The topics of discussion will include the net present valuation, optimal portfolio selection, risk and investment analysis, issuing securities, capital structure with debt financing and real options. CourseProfile (ATLAS)

MFG 456 (IOE 453). Derivative Instruments
Prerequisite: IOE 201, IOE 310, IOE 366. Credit not granted for both IOE 453/MFG 456 and MATH 423. (3 credits)
The main objectives of the course are first, to provide the students with a thorough understanding of the theory of pricing derivatives in the absence of arbitrage, and second, to develop the mathematical and numerical tools necessary to calculate derivative security prices. We begin by exploring the implications of the absence of static arbitrage. We study, for instance, forward and futures contracts. We proceed to develop the implications of no arbitrage in dynamic trading models: the binomial and Black-Scholes models. The theory is applied to hedging and risk management. CourseProfile (ATLAS)

MFG 458 (MATSCIE 485). Design Problems in Materials Science and Engineering
Prerequisite: MATSCIE 480. (1-4 credits) (to be arranged)
The design of production and refining systems for engineering materials. Design of problems for the extraction and refining of metals, production and processing of ceramics, polymeric materials, and electronic materials. Written and oral presentation of solutions to processing design problems. CourseProfile (ATLAS)

MFG 461 (IOE 461). Quality Engineering Principles and Analysis
Prerequisite: IOE 366. (3 credits)
This course provides students with the analytical and management tools necessary to solve manufacturing quality problems and implement effective quality systems. Topics include voice of the customer analysis, the Six Sigma problem solving methodology, process capability analysis, measurement system analysis, design of experiments, statistical process control, failure mode and effects analysis, quality function deployment, and reliability analysis. CourseProfile (ATLAS)

MFG 463 (IOE 463). Measurement and Design of Work
Prerequisite: IOE 333 or IOE 395 or BIOMEDE 231 and IOE 265 and STATS 412. (3 credits)
Design of lean manufacturing systems requires knowledge and skills for describing manual work, identifying value and non-value added work elements, designing efficient work equipment and methods, preventing fatigue and related worker health problems and predicting work performance. CourseProfile (ATLAS)

MFG 466 (IOE 466) (Stat 466). Statistical Quality Control
Prerequisite: IOE 265 (Stat 265 and IOE 366 or Stat 401). (3 credits)
MFG 470 (NAVARCH 470). Foundations of Ship Design
Prerequisite: NAVARCH 321, NAVARCH 332, NAVARCH 340, co-requisite: NAVARCH 310. (4 credits)
Organization of ship design. Preliminary design methods for sizing and form; powering, maneuvering, and seakeeping estimation; arranging; propulsion; structural synthesis; and safety and environmental risk of ships. Extensive use of design computer environment. Given owner’s requirements, students individually create and report the conceptual/preliminary design for a displacement ship. CourseProfile (ATLAS)

MFG 480 (MATSCIE 480). Materials and Engineering Design
Prerequisite: Senior standing. (3 credits)

MFG 488 (MECHENG 487). Welding
Prerequisite: MECHENG 382. (3 credits)
Study of the mechanism of surface bonding, welding metallurgy, effect of rate of heat input on resulting microstructures, residual stresses and distortion, economics and capabilities of the various processes. CourseProfile (ATLAS)

MFG 492 (MECHENG 482). Machining Processes
Prerequisite: Senior standing. (3 credits)

MFG 499. Special Topics (to be specified by department)
(to be arranged) CourseProfile (ATLAS)

500 Level Courses

MFG 501. Topics in Global Operations
Prerequisite: Restricted to Tauber Institute Students (1.5 credits)
This course is intended to provide students with an overview of a broad range of operations-related topics including corporate strategy, lean production systems, supply chain management, design for manufacturability, facilities planning, the environment, legal, and ethical issues in operation, and product design. Students learn how they may apply to Tauber team projects. CourseProfile (ATLAS)

MFG 502. Manufacturing Systems Design
Prerequisite: Graduate standing or permission of instructor. (3 credits)
Manufacturing system design methodologies and procedures. Topics: paradigms of manufacturing; building blocks of manufacturing systems; numerical control and robotics; task allocation and line balancing; system configurations; performance of manufacturing systems including quality, productivity, and responsiveness; economic models and optimization of manufacturing systems; launch and reconfiguration of manufacturing systems; Lean manufacturing. CourseProfile (ATLAS)

MFG 503. Manufacturing Project
Prerequisite: MFG 502. (3 credits)
This project course is intended to provide students with an industrially-relevant team project experience in manufacturing. CourseProfile (ATLAS)

MFG 504. Tauber Institute Project
Prerequisite: Must be enrolled in Tauber Institute Program and MFG 501. (3 credits)
Tauber Institute students will participate in the required Team Project, which is a multidisciplinary
internship. In preparation, students will refine their communications, team building, and project management skills through specialized seminars. Upon completion, each student will perform an advanced analysis of the project results under the supervision of UM faculty. CourseProfile (ATLAS)

MFG 513 (MECHENG 513). Automotive Body Structures
Prerequisite: MECHENG 311. (3 credits)
Emphasis is on body concept for design using first order modeling of thin walled structural elements. Practical application of solid/structural mechanics is considered to design automotive bodies for global bending, torsion, vibration, crashworthiness, topology, material selection, packaging, and manufacturing constraints. CourseProfile (ATLAS)

MFG 514 (MacroSE 514) (MATSCIE 514). Composite Materials
Prerequisite: MATSCIE 350. (3 credits)
Behavior, processing and design of composite materials, especially fiber composites. Emphasis is on the basic chemical and physical processes currently employed and expected to guide the future development of the technology. CourseProfile (ATLAS)

MFG 517 (CHE 517). Biochemical Engineering
Prerequisite: CHE 344, and Biochem 415 or equivalent; permission of instructor. (3 credits)
Concepts necessary in the adaptation of biological and biochemical principles to industrial processing in biotechnology and pharmaceutical industries. Topics include rational screening, functional genomics, cell cultivation, oxygen transfer, etc. Lectures, problems and library study will be used. CourseProfile (ATLAS)

MFG 518. Composite Materials: Mechanics, Manufacturing, and Design
Prerequisite: Senior or graduate standing. (3 credits)
Composite materials, including naturally occurring substances such as wood and bone, and engineered materials from concrete to carbon-fiber reinforced epoxies. Development of micromechanical models for a variety of constitutive laws. Link between processing and as-manufactured properties through coupled fluid and structural analyses. CourseProfile (ATLAS)

MFG 527 (ISD 527). Systems Engineering Architecture and Design
Advised Prerequisite: Basic statistical distribution & models, product development proc & des experiment. (3 credits)
Methods and analysis tools for preventing quality and warranty concerns are explored. This course focuses on the Design for Six Sigma Quality methodology: IDDOV (Identify/Define, Design New System, Optimize, Validate). Using the IDDOV framework, this course examines tools and methods for identifying customer requirements, evaluating design concepts, and optimizing processes to meet quality objectives. CourseProfile (ATLAS)

MFG 534 (BIOMEDE 534) (IOE 534). Occupational Biomechanics
Prerequisite: IOE 333, IOE 334 or IOE 433. (3 credits)
Anatomical and physiological concepts are introduced to understand and predict human motor capabilities, with particular emphasis on the evaluation and design of manual activities in various occupations. Quantitative models are developed to explain (1) muscle strength performance, (2) cumulative and acute musculoskeletal injury, (3) physical fatigue, and (4) human motion control. CourseProfile (ATLAS)

MFG 535 (IOE 533). Human Motor Behavior and Engineering Systems
Prerequisite: IOE 333 and IOE 366. (3 credits)
This course is designed to provide a basic perspective of the major processes of human motor behavior. Emphasis will be placed on understanding motor control and man-(Machine)-environment interaction. Information processing will be presented and linked to motor behavior. Applications of theories to the design of workplace, controls and tools will be underlined and illustrated by substantial examples. CourseProfile (ATLAS)
MFG 536 (CEE 536). Critical Path Methods  
*Prerequisite: Senior or Graduate Standing. (3 credits)*  
Basic critical path planning and scheduling with arrow and precedence networks; project control;  
basic overlapping networks; introduction to resource leveling and least cost scheduling; fundamental  
PERT systems. [CourseProfile (ATLAS)]

MFG 539 (IOE 539). Safety Engineering Methods  
*Prerequisite: IOE 265 or Biostat 500. (3 credits)*  
Recognition, evaluation and control of generic safety hazards (confined spaces, electricity, fire,  
mechanical energy, etc.) found in contemporary workplaces, using case studies from manufacturing,  
transportation and power generation. Students perform an interdisciplinary team project using  
systems safety engineering methods to redesign a work station, manufacturing process or consumer  
product. [CourseProfile (ATLAS)]

MFG 541 (IOE 541). Inventory Analysis and Control  
*Prerequisite: IOE 310, IOE 316. (3 credits)*  
Models and techniques for managing inventory systems and for planning production. Topics include  
single item and multi-item inventory models, production planning and control, and performance  
evaluation of manufacturing systems. [CourseProfile (ATLAS)]

MFG 543 (IOE 543). Scheduling  
*Prerequisite: IOE 316 and IOE 310. (3 credits)*  
The problems that come with scheduling several tasks over time, including the topics of measures of  
performance, single-machine sequencing, flow shop scheduling, the job shop problem, and priority  
dispatching. Integer programming, dynamic programming, and heuristic approaches to various  
problems are presented. [CourseProfile (ATLAS)]

MFG 545 (IOE 545). Queue Networks  
*Prerequisite: IOE 515 or EECS 501. (3 credits)*  
Introduction to queuing networks. Topics include product and non-product form networks, exact  
results and approximations, queuing networks with blocking, and polling systems. Applications from  
manufacturing and service industries are given as examples. [CourseProfile (ATLAS)]

MFG 549 (IOE 549). Plant Flow Systems  
*Prerequisite: IOE 310, IOE 416. (3 credits)*  
Analytical models for the design and throughput performance evaluation of material handling  
systems used in discrete parts flow production facilities. Analysis of design and control issues for  
manual and automated handling systems including lift trucks, micro-load automatic storage/retrieval  
systems and automated guided vehicle systems. [CourseProfile (ATLAS)]

MFG 552 (MECHENG 552). Mechatronic Systems Design  
*Prerequisite: MECHENG 350, MECHENG 360, EECS 314 or equivalent. (3 credits)*  
Mechatronics is the synergistic integration of mechanical disciplines, controls, electronics and  
computers in design of high-performance systems. Case studies, hands-on lab exercises and  
hardware design projects cover the practical aspects of machine design, multi-domain systems  
modeling, sensors, actuators, drives, circuits, simulation tools, DAQ and controls implementation  
using microprocessors. [CourseProfile (ATLAS)]

MFG 553 (MECHENG 553). Microelectromechanical Systems  
*Prerequisite: Senior or Graduate Standing. (3 credits)*  
Basic integrated circuit (IC) manufacturing processes; electronics devices fundamentals;  
microelectromechanical systems fabrications including surface micromachining, bulk  
micromachining, LIGA and others. Introduction to microactuators and microsensors such as  
micromotors, grippers, accelerometers and pressure sensors. Mechanical and electrical issues in  
micromachining. IC CAD tools to design microelectromechanical structures using MCNC MUMPs  
service. Design projects. [CourseProfile (ATLAS)]
MFG 554. Computer Aided Design Methods  
Advisory Prerequisite: MFG 454. (3 credits)  
Generalized Mathematical modeling of engineering systems, methods of solution and simulation languages. Analysis methods in design; load, deformation, stress finite element considerations; nonlinear programming. Computational geometry, definition and generation of curves and surfaces. Computer graphics; transformations, clipping and windowing; graphics systems; data structures; command languages; display processors. [CourseProfile (ATLAS)]

MFG 555 (MECHENG 555, ISD 555). Design Optimization  
Advised Prerequisite: Math 451 and Math 217 or equivalent. (3 credits)  
Mathematical modeling of engineering design problems for optimization. Boundedness and monotonicity analysis of models. Differential optimization theory and selected numerical algorithms for continuous nonlinear models. Emphasis on the interaction between proper modeling and computation. Students propose design term projects from various disciplines and apply course methodology to optimize designs. [CourseProfile (ATLAS)]

MFG 556 (MECHENG 576). Fatigue in Mechanical Design  
Prerequisite: MECHENG 382 or equivalent. (3 credits)  
A broad treatment of stress, strain, and strength with reference to engineering design and analysis. Major emphasis is placed on the analytical and experimental determination of stresses in relationship to the fatigue strength properties of machine and structural components. Also considered are deflection, post-yield behavior, residual stresses, temperature and corrosion effects. [CourseProfile (ATLAS)]

MFG 557 (MECHENG 577). The Use of Materials and Their Selection in Design  
Prerequisite: Senior or Graduate Standing. (3 credits)  
Material properties, including physical, mechanical, thermal, electrical, economic, corrosion and environmental properties interaction of function, shape, choice of materials, processing, economics and environmental impact in design. Methodology for materials selection and optimization, including performance indices, multiple constraints and multiple objectives. Introduction to analysis of environmental impact from materials selection. [CourseProfile (ATLAS)]

MFG 558 (MECHENG 558). Discrete Design Optimization  
Prerequisite: Senior or Graduate Standing. (3 credits)  
Fundamentals of discrete optimization for engineering design problems. Mathematical modeling of engineering design problems as discrete optimization problems, integer programming, dynamic programming, graph search algorithms, and introduction to NP completeness. A term project emphasizes applications to realistic engineering design problems. [CourseProfile (ATLAS)]

MFG 559 (MECHENG 559). Smart Materials and Structures  
Prerequisite: EECS 314 or equivalent. (3 credits)  
This course will cover theoretical aspects of smart materials, sensors and actuator technologies. It will also cover design, modeling and manufacturing issues involved in integrating smart materials and components with control capabilities to engineering smart structures. [CourseProfile (ATLAS)]

MFG 560 (MECHENG 551). Mechanisms Design  
Prerequisite: MECHENG 350. (3 credits)  

MFG 561 (IOE 565) (MECHENG 563). Time Series Modeling, Analysis, Forecasting  
Prerequisite: IOE 366 or MECHENG 401. (3 credits)  
Time series modeling, analysis, forecasting, and control, identifying parametric time series,
autovariance, spectra, Green’s function, trend and seasonality. Examples from manufacturing, quality control, ergonomics, inventory, and management. CourseProfile (ATLAS)

MFG 562 (MECHENG 560). Modeling Dynamic Systems
Prerequisite: MECHENG 360. (3 credits)
A unified approach to the modeling, analysis and simulation of energetic dynamic systems. Emphasis on analytical and graphical descriptions of state-determined systems using Bond Graph language. Analysis using interactive computer simulation programs. Applications to the control and design of dynamic systems such as robots, machine tools and artificial limbs. CourseProfile (ATLAS)

Prerequisite: NAVARCH 260 or P.I. or Graduate Standing. (4 credits)
Business Strategy and Operations Management — Examination of business strategy development, operations management principals and methods, and design-production integration methods applied to the production of complex marine systems such as ships, offshore structures, and yachts. Addresses shipyard and boat yard business and product strategy definition, operations planning and scheduling, performance measurement, process control and improvement. CourseProfile (ATLAS)

MFG 567 (EECS 567) (MECHENG 567). Robot Kinematics and Dynamics
Prerequisite: Graduate standing or permission of instructor. (3 credits)
Geometry, kinematics, differential kinematics, dynamics, and control of robot manipulators. The mathematical tools required to describe spatial motion of a rigid body will be presented in full. Motion planning including obstacle avoidance is also covered. CourseProfile (ATLAS)

MFG 571 (NAVARCH 571). Ship Design Project
Prerequisite: prior arrangement with instructor. (to be arranged)
Individual (or team) project, experimental work, research or directed study of selected advanced topics in ship design. Primarily for graduate students. CourseProfile (ATLAS)

MFG 572 (NAVARCH 570). Advanced Marine Design
Prerequisite: Graduate Standing required. (4 credits)
Organization of marine product development; concurrent marine design. Shipbuilding policy and build strategy development. Group behaviors; leadership and facilitation of design teams. General theories and approaches to design. Conceptual design of ships and offshore projects. Nonlinear programming, multicriteria optimization, and genetic algorithms applied to marine design. CourseProfile (ATLAS)

MFG 574. Global Product Development
Prerequisite: Graduate standing. (3 credits)
A project based course in which each (global) student team comprising students from three universities will be responsible for development of a product for the global market. Teams will use collaboration technology tools extensively. Several case studies on global product development will be presented and follow-up lectures will focus on the issues highlighted. CourseProfile (ATLAS)

MFG 575 (NAVARCH 575). Computer-Aided Marine Design Project
Prerequisite: none. (2-6 credits), (to be arranged)
Development of computer-aided design tools. Projects consisting of formulation, design, programming, testing, and documentation of programs for marine design and constructional use. CourseProfile (ATLAS)

MFG 577 (MATSCIE 577). Failure Analysis of Materials
Prerequisite: MATSCIE 350. (3 credits)
Analysis of failed structures due to tensile overload, creep, fatigue, stress corrosion, wear and abrasion, with extensive use of scanning electron microscope. Identification and role of processing defects in failure. CourseProfile (ATLAS)
MFG 578 (NAVARCH 580). Optimization and Management of Marine Systems
Prerequisite: none. (4 credits)
Optimization methods (linear, integer, nonlinear, deterministic and stochastic sequential optimization) concepts and applications in the operations of marine systems. Elements of maritime management. Risk analysis and utility theory. Fleet deployment optimization for major ocean shipping segments. Forecasting concepts and applications to shipping and shipbuilding decisions. CourseProfile (ATLAS)

MFG 579 (NAVARCH 582). Reliability and Safety of Marine Systems
Prerequisite: EECS 401 or Math 425 or Stat 412. (3 credits)

MFG 580 (MECHENG 572). Rheology and Fracture
Prerequisite: MECHENG 382. (3 credits)
Mechanisms of deformation, cohesion, and fracture of matter. Unified approach to the atomic-scale origins of plastic, viscous, viscoelastic, elastic, and anelastic behavior. The influences of time and temperature on behavior. Stress field of edge and screw dislocations, dislocation interactions, and cross slip. CourseProfile (ATLAS)

MFG 584 (MECHENG 584). Advanced Mechatronics for Manufacturing
Prerequisite: ME 461 or equivalent. (3 credits)
Theoretical principles and practical techniques for controlling mechatronic systems are taught in the context of advanced manufacturing applications. Specifically, the electro-mechanical design/modeling, basic/advanced control, and real-time motion generation techniques for computer-controlled manufacturing machines are studied. Hands-on labs and industrial case studies are used to re-enforce the course material. CourseProfile (ATLAS)

MFG 585 (MECHENG 585). Machining and Machine Tools
Advisory Prerequisite: MECHENG 382 or equivalent. (3 credits)
Provides the knowledge of traditional and non-traditional machining processes as well as modeling and experimental analysis methods for machining. Topics include: the single point, multiple point and abrasive machining processes; machine tools; cutting tools, mechanics, temperatures, and dynamics; electrical discharge, chemical, energy-based, and biomedical machining. CourseProfile (ATLAS)

MFG 587 (MECHENG 587). Global Manufacturing
Prerequisite: one 500-level MFG, DES or BUS class. (3 credits)

MFG 588 (MECHENG 588) (IOE 588). Assembly Modeling for Design and Manufacturing
Prerequisite: MECHENG 381 and 401 or equivalent. (3 credits)
MFG 590. Study or Research in Selected Manufacturing Topics  
*Prerequisite: permission of instructor. (1-3 credits)*  
Individual study of specialized aspects of Manufacturing engineering. [CourseProfile (ATLAS)]

MFG 591 (MECHENG 586). Laser Material Processing  
*Prerequisite: senior or graduate standing. (3 credits)*  

MFG 599. Special Topics  
*Prerequisite: Senior Standing. (1-4 credits)*  
Special Topics in Manufacturing [CourseProfile (ATLAS)]

600 Level Courses

MFG 605 (TO 605). Manufacturing and Supply Operations  
*Prerequisite: none. (1.5-3 credits)*  
This is a course on the basic concepts and techniques of operations and inventory management. The foundation of the course is a system of manufacturing laws collectively known as “Factory Physics”. These laws relate to measures of plant performance, such as throughput, cycle time, work-in-process, customer service, variability, and quality, in a consistent manner and provide a framework for evaluating and improving operations. Concepts and methods are examined via exercises and case studies. [CourseProfile (ATLAS)]

MFG 622 (MATSCIE 622) (NERS 622). Ion Beam Modification and Analysis of Materials  
*Prerequisite: NERS 421, NERS 521 or MATSCIE 350 or permission of instructor. (3 credits)*  
Ion-solid interactions, ion beam mixing, compositional changes, phase changes, micro-structural changes; alteration of physical and mechanical properties such as corrosion, wear, fatigue, hardness; ion beam analysis techniques such as RBS, NRA, PIXE, ion channeling, ion micro-probe; accelerator system design and operation as it relates to implantation and analysis. [CourseProfile (ATLAS)]

900 Level Courses

MFG 990. Dissertation/Pre-Candidate  
*Prerequisite: permission of thesis committee; mandatory satisfactory/unsatisfactory. (2-8 credits); (1-4 credits)*  
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. [CourseProfile (ATLAS)]

MFG 995. Dissertation/Candidate  
*Prerequisite: College of Engineering authorization for admission as a doctoral candidate; mandatory satisfactory/unsatisfactory. (8 credits); (4 credits)*  
Election for dissertation work by a doctoral student who has been admitted to candidacy status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. [CourseProfile (ATLAS)]
Macromolecular Science & Engineering
Macromolecular Science and Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: [https://bulletin.engin.umich.edu/courses/course-info/](https://bulletin.engin.umich.edu/courses/course-info/)

400 Level Courses

MACROMOL 410 (BIOENG 410) (MATSCIE 410). Polymeric Materials
Prerequisites: MATSCIE 250 or permission. (3 credits)
Interactions of materials implanted in the body. Histological and hematological considerations including general foreign body reactions, inflammation and reparations, carcinogenicity, thrombosis, hemolysis, protein and cellular issues, immunogenic and toxic properties. Basic discussion of implants vs. transplants and relevant biological components. Tours of relevant University facilities.

MACROMOL 412 (CHE 412) (MATSCIE 412). Polymeric Materials
Prerequisites: MATSCIE 220 or 250. (3 credits)
The synthesis, characterization, microstructure, rheology, and properties of polymer materials. Polymers in solution and in the liquid, liquid-crystalline, crystalline and glassy states. Engineering and design properties, including viscoelasticity, yielding and fracture. Forming and processing methods. Recycling and environmental issues.

500 Level Courses

MACROMOL 511 (CHE 511) (MATSCIE 511). Rheology of Polymeric Materials
Prerequisite: a course in fluid mechanics or permission from instructor. (3 credits)
An introduction to the relationships between the chemical structure of polymer chains and their rheological behavior. The course will make frequent reference to synthesis, processing, characterization and use of polymers for high technology applications.

MACROMOL 512 (CHE 512) (MATSCIE 512). Polymer Physics
Prerequisite: Senior or Graduate Standing in engineering or physical science. (3 credits)
Structure and properties of polymers as related to their composition, annealing and mechanical treatments. Topics include creep, stress relaxation, dynamic mechanical properties, viscoelasticity, transitions, fracture, impact response, dielectric properties, permeation and morphology.

MACROMOL 514 (MFG 514) (MATSCIE 514). Composite Materials
Prerequisite: MATSCIE 350. (3 credits)
Behavior, processing and design of composite materials, especially fiber composites. Emphasis is on the basic chemical and physical processes currently employed and expected to guide the future development of the technology.

MACROMOL 515 (MATSCIE 515). Mechanical Behavior of Solid Polymeric Materials
Prerequisite: MECHENG 211, MATSCIE 412. (3 credits)
The mechanical behavior of polymers from linear viscoelastic to yield and fracture are covered. Specific topics include dynamic-mechanical relaxations, creep, yielding, crazing, fatigue and fracture mechanics. The materials include toughened plastics, polymer alloys and blends and composite materials. Structured design with plastics is also considered.
MACROMOL 517 (MECHENG 517). Mechanics of Polymers I  
Prerequisite: MECHENG 511 (AM 511) or permission of instructor. (3 credits) 
Constitutive equation for linear small strain viscoelastic response; constant rate and sinusoidal responses; time and frequency dependent material properties; energy dissipation; structural applications including axial loading, bending, torsion; three dimensional response, thermoviscoelasticity, correspondence principle, Laplace transform and numerical solution methods.

MACROMOL 535 (Chem 535). Physical Chemistry of Macromolecules  
Prerequisite: Chem 463 or Chem 468. (3 credits) 
The theory and application of useful methods for studying natural and synthetic polymers will be stressed. The methods discussed include osmotic pressure, sedimentation equilibrium, Brownian motion, diffusion, sedimentation transport, intrinsic viscosity, scattering of light and x-rays, optical and resonance spectra, flow and electric bi-refringence, depolarization of fluorescence, circular dichroism and magneto optical rotatory dispersion, electrophoresis, titration curves, kinetics of polymerization, suitable distribution functions for expressing heterogeneity, rigidity and viscosity of gels.

MACROMOL 536 (Chem 536). Laboratory in Macromolecular Chemistry  
Prerequisite: Chem 535 or permission of instruction. (2 credits) 
Experimental methods for the study of macromolecular materials in solution and in bulk state.

MACROMOL 538 (Chem 538). Organic Chemistry of Macromolecules  
Prerequisite: Chem 215, Chem 216, and Chem 230 or Chem 241/242, 260. (3 credits) 
The preparation, reactions and properties of high molecular weight polymeric materials of both natural and synthetic origin. Two lectures and reading.

MACROMOL 559 (MATSCIE 559). Foundations of Nano II  
(3 credits) 
This course covers the synthesis, properties and processing of nanosized metal, metal oxide and semiconductor powders. It will also include some organic/inorganic and nanobio materials. The emphasis will be on particle properties and the use of these particles to make nanostructured shapes.

700 Level Courses

MACROMOL 751 (Chem 751) (MATSCIE 751) (Physics 751). Special Topics in Macromolecular Science  
Prerequisite: permission of instructor. (2 credits)

MACROMOL 790. Faculty Activities Research Survey  
(1 credit) 
This course introduces students to the research activities of MacroSE faculty with the intent of helping a student to choose his research advisor in the first term.

800 Level Courses

MACROMOL 800. Macromolecular Seminar I, II  
(2 credits) 
Student presentation of selected seminar topics in macromolecular science and engineering.

MACROMOL 890. Introduction to Research Techniques  
Prerequisite: permission of chairman. every term (1-8 credits) 
This course is used for research carried out to earn the master’s degree.
900 Level Courses

MACROMOL 990. Dissertation Research Precandidacy
Prerequisite: permission. every term (1-8 credits)
This course number is used for doctoral research by students not yet admitted to candidacy. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.

MACROMOL 995. Dissertation Research/Candidacy
Prerequisite: permission. every term (8 credits); (4 credits) in half-term
This course number is used for doctoral research by students who have been admitted to candidacy. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
Materials Science & Engineering
Materials Science and Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: https://bulletin.engin.umich.edu/courses/course-info/

100 Level Courses

MATSCIE 193. Special Topics in Materials Science and Engineering
Prerequisite: permission of instructor. (1-4 credits)
Special topics of current interest to students. [CourseProfile (ATLAS)]

200 Level Courses

MATSCIE 220. Introduction to Materials and Manufacturing
Prerequisite: Chem 130 or Chem 210. (4 credits)
Introduction to materials engineering and materials processing in manufacturing. The engineering properties of metals, polymers, semiconductors, ceramics and composites are correlated with the internal structure of the materials and the service conditions. [CourseProfile (ATLAS)]

MATSCIE 242. Physics of Materials
Prerequisite: Physics 240 and preceded or accompanied by Math 216. (4 credits)
Basic principles of modern physics and quantum mechanics as pertain to solid state physics and the physical behavior of materials on the nanometer scale. Applications to solid state and nano-structured materials will be emphasized including band structure, bonding and magnetic, optical and electronic response. [CourseProfile (ATLAS)]

MATSCIE 250. Principles of Engineering Materials
Prerequisite: Chem 130 or Chem 210. (4 credits)
Introductory course to engineering materials. Properties (mechanical, thermal and electrical) of metals, polymers, ceramics and electronic materials. Correlation of these properties with (1) their internal structures (atomic, molecular, crystalline, micro- and macro-), (2) service conditions (mechanical, thermal, chemical, electrical, magnetic and radiation), and (3) processing. [CourseProfile (ATLAS)]

MATSCIE 280. Materials Science and Engineering Undergraduate Research Opportunity
Prerequisite: Open only to 1st- or 2nd-year undergraduate students with permission of instructor. (1-4 credits)
The UROP program enables students to work one-on-one or with a small group of students with faculty members conducting research. Students receive 1 credit per 3 hours of work per week. Students participating in the program are required to attend biweekly research peer group meetings, meet monthly with a peer advisor and keep a research journal. [CourseProfile (ATLAS)]

MATSCIE 293. Special Topics in Materials Science and Engineering
Prerequisite: None. (2-4 credits)
Special Topics in Materials Science and Engineering. [CourseProfile (ATLAS)]
300 Level Courses

MATSCIE 330. Thermodynamics of Materials
Prerequisites: Phys 140/141, Math 215, and MATSCIE 220 or 250. (4 credits)

MATSCIE 335. Kinetics and Transport in Materials Engineering
Prerequisite: Enforced: Math 216, MATSCIE 220 or 250, and MATSCIE 330. (4 credits)
Application of basic principles of molecular transport and mass, energy and momentum balance to the solution of heat, diffusion and fluid flow problems relevant to materials processing. Introduction to radiative heat transfer. Empirical approaches to and dimensional analysis of complex transport problems including convection, turbulence and non-Newtonian flow. CourseProfile (ATLAS)

MATSCIE 350. Structures of Materials
Prerequisite: MATSCIE 220 or MATSCIE 250. (4 credits)
Basic principles of Materials Science & Engineering; including bonding, structure and microstructure and how they are influenced by thermodynamics and kinetics. CourseProfile (ATLAS)

MATSCIE 360. Materials Laboratory I
Prerequisite: MATSCIE 220 or 250. (3 credits)
Laboratory experiences based on principles emphasized in Fundamentals of Materials Science including processing, properties, and structure with a focus on micro structural analysis and structure-property relationships. Continued as MATSCIE 365. CourseProfile (ATLAS)

MATSCIE 365. Materials Laboratory II
Prerequisite: MATSCIE 360 and accompanied by MATSCIE 242. (3 credits)
Laboratory experiences based on principles emphasized in Physics of Materials and Fundamentals of Material Science. Processing, properties, and microstructure with a focus on electronic and magnetic phenomena. CourseProfile (ATLAS)

400 Level Courses

MATSCIE 400. Electronic, Magnetic and Optical Materials for Modern Device Technology
Prerequisites: MATSCIE 242 and either MATSCIE 220 or 250 or equivalents. (3 credits)
Application of solid-state phenomena in engineering structures such as microelectronic, magnetic and optical devices. Review of quantum mechanical descriptions of crystalline solids. Microelectronic, magnetic and optical properties of devices, fabrication and process methods. CourseProfile (ATLAS)

MATSCIE 410 (BIOMEDE 410). Design and Applications of Biomaterials
Prerequisite: MATSCIE 220 or 250 or permission of instructor. (3 credits)

MATSCIE 412 (CHE 412) (MacroSE 412). Polymeric Materials
Prerequisites: MATSCIE 220 or 250 and CHEM 210. (3 credits)
The synthesis, characterization, microstructure, rheology and processing of polymeric materials. Polymers in solution and in the liquid, liquid-crystalline, crystalline and glassy states. Engineering
and design properties, including viscoelasticity, yielding and fracture. Forming and processing methods. Recycling and environmental issues.  

**MATSCIE 420. Mechanical Behavior of Materials**  
*Prerequisite: MATSCIE 220 or 250, MECHENG 211. (3 credits)*  

**MATSCIE 440. Ceramic Materials**  
*Prerequisites: MATSCIE 350 (advised); Enforced Prerequisite: MATSCIE 335. (3 credits)*  
Chemistry, structure, processing, microstructure and property relationships and their applications in design and production of ceramic materials.  

**MATSCIE 454. Computational Approaches in MSE**  
*Prerequisite: MATSCIE 335, 365 or permission by instructor. (3 credits)*  
Computational methods and tools used in materials science and engineering, including the advantages, disadvantages, and pitfalls associated with various methods, the concepts behind the methods and the basics of numerical modeling and simulation. The hands-on laboratory sessions, home problems, and class project provide first-hand learning experience in modeling.  

**MATSCIE 465. Structural and Chemical Characterization of Materials**  
*Prerequisites: MATSCIE 350 and 365. (3 credits)*  
Study of the basic structural and chemical characterization techniques that are commonly used in materials science and engineering. X-ray, electron and neutron diffraction, a wide range of spectroscopies, microscopies and scanning probe methods will be covered. Lectures will be integrated with a laboratory where the techniques will be demonstrated and/or used by the student to study a material. Techniques will be presented in terms of the underlying physics and chemistry.  

**MATSCIE 470. Physical Metallurgy**  
*Prerequisite: MATSCIE 335; MATSCIE 350 (Advised). Minimum grade of a “C-” for enforced prerequisite. (3 credits)*  

**MATSCIE 481. Designing Sustainable Products and Processes**  
*Enforced Prerequisite: Senior Standing. (3 credits)*  

**MATSCIE 482. Product Design and Manufacturing**  
*Enforced Prerequisite: Senior Standing. (3 credits)*  

**MATSCIE 485 (MFG 458). Design Problems in Materials Science and Engineering**  
*Prerequisite: MATSCIE 480. (1-4 credits) (to be arranged)*  
The design of production and refining systems for engineering materials. Design of problems for the
extraction and refining of metals, production and processing of ceramics, polymeric materials, and electronic materials. Written and oral presentation of solutions to processing design problems. 

**MATSCIE 490. Research Problems in Materials Science and Engineering**
*Prerequisite: not open to graduate students. (to be arranged)*
Individual or group work in a particular field or on a problem of special interest to the student. The program of work is arranged at the beginning of each term by mutual agreement between the student and a faculty member. Written and oral reports are required. Laboratory and conferences.

**MATSCIE 493. Special Topics in Materials Science and Engineering**
*Prerequisite: MATSCIE 350. (to be arranged)*
Selected topics of current interest for students entering industry.

### 500 Level Courses

**MATSCIE 500. Materials Physics and Chemistry**
*Prerequisite: Senior level or Graduate Standing. (3 credits)*
Physical properties of a wide range of materials, including crystalline and organic materials from the electronic and atomic point of view. The bonding and structure of materials will be placed in context of quantum mechanics and band theory; and the electrical, optical, thermal, mechanical and magnetic properties will be emphasized.

**MATSCIE 502. Materials Issues in Electronics**
*Prerequisites: MATSCIE 242 and MATSCIE 400 or equivalent. (3 credits)*
This course covers the key materials issues, including defects, diffusion and oxidation relevant to the conversion of a material into an electronic device.

**MATSCIE 505. Materials Science of Thin Films**
*Prerequisites: MATSCIE 242 and MATSCIE 400 or equivalent. (3 credits)*
Thermodynamics and kinetics of film nucleation, growth, structure and stability for a single crystal, polycrystalline and amorphous thin films.

**MATSCIE 510 (CHEM 511). Materials Chemistry**
*(3 credits)*
This course presents concepts in materials chemistry. The main topics covered include structure and characterization, macroscopic properties and synthesis and processing.

**MATSCIE 511 (CHE 511) (MacroSE 511). Rheology of Polymeric Materials**
*Prerequisite: a course in fluid mechanics or permission from instructor. (3 credits)*
An introduction to the relationships between the chemical structure of polymer chains and their rheological behavior. The course will make frequent reference to synthesis, processing, characterization and use of polymers for high technology applications.

**MATSCIE 512 (CHE 512) (MacroSE 512). Polymer Physics**
*Prerequisite: Senior or Graduate Standing in engineering or physical science. (3 credits)*
Structure and properties of polymers as related to their composition, annealing and mechanical treatments. Topics include creep, stress relaxation, dynamic mechanical properties, viscoelasticity, transitions, fracture, impact response, dielectric properties, permeation and morphology.

**MATSCIE 514 (MacroSE 514) (MFG 514). Composite Materials**
*Prerequisite: MATSCIE 220 or 250. (3 credits)*
Behavior, processing, and design of composite materials, especially fiber composites. Emphasis is
on the chemical and physical processes currently employed and expected to guide the future development of the technology. CourseProfile (ATLAS)

MATSCIE 515 (MacroSE 515). Mechanical Behavior of Solid Polymeric Materials
Prerequisite: MECHENG 211, MATSCIE 412. (3 credits)
The mechanical behavior of polymers from linear viscoelastic to yield and fracture are covered. Specific topics include dynamic-mechanical relaxations, creep, yielding, crazing, fatigue and fracture mechanics. The materials include toughened plastics, polymer alloys and blends and composite materials. Structured design with plastics is also considered. CourseProfile (ATLAS)

MATSCIE 516 (MECHENG 516). Mechanics of Thin Films and Layered Materials
Prerequisite: MECHENG 311 or Graduate Standing. (3 credits)
Stresses and deformations in layered materials; energy-release rates and delamination; fracture mechanics of layered materials; spalling; interfacial fracture mechanics; mixed-mode fracture; buckling-driven delamination; cracking of thin films; effects of plasticity on fracture; stress-relaxation mechanisms in multi-layered materials; adhesion and fracture tests. CourseProfile (ATLAS)

MATSCIE 517 (MACROMOL 530). Advanced Function Polymers: Molecular Design and Applications
Prerequisite: MSE 412 or graduate standing. W/ minimum grade of C-. (3 credits)
Development of global perspective of interdisciplinary issues involved in functional polymers. Learn how to design, synthesize, evaluate, and analyze functional polymers. CourseProfile (ATLAS)

MATSCIE 520. Advanced Mechanical Behavior
Prerequisite: Graduate Standing. (3 credits)

MATSCIE 532. Advanced Thermodynamics of Materials
Prerequisite: MATSCIE 330 or equivalent. (3 credits)
Classical and statistical thermochemistry with emphasis on topics important in materials science and engineering, including thermodynamics of solids, solution thermochemistry, heterogeneous equilibria of stable and metastable phases, multicomponent systems, coherent equilibria and strain effects, interfaces and adsorption, polymer alloys and solutions. CourseProfile (ATLAS)

MATSCIE 535. Kinetics, Phase Transformations, and Transport
Prerequisite: MATSCIE 330 or equivalent. (3 credits)
Fundamentals of phase change, diffusion, heat transport, nucleation, and growth applied to solidification, ordering, spinodal decomposition, coarsening, reactions, massive transformations, diffusion-limited transformations and glass transitions. CourseProfile (ATLAS)

MATSCIE 550. Fundamentals of Materials Science and Engineering
Prerequisite: senior or graduate standing or permission of instructor. (3 credits)
An advanced level survey of the fundamental principles underlying the structures, properties, processing and uses of engineering materials. CourseProfile (ATLAS)

MATSCIE 554 (CHE 554). Computational Methods in MATSCIE and CHE
Prerequisite: Senior level or Graduate Standing. (3 credits)
Broad introduction to the methods of numerical problem solving in Materials Science and Chemical Engineering. Topics include numerical techniques, computer algorithms and the formulation and use of computational approaches for the modeling and analysis of phenomena peculiar to these disciplines. CourseProfile (ATLAS)
MATSCIE 555. Materials Energy Conversion  
*Prerequisite: Senior standing or higher (3 credits)*  
The course includes an introduction to energy conversion and storage issues. Next, the operating principles of energy conversion and storage devices are discussed. The remainder of the course focuses on the physics and chemistry of nanostructures and nanomaterial design and processing approaches to enhanced performance photovoltaics, thermoelectrics and fuel cells. CourseProfile (ATLAS)

MATSCIE 556. Molecular Simulation of Materials  
*Prerequisite: Senior level or graduate standing. (3 credits)*  
Practical and theoretical consideration in the simulation of materials on the molecular level. Molecular dynamics and Monte Carlo techniques. Empirical interaction potentials for metals, ceramics and polymers. Statistical mechanics and thermodynamics of simulated systems. CourseProfile (ATLAS)

MATSCIE 557 (CHE 557). Computational Nanoscience of Soft Matter  
*Prerequisites: Differential equations course, and a statistical thermodynamics or statistical mechanics course. (3 credits)*  
Provides an understanding of strategies, methods, capabilities and limitations of computer simulation as it pertains to the modeling and simulation of soft materials at the nanoscale. The course consists of lectures and hands-on, interactive simulation labs using research codes and commercial codes. Ab initio, molecular dynamics, Monte Carlo and mesoscale methods. CourseProfile (ATLAS)

MATSCIE 558 (CHE 558) (MacroE 558). Foundations of Nanotechnology  
*Prerequisites: Senior or graduate standing. (3 credits)*  
The focus of this course is on the scientific foundations of nanotechnology. The effects of nanoscale dimensions on optical, electrical and mechanical properties are explained based on atomistic properties and related to applications in electronics, optics, structural materials and medicine. Projects and discussions include startup technological assessment and societal implications of the nanotechnology revolution. CourseProfile (ATLAS)

MATSCIE 559 (CHE 559) (MacroE 559). Foundations of Nanotechnology II  
*Prerequisites: Senior or graduate standing. (3 credits)*  
This course will cover the synthesis and processing of nano-sized metal, metal oxide and semiconductor powders. It will also include organic/inorganic and nanobiomaterials. Emphasis will be on particle properties and their use in making nonstructured materials with novel properties. CourseProfile (ATLAS)

MATSCIE 560. Structure of Materials  
*Prerequisite: MATSCIE 550. (3 credits)*  
Atomic arrangements in crystalline and noncrystalline materials. Crystallography, kinematic and dynamical theories of diffraction, applications to x-rays, electrons and neutrons. Interpretation of diffraction patterns and intensity distributions, applications to scattering in perfect and imperfect crystals and amorphous materials. Continuum description of structure emphasizing the tensor analysis of distortions in solids. CourseProfile (ATLAS)

MATSCIE 562. Electron Microscopy I  
*(4 credits)*  
An introduction to electron optics, vacuum techniques and the operation of electron optical instruments. The theory and applications of transmission and scanning electron microscopy and electron microprobe analysis in the study of nonbiological materials. CourseProfile (ATLAS)

MATSCIE 563. (BIOMEDE 563) (CHE 563) Biomolecular Engineering of Interfaces  
*Prerequisite: senior or graduate standing. (3 credits)*  
This class focuses on biomolecular engineering of surfaces and interfaces in contact with biological
Recent advances in the interfacial design of materials as well as methods that enable studying such systems will be highlighted. **CourseProfile (ATLAS)**

**MATSCIE 574. High-Temperature Materials**  
*Prerequisite: MATSCIE 350. (3 credits)*  
Principles of behavior of materials at high temperatures. Microstructure-property relationships including phase stability and corrosion resistance to high temperature materials. Fracture and fatigue at elevated temperatures. Damage accumulation behavior and engineering applications of service life techniques. **CourseProfile (ATLAS)**

**MATSCIE 577 (MFG 577). Failure Analysis of Materials**  
*Prerequisite: MATSCIE 350. (3 credits)*  
Analysis of failed structures due to tensile overload, creep, fatigue, stress corrosion, wear and abrasion, with extensive use of scanning electron microscope. Identification and role of processing defects in failure. **CourseProfile (ATLAS)**

**MATSCIE 583 (BIOMEDE 583) (CHE 583). Biocompatibility of Materials**  
*Prerequisite: undergraduate course in biology and/or physiology; undergraduate course in biochemistry, organic chemistry, or molecular biology. (2 credits)*  
This course describes the interactions between tissue and materials and the biologic/pathologic processes involved. In addition, specifications which govern biocompatibility testing, various strengths and weaknesses of a number of approaches to testing, and future directions are discussed. **CourseProfile (ATLAS)**

**MATSCIE 585. Materials or Metallurgical Design Problem**  
*Prerequisite: MATSCIE 480. (2 credits)*  
Engineering design and economic evaluation of a specific process and/or materials application. Original and individual work and excellence of reporting emphasized. Written and oral presentation of design required. **CourseProfile (ATLAS)**

**MATSCIE 593. Special Topics in Materials Science & Engineering**  
*Prerequisite: Permission of instructor. (1-4 credits)*  
Special topics of interest to graduate students; and, possibly, undergraduate students. **CourseProfile (ATLAS)**

**600 Level Courses**

**MATSCIE 621 (NERS 621). Nuclear Waste Forms**  
*Prerequisites: NERS 531 (recommended). (3 credits)*  
This interdisciplinary course will review the materials science of radioactive waste remediation and disposal strategies. The main focus will be on corrosion mechanisms, radiation effects and the long-term durability of glasses and crystalline ceramics proposed for the immobilization and disposal of nuclear waste. **CourseProfile (ATLAS)**

**MATSCIE 622 (MFG 622) (NERS 622). Ion Beam Modification and Analysis of Materials**  
*Prerequisite: NERS 421, NERS 521 or MATSCIE 350 or permission of instructor. (3 credits)*  
Ion-solid interactions, ion beam mixing, compositional changes, phase changes, micro-structural changes; alteration of physical and mechanical properties such as corrosion, wear, fatigue, hardness; ion beam analysis techniques such as RBS, NRA, PIXE, ion channeling, ion microprobe; accelerator system design and operation as it relates to implantation and analysis. **CourseProfile (ATLAS)**

**MATSCIE 662. Electron Microscopy II**  
*Prerequisite: MATSCIE 562. (3 credits)*  
Advanced methods in electron microscopy such as high resolution bright field and dark field imaging,
micro and convergent beam diffraction, analysis of thin film specimens and electron energy loss spectroscopy. Two lectures and one three-hour laboratory-discussion session per week. CourseProfile (ATLAS)

MATSCIE 690. Research Problems in Materials Science and Engineering
(to be arranged)
Laboratory and conferences. Individual or group work in a particular field or on a problem of special interest to the students. The program of work is arranged at the beginning of each term by mutual agreement between the student and a member of the faculty. Any problem in the field of materials and metallurgy may be selected. The student writes a final report on this project. CourseProfile (ATLAS)

MATSCIE 693. Special Topics in Materials Science and Engineering
(to be arranged)
CourseProfile (ATLAS)

700 Level Courses

MATSCIE 751 (CHE 751) (Chem 751) (MacroSE 751) (Physics 751). Special Topics in Macromolecular Science
Prerequisite: permission of instructor. (2 credits)
Advanced topics of current interest will be stressed. The specific topics will vary with the instructor. CourseProfile (ATLAS)

800 Level Courses

MATSCIE 890. Colloquium in Materials Science and Engineering
(1 credit)
Colloquium presentations covering a variety of topics at the forefront of research and development in materials science and engineering, including design, synthesis, fabrication, characterization and applications of metallic materials, inorganic, electronic, organic, and polymeric materials. Colloquia are delivered by renowned experts in their respective fields from academia, industry and national laboratories. CourseProfile (ATLAS)

900 Level Courses

MATSCIE 990. Dissertation/Pre-Candidate
(2-8 credits); (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

MATSCIE 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate (8 credits); (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)
Mechanical Engineering
Mechanical Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under “How to Read a Course Description”, in the CoE Bulletin Website: https://bulletin.engin.umich.edu/courses/course-info/

200 Level Courses

MECHENG 211. Introduction to Solid Mechanics
Prerequisite: Physics 140 & 141, and (Math 116 or Math 121 or 156.) “Minimum grade of “C” required for enforced prerequisites. (4 credits)
Statics: moment and force resultants, equilibrium. Mechanics of deformable bodies: stress/strain, classification of material behavior, generalized Hooke’s law. Engineering applications: axial loads, torsion of circular rods and tubes, bending and shear stresses in beams, deflection of beams, combined stresses, stress and strain transformation. Four lecture classes per week. CourseProfile (ATLAS)

MECHENG 235. Thermodynamics I
Prerequisite: Chem 130 & 125 or Chem 210 & 211, and (Math 116 or Math 121 or Math 156.) Minimum grade of “C” required for enforced prerequisites. (3 credits)
Introduction to engineering thermodynamics. First law, second law system and control volume analyses; properties and behavior of pure substances; application to thermodynamic systems operating in a steady state and transient processes. Heat transfer mechanisms. Typical power producing cycles and refrigerators. Ideal gas mixtures and moist air applications. CourseProfile (ATLAS)

MECHENG 240. Introduction to Dynamics and Vibrations
Prerequisite: Physics 140 &141, and preceded or accompanied by (Math 216 or Math 156.) Minimum grade of “C” required for enforced prerequisites. (4 credits)

MECHENG 250. Design and Manufacturing I
Prerequisite: Math 116 or equivalent (Math 119 or Math 121 or Math 156 or Math 176 or Math 186 or Math 296) and (ENGR 101 or ENGR 151 or EECS 183 ). Minimum grade of “C” required for enforced prerequisite. (4 credits)
Basics of mechanical design: visual thinking, engineering drawing, and machine anatomy. Basics of manufacturing: processes, materials and thermo-fluid aspects. Use of computers in various phases of design and manufacturing. Exposure to CAD systems and basic machine shop techniques. Design/manufacturing project. Three hours lecture and two hours laboratory CourseProfile (ATLAS)

MECHENG 290. RISE 2 – Research, Innovation, Service and Entrepreneurship
Prerequisite: permission of instructor. (1-3 credits)
Individual or group project work where student(s) must apply mechanical engineering principles to research, innovation, service or entrepreneurship projects. Student(s) work under the direction of mechanical engineering faculty. CourseProfile (ATLAS)
300 Level Courses

MECHENG 305. Introduction to Finite Elements in Mechanical Engineering
Prerequisite: MECHENG 311. (3 credits)
Introduction to theory and practice of the finite element method. One-dimensional, two-dimensional and three dimensional elements is studied, including structural elements. Primary fields of applications are strength of materials (deformation and stress analysis) and dynamics and vibrations. Extensive use of commercial finite element software packages, through computer labs and graded assignments. Two hour lecture and one hour lab. CourseProfile (ATLAS)

MECHENG 311. Strength of Materials
Prerequisite: MECHENG 211, Math 216. (3 credits)
Energy methods; buckling of columns, including approximate methods; bending of beams of asymmetrical cross-section; shear center and torsion of thin-walled sections; membrane stresses in axisymmetric shells; elastic-plastic bending and torsion; axisymmetric bending of circular plates. CourseProfile (ATLAS)

MECHENG 320. Fluid Mechanics I
Prerequisite: (Math 215 or Math 255), MECHENG 235, and MECHENG 240. Minimum grade of “C” required for enforced prerequisites. (3 credits)
Fluid statics; conservation of mass, momentum and energy in fixed and moving control volumes; steady and unsteady Bernoulli’s equation; differential analysis of fluid flow; dimensional analysis and similarity; laminar and turbulent flow; boundary layers; lift and drag; applications to mechanical, biological, environmental, and micro-fluidic systems. CourseProfile (ATLAS)

MECHENG 335. Heat Transfer
Prerequisite: MECHENG 320. Minimum grade of “C” required for enforced prerequisites. (3 credits)
Heat transfer by conduction, convection, radiation; heat storage, energy conservation; steady-state/transient conduction heat transfer; thermal circuit modeling; multidimensional conduction; surface radiation properties, enclosure radiation exchange; surface convection/fluid streams over objects, non-dimensional numbers, laminar, turbulent, thermo-buoyant flow, boiling and condensation; heat exchangers; design of thermal systems, solvers for problem solving/design. CourseProfile (ATLAS)

MECHENG 336. Thermodynamics II
Prerequisite: MECHENG 235. (3 credits)
Thermodynamic power and refrigeration systems; availability and evaluation of thermodynamic properties; general thermodynamic relations, equations of state and compressibility factors; chemical reactions; combustion; gaseous dissociation; phase equilibrium. Design and optimization of thermal systems. CourseProfile (ATLAS)

MECHENG 350. Design and Manufacturing II
Prerequisite: MECHENG 211, MECHENG 240, MECHENG 250. Minimum grade of “C” required for enforced prerequisites. (4 credits)
Principles of machine and mechatronic design and manufacturing. Analysis, synthesis and selection of mechanisms, machine components, mechatronic components, and associate manufacturing processes. Semester-long, model-based design/build/test project in a team setting CourseProfile (ATLAS)

MECHENG 360. Modeling, Analysis and Control of Dynamic Systems
Prerequisite: MECHENG 240 and preceded or accompanied by EECS 215 or EECS 314. Minimum grade of “C” required for enforced prerequisites. (4 credits)
Developing mathematical models of dynamic systems, including mechanical, electrical, electromechanical and fluid/thermal systems and representing these models in transfer function and state space form. Analysis of dynamic system models, including time and frequency responses.
Introduction to linear feedback control techniques. Synthesis and analysis by analytical and computer methods. Four hours of lecture per week. CourseProfile (ATLAS)

MECHENG 382. Mechanical Behavior of Materials  
Prerequisite: MECHENG 211. Minimum grade of “C” required for enforced prerequisite. (4 credits)  
Material microstructures, dislocations and defects; processing and mechanical properties of metals, polymers and composites; heat treatment of metals; elastic, plastic, and viscoelastic behavior of materials; strain hardening; fracture, fracture mechanics, fatigue and multiaxis loading; creep and stress relaxation; materials-related design issues, materials selection, corrosion and environmental degradation of materials. CourseProfile (ATLAS)

MECHENG 390. RISE 3 – Research, Innovation, Service, Entrepreneurship  
Prerequisite: Permission of instructor. (2-3 credits)  
Individual or group project work where student(s) must apply mechanical engineering principles to research, innovation, service or entrepreneurship projects. Student(s) work under the direction of Mechanical Engineering faculty. The student(s) submits proposal and presents poster at ME Undergraduate Symposium. CourseProfile (ATLAS)

MECHENG 395. Laboratory I  
Enforced prerequisites: PHYS 240 or 260, and PHYS 241 or 261, and MECHENG 211, and MECHENG 235, and MECHENG 240; preceded or accompanied by MECHENG 320, and MECHENG 382. Minimum grade of “C” required for enforced prerequisites. (4 credits)  
Weekly lectures and experiments designed to introduce the student to the basics of experimentation, instrumentation, data collection and analysis, error analysis and reporting. Topics will include fluid mechanics, thermodynamics, mechanics, materials and dynamical systems. Emphasis is placed on report writing and team-building skills. CourseProfile (ATLAS)

400 Level Courses

MECHENG 400. Mechanical Engineering Analysis  
Prerequisite: MECHENG 211, MECHENG 240, Math 216. (3 credits)  
Exact and approximate techniques for the analysis of problems in mechanical engineering including structures, vibrations, control systems, fluids, and design. Emphasis is on application. CourseProfile (ATLAS)

MECHENG 401. (MFG 402) Statistical Quality Control and Design  
Prerequisite: senior or graduate standing. (3 credits)  

Prerequisites: MECHENG 320 and MECHENG 382. (3 credits)  
Fundamental properties of biological systems, followed by a quantitative, mechanical analysis. Topics include mechanics of the cytoskeleton, biological motor molecules, cell motility, muscle, tissue and bio-fluid mechanics, blood rheology, bio-viscoelasticity, biological ceramics, animal mechanics and locomotion, biomimetics and effects of scaling. Individual topics will be covered on a case by case study basis. CourseProfile (ATLAS)

MECHENG 412. Advanced Strength of Materials  
Prerequisite: MECHENG 311. (3 credits)  
Review of energy methods, Betti’s reciprocal theorem; elastic, thermoelastic and elastoplastic
analysis of axisymmetric thick cylinders and rotating discs; bending of rectangular and circular plates, including asymmetric problems; beams on elastic foundations; axisymmetric bending of cylindrical shells; torsion of prismatic bars. CourseProfile (ATLAS)

MECHENG 420. Fluid Mechanics II  
Prerequisite: MECHENG 320. (3 credits)  
Use of commercial CFD packages for solving realistic fluid mechanics and heat transfer problems of practical interest. Introduction to mesh generation, numerical discrimination, stability, convergence, and accuracy of numerical methods. Applications to separated, turbulent and two-phase flows, flow control and flows involving heat transfer. Open-ended design project. CourseProfile (ATLAS)

MECHENG 424 (BME 424). Engineering Acoustics  
Prerequisite: Math 216 or Physics 240. (3 credits)  
Vibrating systems; acoustic wave equation; plane and spherical waves in fluid media; reflection and transmission at interfaces; propagation in lossy media; radiation and reception of acoustic waves; pipes, cavities and waveguides; resonators and filters; noise; selected topics in physiological, environmental and architectural acoustics. CourseProfile (ATLAS)

MECHENG 432. Combustion  
Prerequisite: MECHENG 336, preceded or accompanied by MECHENG 320. (3 credits)  
Introduction to combustion processes; combustion thermodynamics, reaction kinetics and combustion transport. Chain reactions, ignition, quenching and flammability limits, detonations, deflagrations and flame stability. Introduction to turbulent premixed combustion. Applications in IC engines, furnaces, gas turbines, and rocket engines. CourseProfile (ATLAS)

MECHENG 433 (AUTO 533). Advanced Energy Solutions  
Prerequisite: MECHENG 235. (3 credits)  
Introduction to the challenges of power generation for a global society using the thermodynamics to understand basic principles and technology limitations. Covers current and future demands for energy; methods of power generation including fossil fuel, solar, wind and nuclear; associated detrimental by-products; and advanced strategies to improve power densities, efficiencies and emissions. CourseProfile (ATLAS)

MECHENG 438. Internal Combustion Engines  
Prerequisite: MECHENG 235, MECHENG 336 or permission of instructor. (4 credits)  

MECHENG 440. Intermediate Dynamics and Vibrations  
Prerequisite: MECHENG 240. (4 credits)  
Newton/Euler and Lagrangian formulations for three-dimensional motion of particles and rigid bodies. Linear free and forced responses of one and two degree of freedom systems and simple continuous systems. Applications to engineering systems involving vibration isolation, rotating imbalance and vibration absorption. CourseProfile (ATLAS)

MECHENG 450. Design and Manufacturing III  
Prerequisite: MECHENG 320, MECHENG 350, MECHENG 360, and either MECHENG 395 or AEROSP 305. May not be taken concurrently with MECHENG 455 or MECHENG 495. Not open to graduate students. (4 credits)  
A mechanical engineering design project by which the student is exposed to the design process from concept through analysis to layout and report. Projects are proposed from the different areas of study within mechanical engineering and reflect the expertise of instructional faculty and industrial representatives. CourseProfile (ATLAS)
MECHENG 451 (MFG 453). Properties of Advanced Materials for Design Engineers
Prerequisite: MECHENG 382. (3 credits)
Mechanical behavior and environmental degradation of polymeric-, metal- and ceramic-matrix composites; manufacturability of advanced engineering materials; use of composite materials in novel engineering designs. CourseProfile (ATLAS)

MECHENG 452 (MFG 452). Design for Manufacturability
Prerequisite: MECHENG 350. (3 credits)
Conceptual design. Design for economical production, Taguchi methods, design for assembly; case studies. Product design using advanced polymeric materials and composites; part consolidation, snap-fit assemblies; novel applications. Design projects. CourseProfile (ATLAS)

MECHENG 455. Analytical Product Design
Prerequisite: MECHENG 350, MECHENG 360, MECHENG 395 for MECHENG majors. PI for all others. (3-4 credits)
Design of artifacts is addressed from a multidisciplinary perspective that includes engineering, art, psychology, marketing and economics. Using a decision-making framework, emphasis is placed on quantitative methods. Building mathematical models and accounting for interdisciplinary interactions. Students work in team design projects from concept generation to prototyping and design verification. Four credit-hour election requires prototyping of project. CourseProfile (ATLAS)

MECHENG 456 (BIOMEDE 456). Tissue Mechanics
Prerequisite: MECHENG 211, MECHENG 240. (3 credits)
Definition of biological tissue and orthopedic device mechanics including elastic, viscoelastic and non-linear elastic behavior. Emphasis on structure function relationships. Overview of tissue adaptation and the interaction between tissue mechanics and physiology. CourseProfile (ATLAS)

MECHENG 457. Front-End Design
Advised Prerequisite: MECHENG 350 or equivalent design course. (3 credits)
This course examines processes of front-end of engineering design, including opportunity discovery, problem definition, developing mechanisms to gather data from users and other stakeholders, translating user data into design requirements and specifications, creating innovative solutions during concept generation, representing design ideas, and evaluating possible solutions. CourseProfile (ATLAS)

MECHENG 458. Automotive Engineering
Prerequisite: MECHENG 350. (3 credits)
Emphasizes systems approach to automotive design. Specific topics include automotive structures, suspension steering, brakes and driveline. Basic vehicle dynamics in the performance and handling modes are discussed. A semester team-based design project is required. CourseProfile (ATLAS)

MECHENG 461. Automatic Control
Prerequisite: MECHENG 360. (3 credits)
Feedback control design and analysis for linear dynamic systems with emphasis on mechanical engineering applications; transient and frequency response; stability; system performance; control modes; state space techniques; digital control systems. CourseProfile (ATLAS)

MECHENG 476 (BIOMEDE 476). Biofluid Mechanics
Prerequisite: MECHENG 320. (4 credits)
This is an intermediate level fluid mechanics course which uses examples from biotechnology processes and physiologic applications including the cardiovascular, respiratory, ocular, renal, musculo-skeletal and gastrointestinal systems. CourseProfile (ATLAS)

MECHENG 481. Manufacturing Processes
Prerequisite: MECHENG 382. (3 credits)
Mathematical modeling of manufacturing processes used in industry to manufacture mechanical
systems: machining, deformation, welding, assembly, surface treatment, and solidification processes. Process costs and limits; influence of processes on the final mechanical properties of the product. Reconfigurable manufacturing, Rapid prototyping, Direct Metal Deposition (DMD) and semiconductor manufacturing. CourseProfile (ATLAS)

MECHENG 482 (MFG 492). Machining Processes
Prerequisite: MECHENG 382. (3 credits)

MECHENG 483. Manufacturing System Design
Prerequisite: MECHENG 250. (3 credits)
Manufacturing system design methodologies and procedures. Topics: paradigms of manufacturing; building blocks of manufacturing systems; numerical control and robotics; task allocation and line balancing; system configurations, performance of manufacturing systems including quality, productivity, and responsiveness; economic models and optimization of manufacturing systems; launch and reconfiguration of manufacturing systems; Lean manufacturing. CourseProfile (ATLAS)

MECHENG 487 (MFG 488). Welding
Prerequisite: MECHENG 382. (3 credits)
Study of the mechanism of surface bonding, welding metallurgy, effect of rate of heat input on resulting microstructures, residual stresses and distortion, economics and capabilities of the various processes. CourseProfile (ATLAS)

MECHENG 489. Sustainable Engineering and Design
Prerequisite: MECHENG 235. Minimum Grade of “C-” required for enforced prerequisite. (3 credits) Credit for only one: CEE 265 or MECHENG 489
ME 489 covers economic, environmental and social aspects of sustainability as they pertain to engineering design. The course covers life cycle assessment, carbon/water/energy footprints, economic assessments, mass/energy balances, air/water pollutants, modeling of environmental pollutant concentrations, engineering economics, social considerations, pollution prevention, resource conservation, human and eco-toxicity, life cycle costing, and energy systems. CourseProfile (ATLAS)

MECHENG 490. RISE 4 – Research, Innovation, Service, Entrepreneurship
Prerequisite: permission of instructor. (3 credits)
Individual or group project work where student(s) must apply mechanical engineering principles to research, innovation, service or entrepreneurship projects. Student(s) work under the direction of Mechanical Engineering faculty. (Students should work on project approximately 10 hours/week for 3 credits. The student(s) submits proposal and presents poster at ME Undergraduate Symposium.) CourseProfile (ATLAS)

MECHENG 491. Independent Study
Prerequisite: MECHENG 490, permission of instructor; mandatory pass/fail. (1-3 credits)
Individual or group experimental or theoretical research in the area of mechanical engineering. A topic in mechanical engineering under the direction of a member of the department. The student will submit a final report. Two four-hour laboratories per week. For undergraduates only. CourseProfile (ATLAS)

MECHENG 495. Laboratory II
Prerequisite: [MECHENG 360 and 395; (C- or better)] AND [MECHENG 335 (D or better, or concurrent enrollment) and 350 (C- or better, or concurrent enrollment)] AND Not open to graduate students. (4 credits)
Weekly lectures and extended experimental projects designed to demonstrate experimental and analytical methods as applied to complex mechanical systems. Topics will include controls, heat
transfer, fluid mechanics, thermodynamics, mechanics, materials and dynamical systems. Emphasis on laboratory report writing, oral presentations and team-building skills, and the design of experiments. CourseProfile (ATLAS)

MECHENG 499. Special Topics in Mechanical Engineering
Prerequisite: permission of instructor. (to be arranged)
Selected topics pertinent to mechanical engineering. CourseProfile (ATLAS)

500 Level Courses

MECHENG 500. Professional Skills for Graduate Student Success
(1 credits)
Broadly describe best practices for research; introduce policies/procedures for successful completion of graduate studies in Mechanical Engineering. Steps in the PhD process; Mentoring; The research process; Identifying research opportunities and formulating hypotheses; Research methodologies; Monitoring and using the literature; Improving writing, presentation, time management skills; Mental health; DEI; Career planning. CourseProfile (ATLAS)

MECHENG 501. Mathematical Methods in Mechanical Engineering
Prerequisite: advised Math 216; Math 217 or equivalent recommended. (3 credits)
Applied mathematics for mechanical engineering with an emphasis on mathematical principles and analytical methods. Topics include: complex analysis (functions of complex variables, contour integrals, conformal mappings), linear operator theory (vector spaces, linear algebra), ordinary differential equations (series solutions, Laplace and Fourier transforms, Green’s functions). CourseProfile (ATLAS)

MECHENG 502. Methods of Differential Equations in Mechanics
Prerequisite: Math 454. (3 credits)
Applications of differential equation methods of particular use in mechanics. Boundary value and eigenvalue problems are particularly stressed for linear and nonlinear elasticity, analytical dynamics, vibration of structures, wave propagation, fluid mechanics and other applied mechanic topics. CourseProfile (ATLAS)

MECHENG 505. Finite Element Methods in Mechanical Engineering
Prerequisite: MECHENG 501 (MECHENG 311 or MECHENG 320). (3 credits)
Theoretical and computational aspects of finite element methods. Examples from areas of thermal diffusion, potential/irrotational flows, lubrication, structural mechanics, design of machine components, linear elasticity and Navier-Stokes flows problems. Program development and modification are expected as well as learning the use of existing codes. CourseProfile (ATLAS)

MECHENG 506 (BIOMEDE 506). Computational Modeling of Biological Tissues
(3 credits)
Biological tissues have multiple scales and can adapt to their physical environment. This course focuses on visualization and modeling of tissue physics and adaptation. Examples include electrical conductivity of heart muscle and mechanics of hard and soft tissues. Homogenization theory is used for multiple scale modeling. CourseProfile (ATLAS)

MECHENG 507. Atomistic Computer Modeling of Materials
Introductory quantum mechanics recommended, but not required. (3 credits)
Describes the core methods used to simulate matter at the atomic scale. Topics include: Structure of matter and interatomic potentials; High-performance computing; Electronic structure methods; Molecular dynamics; Monte Carlo; Transition state theory; Accelerated dynamics and multi-scale modeling. Applications of these methods are illustrated in hands-on laboratories involving research-caliber simulation tools. CourseProfile (ATLAS)
MECHENG 511. Theory of Solid Continua  
*Prerequisite: MECHENG 211, Math 450. (3 credits)*  
The general theory of a continuous medium. Kinematics of large motions and deformations; stress tensors; conservation of mass, momentum and energy; constitutive equations for elasticity, viscoelasticity and plasticity; applications to simple boundary value problems. [CourseProfile (ATLAS)]

MECHENG 512 (CEE 509). Theory of Elasticity  
*Prerequisite: MECHENG 311 or MECHENG 412, or MECHENG 511 or equivalent. (3 credits)*  
Stress, strain and displacement, equilibrium and compatibility. Use of airy stress function in rectangular and polar coordinates, asymptotic fields at discontinuities, forces and dislocations, contact and crack problems, rotating and accelerating bodies. Galerkin and Papcovich-Neuber solutions, singular solutions, spherical harmonics. Thermoelasticity. Axisymmetric contact and crack problem. Axisymmetric torsion. [CourseProfile (ATLAS)]

MECHENG 513 (Auto 513, MFG 513). Automotive Body Structures  
*Prerequisite: MECHENG 311. (3 credits)*  
Emphasis is on body concept for design using first order modeling of thin walled structural elements. Practical application of solid/structural mechanics is considered to design automotive bodies for global bending, torsion, vibration, crashworthiness, topology, material selection, packaging and manufacturing constraints. [CourseProfile (ATLAS)]

MECHENG 515. Contact Mechanics  
*Prerequisite: MECHENG 311 or MECHENG 350. (3 credits)*  
Hertzian elastic contact; elastic-plastic behavior under repeated loading; shakedown. Friction; transmission of frictional tractions in rolling; fretting; normal and oblique impact. Dynamic loading. Surface durability in rolling. Surface roughness effects. Conduction of heat and electricity across interfaces. Thermal and thermoelastic effects in sliding and static contact. [CourseProfile (ATLAS)]

MECHENG 516. Fracture and Adhesion of Interfaces, and the Mechanics of Layered Materials  
*Advisory Prerequisite: ME 311 or graduate standing. (3 credits)*  
Stresses and deformations in layered materials and laminated composites; cohesive-zone models of fracture; energy-release rates and delamination; fracture mechanics of layered materials; physics of adhesion; spalling; interfacial fracture mechanics; mixed-mode fracture; buckling-driven delamination; cracking of thin films and coating; adhesion and fracture tests; measurement of cohesive fracture parameters. [CourseProfile (ATLAS)]

MECHENG 517. (MacroSE 517) Mechanics of Polymers I  
*Prerequisite: MECHENG 511 or permission of instructor. (3 credits)*  
Constitutive equation for linear small strain viscoelastic response; constant rate and sinusoidal responses; time and frequency dependent material properties; energy dissipation; structural applications including axial loading, bending, torsion; three dimensional response, thermo-viscoelasticity, correspondence principle, Laplace transform and numerical solution methods. [CourseProfile (ATLAS)]

MECHENG 519. Theory of Plasticity I  
*Prerequisite: MECHENG 511. (3 credits)*  
Fundamentals of plasticity; stress-strain relations, yield criteria and the general behavior of metals and nonmetals beyond proportional limit in the light of experimental evidence. Various approximate theories with emphasis on the theory of plastic flow. Application to problems of bending, torsion, plane strain and plane stress, technological problems. [CourseProfile (ATLAS)]

MECHENG 520. Advanced Fluid Mechanics I  
*Prerequisite: MECHENG 320. (3 credits)*  
Fundamental concepts and methods of fluid mechanics; inviscid flow and Bernoulli theorems; potential flow and its application; Navier-Stokes equations and constitutive theory; exact solutions of
the Navier-Stokes equations; boundary layer theory; integral momentum methods; introduction to turbulence.  

MECHENG 521. Advanced Fluid Mechanics II  
Prerequisite: MECHENG 520. (3 credits)  
Viscous flow fundamentals; vorticity dynamics; solution of the Navier-Stokes equations in their approximate forms; thin shear layers and free surface flows; hydrodynamic stability and transition to turbulence; fundamental concepts of turbulence; the turbulent boundary layer; introduction to turbulence modeling.  

MECHENG 523 (AEROSP 523). Computational Fluid Dynamics I  
Prerequisite: AEROSP 325 or preceded or accompanied by MECHENG 520. (3 credits)  

MECHENG 524. Advanced Engineering Acoustics  
Prerequisite: MECHENG 424, (BIOMEDE 424). (3 credits)  

MECHENG 527. Multiphase Flow  
Prerequisite: MECHENG 520. (3 credits)  
Selected topics in multiphase flow including nucleation and cavitation; dynamics of stationary and translating particles and bubbles; basic equations of homogeneous two-phase gas/liquid, gas/solid and vapor/liquid flows; kinematics and acoustics of bubbly flows; instabilities and shock waves in bubbly flows; stratified, annular and granular flow.  

MECHENG 530. Advanced Heat Transfer  
Prerequisite: MECHENG 320 or equivalent background in fluid mechanics and heat transfer. (3 credits)  
Advanced topics in conduction and convection including the presentation of several solution methods (semi-quantitative analysis, finite difference methods, superposition, separation of variables) and analysis of multi-mode heat transfer systems. Fundamentals of radiation heat transfer including; blackbody radiation, radiative properties, view factors, radiative exchange between ideal and non-ideal surfaces.  

MECHENG 533. Radiative Heat Transfer  
Prerequisite: MECHENG 335. (3 credits)  
Electromagnetic, optical and quantum aspects of radiative equilibrium. Enclosure radiation including spatial, specular, and spectral distributions. Gas radiation including boundary affected thin gas and thick gas approximations. Averaged and spectral properties. Technological applications.  

MECHENG 535. Thermodynamics III  
Prerequisite: MECHENG 336. (3 credits)  
Definitions and scope of thermodynamics; first and second laws. Maxwell’s relations. Clapeyron relation, equation of state, thermodynamics of chemical reactions, availability.  

CourseProfile (ATLAS)
MECHENG 537. Advanced Combustion  
*Prerequisite: MECHENG 432 or equivalent. (3 credits)*  
Advanced treatment of fundamental combustion processes. Conservation equations for reacting gas mixtures. The structure of one-dimensional diffusion and premixed flames; introduction to activation energy asymptotics. Two-dimensional Burke-Schumann flames and boundary layer combustion. Flame instabilities and flame stretch; turbulent combustion. [CourseProfile (ATLAS)](ATLAS)

MECHENG 538. Advanced Internal Combustion Engines  
*Prerequisite: MECHENG 438. (3 credits)*  
Modern analytical approach to the design and performance analysis of advanced internal combustion engines. Study of thermodynamics, fluid flow, combustion, heat transfer and other factors affecting the design, operating and emissions characteristics of different engine types. Application of course techniques to engine research projects. [CourseProfile (ATLAS)](ATLAS)

MECHENG 539 (APPLIED PHYSICS 639). Heat Transfer Physics  
*Prerequisite: MECHENG 235, MECHENG 335. (3 credits)*  
Unified treatment of thermal energy storage, transport and conversion, by principal carriers: phonon, electron, fluid particle and photon. Quantum, molecular dynamics and Boltzmann transport treatments are used, along with applications (e.g., thermoelectrics, photovoltaics, laser cooling, phonon recycling, size effects). [CourseProfile (ATLAS)](ATLAS)

MECHENG 540 (AEROSP 540). Intermediate Dynamics  
*Prerequisite: MECHENG 240. (3 credits)*  
Newton/Euler and Lagrangian formulations for three dimensional motion of particles and rigid bodies. Principles of dynamics applied to various rigid-body and multi-body dynamics problems that arise in aerospace and mechanical engineering. [CourseProfile (ATLAS)](ATLAS)

MECHENG 541. Mechanical Vibrations  
*Prerequisite: MECHENG 440. (3 credits)*  

MECHENG 542 (AUTO 542). Vehicle Dynamics and Automation  
*Advisory Prerequisite: MECHENG 440 or 540. (3 credits)*  
This course focuses on the dynamics and control of road vehicles. Dynamical models of automobiles and trucks are constructed and analyzed. Controllers are designed for driver assistance and vehicle automation. Topics include: longitudinal vehicle dynamics; cruise control and adaptive cruise control; ride dynamics; passive and active suspension design; nonholonomic dynamics of rolling; kinematic and dynamic bicycle models of automobile steering; lane-keeping control; motion planning for automated vehicles, longitudinal and lateral tire models; vehicle handling with tires. [CourseProfile (ATLAS)](ATLAS)

MECHENG 543. Analytical and Computational Dynamics I  
*Prerequisite: MECHENG 440. (3 credits)*  
Modern analytical rigid body dynamics equation formulation and computational solution techniques applied to mechanical multibody systems. Kinematics of motion generalized coordinates and speeds, analytical and computational determination of inertia properties, generalized forces, Gibb’s function, Routhian, Kanes’s equations, Hamilton’s principle, Lagrange’s equations holonomic and nonholonomic constraints, constraint processing, computational simulation. [CourseProfile (ATLAS)](ATLAS)

MECHENG 548. Applied Nonlinear Dynamics  
*Prerequisite: MECHENG 360 or graduate standing. (3 credits)*  
Geometrical representation of the dynamics of nonlinear systems. Stability and bifurcation theory for
autonomous and periodically forced systems. Chaos and strange attractors. Introduction to pattern formation. Applications to various problems in rigid-body dynamics, flexible structural dynamics, fluid-structure interactions, fluid dynamics, and control of electromechanical systems. CourseProfile (ATLAS)

MECHENG 551 (MFG 560). Mechanisms Design
Prerequisite: MECHENG 350. (3 credits)

MECHENG 552 (MFG 552). Mechatronic Systems Design
Advised Prerequisite: MECHENG 350, MECHENG 360, EECS 314 or equivalent (4 credits)
Mechatronics is the synergistic integration of mechanical disciplines, controls, electronics and computers in the design of high-performance systems. Case studies, hands-on lab exercises and hardware design projects cover the practical aspects of machine design, multi-domain systems modeling, sensors, actuators, drives circuits, simulation tools, DAQ and controls implementation using microprocessors. CourseProfile (ATLAS)

MECHENG 553 (MFG 553). Microelectromechanical Systems
Prerequisite: senior or graduate standing. (3 credits)
Basic integrated circuit (IC) manufacturing processes; electronics devices fundamentals; microelectromechanical systems fabrications including surface micromachining, bulk micromachining, LIGA and others. Introduction to micro-actuators and microsensors such as micromotors, grippers, accelerometers and pressure sensors. Mechanical and electrical issues in micromachining. IC CAD tools to design microelectromechanical structures using MCNC MUMPs service. Design projects. CourseProfile (ATLAS)

MECHENG 555 (ISD 555, MFG 555). Design Optimization
Advised Prerequisite: Math 451 and Math 217 or equivalent. (3 credits)
Mathematical modeling of engineering design problems for optimization. Boundedness and monotonicity analysis of models. Differential optimization theory and selected numerical algorithms for continuous nonlinear models. Emphasis on the interaction between proper modeling and computation. Students propose design term projects from various disciplines and apply course methodology to optimize designs. CourseProfile (ATLAS)

MECHENG 557. Front-End Design
Advised Prerequisite: MECHENG 350 or equivalent design course. (3 credits)
This course examines processes of front-end of engineering design, including opportunity discovery, problem definition, developing mechanisms to gather data from users and other stakeholders, translating user data into design requirements and specifications, creating innovative solutions during concept generation, representing design ideas, and evaluating possible solutions. CourseProfile (ATLAS)

MECHENG 558 (MFG 558). Discrete Design Optimization
Prerequisite: senior or graduate standing. (3 credits)
Fundamentals of discrete optimization for engineering design problems. Mathematical modeling of engineering design problems as discrete optimization problems, integer programming, dynamic programming, graph search algorithms, and introduction to NP completeness. A term project emphasizes applications to realistic engineering design problems. CourseProfile (ATLAS)

MECHENG 559 (MFG 559). Smart Materials and Structures
Prerequisite: EECS 314 or equivalent. (3 credits)
This course will cover theoretical aspects of smart materials, sensors and actuator technologies. It
will also cover design, modeling and manufacturing issues involved in integrating smart materials and components with control capabilities to engineering smart structures. CourseProfile (ATLAS)

MECHENG 560 (MFG 562). Modeling Dynamic Systems
Prerequisite: MECHENG 360. (3 credits)
A unified approach to the modeling, analysis and simulation of energetic dynamic systems. Emphasis on analytical and graphical descriptions of state-determined systems using Bond Graph language. Analysis using interactive computer simulation programs. Applications to the control and design of dynamic systems such as robots, machine tools and artificial limbs. CourseProfile (ATLAS)

MECHENG 561 (EECS 561). Design of Digital Control Systems
Prerequisite: EECS 460 or MECHENG 461. (3 credits)

MECHENG 563. Time Series Modeling and System Analysis
Prerequisite: None. (3 credits)
This course will cover topics related to the modeling techniques for time series data and related system analysis methods. CourseProfile (ATLAS)

MECHENG 564 (AEROSP 550, CEE 571, EECS 560). Linear Systems Theory
Prerequisite: graduate standing. (4 credits)

MECHENG 565 (SD 565). Battery Systems and Control
Advised Prerequisite: MECHENG 360 or equivalent. Advised Co-requisite: MECHENG 461 or equivalent. (3 credits)
Battery modeling, control and diagnostic methodologies associated to battery electric and battery hybrid electric vehicles. Emphasis is placed upon system-level modeling, model order reduction from micro-scale to macro-scale and surrogate models for load control, estimation, on-board identification and diagnostics for Lithium Ion batteries. CourseProfile (ATLAS)

MECHENG 566 (AUTO 566). Modeling, Analysis, and Control of Hybrid Electric Vehicles
Prerequisite: MECHENG 438 and MECHENG 461 or equivalent is recommended. (3 credits)
Modeling, analysis and control of vehicles with electrified propulsion systems, including electric vehicles, hybrid vehicles, plug-in and fuel cell vehicles. Introduction of the concepts and terminology, the state of the art development, energy conversion and storage options, modeling, analysis, system integration and basic principles of vehicle controls. CourseProfile (ATLAS)

MECHENG 567 (EECS 567) (ROB 510) (MFG 567). Robot Kinematics and Dynamics
Prerequisite: None. (3 credits)
Geometry, kinematics, differential kinematics, dynamics, and control of robot manipulators. The mathematical tools required to describe spatial motion of a rigid body will be presented in full. Motion planning including obstacle avoidance is also covered. CourseProfile (ATLAS)

MECHENG 568. Vehicle Control Systems
Prerequisite: MECHENG 461 or equivalent. (3 credits)
Design and analysis of vehicle control systems such as cruise control, traction control, active suspensions and advanced vehicle control systems for Intelligent Vehicle-Highway Systems (IVHS).
Human factor considerations such as driver interfaces. This course may be used as part of the IVHS certification program. CourseProfile (ATLAS)

MECHENG 569. Control of Advanced Powertrain Systems
Prerequisite: MECHENG 360; preceded or accompanied by MECHENG 461. (3 credits)
Will cover essential aspects of electronic engine control for spark ignition (gasoline) and compression ignition (diesel) engines followed by recent control developments for direct injection, camless actuation, active boosting technologies, hybrid-electric and fuel cell power generation. Will review system identification, averaging, feedforward, feedback, multivariable (multiple SISO and MIMO), estimation, dynamic programming and optimal control techniques. CourseProfile (ATLAS)

MECHENG 570. Fundamentals of Defects in Materials and Applications of Atomistic Modeling
Advisory Prerequisite: MECHENG 235 and MECHENG 382. (3 credits)
Introduction of the correlation between various types of microstructural defects and materials’ macroscopic phenomena, such as diffusion, deformation, radiation response, phase transformation, etc. Fundamentals of atomistic modeling and demo applications are also introduced to help students build better intuition about defects’ structures and behaviors. CourseProfile (ATLAS)

MECHENG 571 (ESENG 505). Energy Generation and Storage Using Modern Materials
Prerequisite: MECHENG 382 and MECHENG 335 or equivalent. (3 credits)
Energy and power densities previously unattainable in environmentally-friendly energy technologies have been achieved through use of novel materials. Insertion of new materials into power supplies has changed the landscape of options. Design strategies for power systems are described, in the context of growing global demand for power and energy. CourseProfile (ATLAS)

MECHENG 572 (MFG 580). Rheology and Fracture
Prerequisite: MECHENG 382. (3 credits)
Mechanisms of deformation, cohesion, and fracture of matter. Unified approach to the atomic-scale origins of plastic, viscous, viscoelastic, elastic, and anelastic behavior. The influences of time and temperature on behavior. Stress field of edge and screw dislocations, dislocation interactions, and cross slip. CourseProfile (ATLAS)

MECHENG 574. Nano/Micro Structure Evolution
Prerequisite: graduate standing and seniors by PI. (3 credits)
This course will focus on scientific understanding and computational techniques. Students will have the opportunity to develop a program to implement the methods to simulate nanostructure evolution. Topics covered include: configurational forces, formulation of migration, simulation of structural evolution, surface roughening, motion of thin film, composition modulation, electromigration and assembly. CourseProfile (ATLAS)

MECHENG 576 (MFG 556). Fatigue in Mechanical Design
Prerequisite: 382 or equivalent. (3 credits)
A broad treatment of stress, strain and strength with reference to engineering design and analysis. Major emphasis is placed on the analytical and experimental determination of stresses in relationship to the fatigue strength properties of machine and structural components. Also considered are deflection, post-yield behavior, residual stresses, temperature and corrosion effects. CourseProfile (ATLAS)

MECHENG 577 (MFG 557). Use of Materials and their Selection in Design
Prerequisite: MECHENG 382 and senior, or graduate standing. (3 credits)
Material properties, including physical, mechanical, thermal, electrical, economic, corrosion and environmental properties. Interaction of function, shape, choice of materials, processing, economics and environmental impact in design. Methodology for materials selection and optimization, including performance indices, multiple constraints and multiple objectives. Introduction to analysis of environmental impact of materials selection. CourseProfile (ATLAS)
MECHENG 580. Transport Phenomena in Materials Processing
Prerequisite: senior or graduate standing. (3 credits)
Proficiency in the fundamental understanding of materials processing techniques. Lectures will cover: techniques for model development and simplification with an emphasis on estimation and scaling; ‘classical’ analytic solutions to simple problems, physical phenomena in materials processing including non-Newtonian fluid flow, solidification, and microstructure development. Techniques for measurement of monitoring of important process variables for model verification and process control. Case studies (heat treatment; welding; polymer extrusion and molding; various metal casting processes; crystal growth).  
CourseProfile (ATLAS)

MECHENG 582 (MFG 582) (MATSCIE 523). Metal-Forming Plasticity
Prerequisite: MECHENG 211. (3 credits)
Elastic and plastic stress-strain relations; yield criteria and flow rules; analyses of various plastic forming operations. Effects of hardening and friction, temperature, strain rate and anisotropy. 
CourseProfile (ATLAS)

MECHENG 584 (MFG 584). Advanced Mechatronics for Manufacturing
Prerequisite: ME 461 or equivalent. (3 credits)
Theoretical principles and practical techniques for controlling mechatronic systems are taught in the context of advanced manufacturing applications. Specifically, the electro-mechanical design/modeling, basic/advanced control, and real-time motion generation techniques for computer-controlled manufacturing machines are studied. Hands-on labs and industrial case studies are used to re-enforce the course material.  
CourseProfile (ATLAS)

MECHENG 585 (MFG 585). Machining and Machine Tools
Advisory Prerequisite: MECHENG 382 or equivalent. (3 credits)
Provides the knowledge of traditional and non-traditional machining processes as well as modeling and experimental analysis methods for machining. Topics include: the single point, multiple point and abrasive machining processes; machine tools; cutting tools, mechanics, temperatures, and dynamics; electrical discharge, chemical, energy-based, and biomedical machining. 
CourseProfile (ATLAS)

MECHENG 586 (MFG 591). Laser Materials Processing
Prerequisite: senior or graduate standing. (3 credits)
CourseProfile (ATLAS)

MECHENG 587 (MFG 587). Global Manufacturing
Prerequisite: one 400-level MFG or DES or BUS class. (3 credits)
CourseProfile (ATLAS)

MECHENG 588 (IOE 588) (MFG 588). Assembly Modeling for Design and Manufacturing
Prerequisites: MECHENG 481 and MECHENG 401 or equivalent. (3 credits)
CourseProfile (ATLAS)
Prerequisite: senior or graduate standing. (3 credits)
Scientific perspectives on grand challenges to environment and society created by the production of energy, water, materials and emissions to support modern life styles. Integration of economic indicators with life cycle environmental and social metrics for evaluating technology systems. Case studies: sustainable design of consumer products, manufacturing and infrastructure systems. CourseProfile (ATLAS)

MECHENG 590. Study or Research in Selected Mechanical Engineering Topics
Prerequisite: graduate standing; permission of the instructor who will guide the work; mandatory satisfactory/unsatisfactory. (3/6 credits)
Individual or group study, design or laboratory research in a field of interest to the student. Topics may be chosen from any of the areas of mechanical engineering. The student will submit a report on the project at the close of the term. CourseProfile (ATLAS)

MECHENG 599. Special Topics in Mechanical Engineering
Prerequisite: permission of instructor (to be arranged)
Selected topics pertinent to mechanical engineering. CourseProfile (ATLAS)

600 Level Courses

MECHENG 605. Advanced Finite Element Methods in Mechanics
Prerequisite: MECHENG 505 or CEE 510, (NAVARCH 512). (3 credits)
Recent developments in finite element methods; mixed, hybrid, mixed-hybrid, reduced integration penalty, singular, boundary integral elements. Emphasis on the methodology for developing elements by using calculus of variations. Applications selected from various branches of solid and fluid mechanics. CourseProfile (ATLAS)

MECHENG 617. Mechanics of Polymers II
Prerequisite: MECHENG 511, MECHENG 517, (MacroSE 517), or permission of instructor. (3 credits)
Selected advanced topics in the mechanics of polymeric solids and fluids, including nonlinear elasticity, nonlinear viscoelastic solids, viscoplasticity in amorphous and crystalline polymer solids, constitutive models and associated flow properties for polymer fluids, temperature dependence and solidification, applications. CourseProfile (ATLAS)

MECHENG 623. Hydrodynamic Stability
Prerequisite: MECHENG 520. (3 credits)
An introduction to the theory of hydrodynamic stability with applications to stability of thermal flows, rotating and curved flows, wallbounded and free shear flows. Development of the asymptotic theory of the Orr-Sommerfeld equation. Review of the fundamental concepts and current work in nonlinear theory of hydrodynamic stability. CourseProfile (ATLAS)

MECHENG 624. Turbulent Flow
Prerequisite: MECHENG 520. (3 credits)
Fundamentals of turbulent flows; the basic equations and the characteristic scales, statistical description of turbulence. Review of experimental results on the statistics and structure of turbulent flows. Methods for calculation of turbulent flows; the problem of closure, semi-empirical, phenomenological and analytical theories of turbulence, large-eddy and direct simulations of turbulence. CourseProfile (ATLAS)

MECHENG 625. Nonhomogeneous Fluids
Prerequisite: MECHENG 520. (3 credits)
Motion of fluids of variable density and entropy in gravitational field, including the phenomenon of
blocking and selective withdrawal; waves of small finite amplitudes, including waves in the lee of mountains; stability of stratified flows; flow of Nonhomogeneous fluids in porous media. Analogy with rotating fluids.  

**MECHENG 626. Perturbation Methods for Fluids**  
*Prerequisite: MECHENG 520. (3 credits)*  
Application of asymptotic methods to fluid mechanics, with special emphasis on the method of matched expansions. Regular perturbation solutions; suppression of secular terms; method of multiple scales; boundary layer and low Reynolds number flows by inner and outer expansions; phenomena in rotating flows. Applications to computational fluid mechanics.  

**MECHENG 627 (NAVARCH 627). Wave Motion in Fluids**  
*Prerequisite: MECHENG 520 or NAVARCH 520 or equivalent. (3 credits)*  
Surface waves in liquids; group velocity and dispersion; water waves created by and wave resistance to a moving body; Korteweg de Vries equation; conoidal and solitary waves in water; wave reflection and diffraction; shallow-water waves by the method of characteristics; statistical approach and spectral analysis; wave generation.  

**MECHENG 631. Statistical Thermodynamics**  
*Prerequisite: MECHENG 230 or MECHENG 336. (3 credits)*  
Introduction to statistical methods for evaluating thermodynamic and transport properties. Elements of quantum mechanics, statistical mechanics and kinetic theory, as applied to engineering thermodynamics.  

**MECHENG 641. Advanced Vibrations of Structures**  
*Prerequisite: MECHENG 541. (3 credits)*  

**MECHENG 645. Wave Propagation in Elastic Solids**  
*Prerequisite: MECHENG 541. (3 credits)*  

**MECHENG 646 (BIOMEDE 646, ROB 646). Locomotor Mechanics and Design/Control of Wearable Robotic Systems**  
*advised Prerequisite: MECHENG 540, (AEROSP 540) or MECHENG 543, or equivalent. (3 credits)*  
The primary objective of this course is to learn how to analyze, understand, and model human locomotion, as well as develop bio-inspired assistive technologies and assess their impact. We will learn about the human machine-the sensing, acting, and reasoning components of the human neuromusculoskeletal systems, as well as how to replicate this functionality with traditional approaches from robotics, including modeling, machine design, mechatronics, and control.  

**MECHENG 648. Nonlinear Oscillations and Stability of Mechanical Systems**  
*Prerequisite: MECHENG 541. (3 credits)*  
Large amplitude mechanical vibrations; phase-plane analysis and stability; global stability, theorems of Liapunov and Chetayev; asymptotic and perturbation methods of Lindstedt-Poincare, multiple scales, Krylov-Bogoliubov-Mitropolsky; external excitation, primary and secondary resonances; parametric excitation, Mathieu/Hill equations, Floquet theory; multi-degree of freedom systems and modal interaction.
MECHENG 649 (AEROSP 615) (CEE 617). Random Vibrations
Prerequisite: Math 425 or equivalent, CEE 513 or MECHENG 541, or AEROSP 543 or equivalent. (3 credits)
Introduction to concepts of random vibration with applications in civil, mechanical and aerospace engineering. Topics include: characterization of random processes and random fields, calculus of random processes, applications of random vibrations to linear dynamical systems, brief discussion on applications to nonlinear dynamical systems. CourseProfile (ATLAS)

MECHENG 662 (AEROSP 672) (EECS 662). Advanced Nonlinear Control
Prerequisite: EECS 562 or MECHENG 548. (3 credits)
Geometric and algebraic approaches to the analysis and design of nonlinear control systems. Nonlinear controllability and observability, feedback stabilization and linearization, asymptotic observers, tracking problems, trajectory generation, zero dynamics and inverse systems, singular perturbations and vibrational control. CourseProfile (ATLAS)

MECHENG 695. Master's Thesis Research
Prerequisite: MECHENG 595; mandatory satisfactory/unsatisfactory. (3 credits)
Student must complete a dissertation and defend his/her thesis in front of a committee of at least 2 faculty members. CourseProfile (ATLAS)

MECHENG 699. Advanced Special Topics in Mechanical Engineering
Prerequisite: permission of instructor. (to be arranged)
Advanced selected topics pertinent to mechanical engineering. CourseProfile (ATLAS)

900 Level Courses

MECHENG 990. Dissertation/Pre-Candidate
(1-8 credits); (1-4 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

MECHENG 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. (8 credits); (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)
Climate and Space Sciences and Engineering Minor

The primary goal of the Climate and Space Sciences and Engineering (Climate & Space) Minor is to provide exposure to research opportunities in atmospheric, climate and space science and engineering for those students who wish to work in the geoscience or space industry but are not majoring in Climate and Space Sciences and Engineering. The secondary goal is to increase awareness of the Climate and Space Sciences and Engineering and the educational and research opportunities within Climate & Space within the College of Engineering as a whole. This program is for undergraduate students in the College of Engineering and the College of Literature, Science, and the Arts.

Students must have:

- Registered no later than the last day to add courses for the semester in which they complete the last courses for the minor
- Submitted his or her program of study for the minor to the Climate & Space undergraduate advisor
- Attained a minimum GPA of 2.0 in the designated courses
- Completed the Climate & Space Minor as part of a degree program

Requirements:

1. Prerequisite coursework:
   - Math (8 Credits)
     - MATH 115, and
     - MATH 116
   - Physics: (10 Credits)
     - PHYSICS 140, 141, and
     - PHYSICS 240, 241

2. Required Coursework (6 credits)
   - One course from SPACE 101 (Introduction to Rocket Science – 3 credits), CLIMATE 102 (Extreme Weather – 3 credits), SPACE 103 (Introduction to Space Weather – 3 credits) or CLIMATE 105 (Our Changing Climate – 3 credits)
   - CLIMATE 320/SPACE 320 (Earth and Space System Evolution, 3 credits)
   - Students declaring prior to FA18, CLIMATE 321/SPACE 321 (Earth and Space System Dynamics, 3 credits) is required.
   - Students declaring FA18 or later are not required to take CLIMATE 321/SPACE 321.

1. Core Focus Courses (minimum 9 credits)
   - At least three courses from one of the following tracks:
     - Meteorology
     - Climate Science and Impacts Engineering
     - Space Sciences
     - Space Engineering

For additional information go to: http://clasp.engin.umich.edu/academics/undergraduate/minor-climate-space-sciences-engineering
International Minor for Engineers

The engineering field of today and the foreseeable future requires engineers that combine technical acumen with intercultural understanding. Engineers now work in multinational teams, create products for a global marketplace and solve problems that cross national borders and cultures. The International Minor for Engineers enables CoE students to develop their core set of skills and experiences necessary to meet challenges of the global engineering profession and to have this focus recognized on their CoE transcript.

- **Foreign Language Requirement**
  - Language proficiency (cannot be English or dead/extinct language) equivalent to fourth-semester college-level.
  - May be satisfied by U-M courses, transfer credit, or intensive language programs abroad.

- **International Courses (7-13 credits of graded coursework)**
  - This requirement includes non-U.S. cultures or societies, including one comparative perspectives course. At least three credit hours of coursework must be listed at the 300-level or above.
  - Courses to meet the international coursework requirement may be taken abroad; pre-approval of these courses is required.

- **ENGR 260: Engineering Across Cultures (1 credit)**
  - This course explores the role of local culture in identifying and solving engineering problems and assists students in identifying and planning for their international/intercultural experience. Lectures, guest speakers and group discussions will focus on intercultural knowledge and case studies of engineering projects in a global context.

- **ENGR 460: Engineering Across Cultures II (1 credit)**
  - This course is designed to help students un-pack their international/intercultural experience leveraging discussions, assessment of skills and learning, and tools such as the Intercultural Development Inventory (IDI) to synthesize past experiences and intercultural skills toward the global engineering profession.

- **Required International or Intercultural Experience**
  - Students may satisfy this requirement through study, work, research, or organized volunteering, spanning a minimum of six weeks interacting with a culture other than the one they grew up in. Students will explore and make a plan for their experience as part of ENGR 260. International students may not satisfy this requirement through programs in their home countries.

In total, the minor requires a minimum of 15 graded credit hours to complete beyond the two-semester (or equivalent) foreign language prerequisite needed to declare the minor. More information can be found at [https://ipe.engin.umich.edu/international-minor/](https://ipe.engin.umich.edu/international-minor/).

**Minor in Electrical Engineering (EE)**

A Minor in Electrical Engineering (EE), offered through the EECS Department, is open to College of Engineering, College of Literature, Science, and the Arts, and School of Music, Theatre & Dance students. LSA requirements are described in the LSA Bulletin and interested students should consult with both LSA and CoE Electrical Engineering Advisors. CoE students may declare the EE minor provided they have met the following eligibility requirements:
1. Students must have an average of 2.0 or higher at time of declaring the EE minor
2. Students must have completed all Math and Physics prerequisites with a grade of C or better
3. Students pursuing a major in Electrical Engineering (EE) and Computer Engineering (CE) are not eligible for the EE minor

The EE minor is completed in 15 credit hours; at least one elective must be at the 400-level. All courses for the EE minor must be completed with a grade of C or better.

- EECS 215
- One of the following program core courses: 216, 230, 270, 320
- Two electives from among the following courses: 216, 230, 270, 320, 311, 312, 330, 334, 351, 370, 373, 411, 413, 414, 418, 419, 420, 421, 423, 425, 427, 429, 430, 434, 452, 455, 460, 461, 463, 470, 530

Suggested Program Options

1. Systems: Communications, Control, Signal Processing
2. Electromagnetics and Optics
3. Circuits and Solid State

Sample Paths

<table>
<thead>
<tr>
<th>Paths Option</th>
<th>Required Core</th>
<th>Path Preparation Core</th>
<th>Elective 1</th>
<th>Elective 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems</td>
<td>215</td>
<td>216</td>
<td>351, 455, 460</td>
<td>351, 452, 455, 460, 461 (no duplicates)</td>
</tr>
<tr>
<td>Electromagnetics and Optics</td>
<td>215</td>
<td>230</td>
<td>330, 334</td>
<td>411, 430, 434, 438, 530</td>
</tr>
</tbody>
</table>

Minor in Environmental Engineering

Administered through the Department of Civil and Environmental Engineering, the minor in Environmental Engineering provides students with a basic background in the tools environmental engineers use to assess environmental impacts, model contaminant fate, and perform sustainable engineering decisionmaking. CoE students may declare the minor provided they meet the following eligibility requirements:

- Students must have a grade point average of 2.0 or higher at the time of declaration
Students must have completed the prerequisite coursework for the “core” minor courses with a C or better
Students pursuing a major in Civil or Environmental Engineering are not eligible for the minor

A minimum of 16 credit hours, three core courses and two electives, is required to complete the Environmental Engineering minor. All courses for the minor must be completed with a grade of C or better as follows: Required core courses (10-11 credits):

- CEE 265 Sustainable Engineering Principles or ME 499: Sustainable Engineering and Design
- CEE 325 Fluid Mechanics (or equivalent from: MECHENG 320, CHE 341, NERS 344, NAVARCH 320, BIOMEDE 331, MATSCIE 335)
- CEE 365 Environmental Engineering Principles

Two electives (6 credits) from the following courses:

- CEE 482 Groundwater Hydrology
- CEE 480 Design of Environmental Engineering Systems
- CEE 465 Environmental Process Engineering
- CEE 481 Aquatic Chemistry
- CEE 482 Environmental Microbiology
- CEE 563 Air Quality Engineering Fundamentals

For additional information, please visit the Civil and Environmental Department website at [http://cee.umich.edu/minor-environmental-engineering](http://cee.umich.edu/minor-environmental-engineering).

To declare, please visit the advising calendar ([https://webapps.lsa.umich.edu//advappts/AA_StuSelfSvc1.aspx?ctgy=CEE](https://webapps.lsa.umich.edu//advappts/AA_StuSelfSvc1.aspx?ctgy=CEE))

**Minor in Materials Science and Engineering**

The understanding and selection of materials is a common requirement in many science and engineering disciplines. To help serve this need, the Department of Materials Science and Engineering is offering to science and engineering undergraduate students whose major is outside of Materials Science and Engineering a minor in Materials Science and Engineering.

To complete the minor, the student is required to take a minimum of five courses, entailing a minimum of 17 credits. The five courses required should be distributed as follows:

- MATSCIE 220 “Introduction to Materials and Manufacturing” or MATSCIE 250 “Principles of Engineering Materials” (4 credits)
- MATSCIE 350 “Structures of Materials” (4 credits)
- Two MSE courses from the following “Selectives” list (3 credits each, and the prerequisites for each include MATSCIE 220/250 and in many cases, MATSCIE 350):
  1. MATSCIE 400. “Electronic, Magnetic and Optical Materials for Modern Device Technology” (Prerequisite: MATSCIE 242)
  2. MATSCIE 410 “Design and Applications of Biomaterials”
  3. MATSCIE 412 “Polymeric Materials” (Prerequisite: CHEM 210)
  4. MATSCIE 440 “Ceramic Materials”
  5. MATSCIE 454 “Computational Approaches in MSE” (Prerequisite: MATSCIE 330, 335, and 365)
6. MATSCIE 465 “Structural and Chemical Characterization of Materials”
   (Prerequisites: MATSCIE 242 and MATSCIE 360)
7. MATSCIE 470 “Physical Metallurgy”
8. MATSCIE 514 “Composite Materials”
   • One more MATSCIE course, other than lab research or special studies (3 or 4 credits)

**Minor in Civil Engineering**

Any student pursuing an undergraduate degree at the University of Michigan, excluding the BSE degree in Civil Engineering, may pursue a minor in Civil Engineering. To be eligible, a student must be in good academic standing (with a GPA of 2.0 or higher), and must have completed all course prerequisites with a grade of C or better. All courses counted toward the minor must be completed with a grade of C- or better, and the overall GPA for the courses pursued for the minor must be a 2.0 or higher. Students pursuing a Minor in Civil Engineering must choose from one of three tracks, shown below.

- **Track 1: Structural, Geotechnical, and Materials Engineering**
  - **Prerequisites:** MATH 115, MATH 116, CEE 211, and CEE 212, or equivalents
  - **Required Core Courses:** CEE 312, CEE 345 and CEE 351
  - **Elective Courses (must take at least one):** CEE 413, CEE 415, CEE 545, CEE 546, CEE 547
- **Track 2: Construction Engineering and Management**
  - **Prerequisites:** MATH 115, MATH 116, CEE 211 and CEE 212, or equivalents
  - **Required Core Courses:** CEE 331, CEE 351 and either CEE 312 or CEE 345
  - **Elective Courses (must take at least one):** CEE 435, CEE 534
- **Track 3: Mobility Systems Engineering**
  - **Prerequisites:** MATH 215, MATH 216, and PHYSICS 240, or equivalents
  - **Required Courses:** CEE 373 (can substitute MATH 425 or STATS 425), CEE 375, CEE 450, CEE 551 and CEE 552

**Multidisciplinary Design Minor**

The Multidisciplinary Design Minor offers multi-term, on-campus, immersive design team experiences for academic credit. This minor is not built on a list of required courses; but is earned through a set of four experiences that can be tailored to a student’s interests. Note: this minor is also open to students from outside the College of Engineering.

The minor in Multidisciplinary Design is comprised of 15 total credits across four experiences:

1. Introductory “Design, Build, Test” Experience
2. Multi-Term Design Project Work
3. Connections Course
4. ENGR 456: Leadership/Mentorship Course

**Introductory “Design, Build, Test” Experience (at least 2 credits)**

Must include a team-based, complete Design/Build/Test process. For Engineering students this is most often fulfilled through ENGR 100. For non-Engineering students, other design-based courses or an introductory/extra semester on the design project team may also be allowed to fulfill this requirement.
Multi-Term Design Project Work (at least 7 upper-level design credits over at least 2 semesters)

The Multidisciplinary Design Program offers various team-based, multidisciplinary engineering design project options, including:

1. MDP-organized* partner-sponsored industry/government/non-profit projects
2. MDP-organized* faculty-based research teams
3. Significant work on student organization project teams (Solar Car, Steel Bridge, BlueLab, etc) with permission from the team’s faculty advisor and MDP
4. Students may also propose their own, unique multi-term design project. To propose a project, please contact the MDP Office.

The Multi-term Design Project can be curricularized utilizing the ENGR x55 course sequence, departmental design courses and/or independent study courses (all credits must be earned at the 300-level or higher). The project must span a minimum of two consecutive semesters of in-depth work: the credits cannot all be earned in the same semester.

*Recruitment for MDP-organized projects occurs annually in October

Connections Course (3+ credits)

A Connections Course is required to support the Multi-Term Design Project: providing additional breadth or depth in specific skills relevant to the project, but outside of the student’s major coursework. This requirement can be met with any course outside of a student’s required classes for their major. This course is taken prior to or during the final semester of project work.

ENGR 456: Leadership/Mentorship Course (2 credits)

Students study models of leadership and mentorship while participating in reflective and integrative learning exercises based on previous design team experience. Simultaneously, students take on mentorship/leadership roles within a design team to offer technical, professional, and interpersonal guidance. Students must have significant previous multidisciplinary design project experience to enroll.

Completing the minimum credit hours for the above list adds up to 14 credit hours; therefore the student needs at least one extra credit hour in any one of the first three components to meet the minimum of 15 required credits. The following rules apply to the Multidisciplinary Design Minor:

1. Transfer credit may not be used to fulfill requirements of this minor.
2. Only the 2-credit mentorship and leadership requirement (ENGR 456) can be taken Pass/Fail.
3. The Academic Advisor of the Multidisciplinary Design Minor Program is responsible for approving any variance in course requirements for the minor.

For more information, please visit mdp.engin.umich.edu.

Supplemental Studies Policy

An engineering supplemental studies program is a coherent program of study, but with requirements far less comprehensive than those of a BS/BSE degree or minor. Supplemental studies can be sponsored by CoE departments, programs, or, for the purpose of supporting cross-departmental programs, sponsored by the Office of the Associate Dean for Undergraduate Education.
Undergraduate supplemental studies can provide opportunities for Engineering students to develop additional experience and skills to complement their major(s) or minor(s).

Engineering undergraduate students may complete one or more supplemental studies programs approved by the College. Electing to earn supplemental studies is optional, and there is no limit to the number of supplemental studies a student may elect.

Supplemental studies must require no fewer than nine credits of course work, show structure and coherence, and contain some upper-level courses. Students who declare and complete approved supplemental studies will receive a notation on their student transcript but not on their diploma.

Policies for Supplemental Studies:

1. An Engineering student may complete one or more supplemental studies program.
2. Each student who wishes to complete a supplemental studies program must develop a plan in consultation with a program advisor.
3. After developing a plan with the student, the program or department advisor has the supplemental studies program entered on the student’s record.
4. Students may not elect courses included in a supplemental studies program using the pass/fail grading option.
5. A department or program may include experiential or directed reading/independent study courses that are graded on a credit/no credit basis in a supplemental studies program, but all other courses in the supplemental studies program must be taken for a grade.
6. No course may be shared between the requirements of two supplemental studies programs, or between a minor and a supplemental studies program.
7. One course may be shared between the departmental course requirement and the supplemental studies program.
8. Advanced Placement (AP) credits may not be used to meet the requirements of a supplemental studies program.
9. A student must earn a overall GPA of at least 2.0 in the required courses in the supplemental studies program.
10. Courses elected to meet the requirements of a supplemental studies program may count toward Intellectual Breadth and General Electives.
11. Students may not complete a supplemental studies program after graduation, and a supplemental studies program may not be converted to an academic minor after graduation.

Program in Sustainable Engineering (PISE)

Administered through the Department of Civil and Environmental Engineering, the Program in Sustainable Engineering (PISE) provides students an opportunity to develop their understanding of the challenges associated with sustainable design of technology systems, exploring economic, environmental and social challenges of sustainable development across disciplines. Upon completing the program, students should be able to:

- Quantify the environmental and economic impacts of design decisions
- Understand the difference between life cycle design and environmentally sustainable design
- List key sustainability considerations in the design of an engineering system
- Identify tradeoffs among social, economic and environmental drivers in engineering decision making
- Identify more sustainable choices among engineering options

The program consists of the following requirements:
- 3-credit foundation course Sustainable Engineering Principles (CEE 265) or Sustainable Engineering and Design (ME 499)
- 3 credits of coursework from a selection of courses identified within the College of Engineering that feature significant content in sustainable engineering.
- 3 credits of coursework from a selection of courses identified outside the College of Engineering that feature significant content in sustainability, specifically considering non-engineering issues at the intersection of technology and society.

If planned well in advance of the senior year, the program should not add to the 128 credits required for a B.S.E. For complete information, visit the Program in Sustainable Engineering website at: http://pise.engin.umich.edu.

**Program in Socially Engaged Design (PSED)**

The Program in Socially Engaged Design is an academic program that allows undergraduate Engineering students to focus on techniques of socially engaged design.

There are four requirements to ensure program completion and earn the following notation on their transcript: “Program in Socially Engaged Design”:

1. **Foundations Course (3 credits)**
   - Complete one of the following foundation design courses:
     - ME499/599 – Front End Design with Prof. Shanna Daly
     - ENGRX55 – Finding Genuine Design Opportunities

2. **Supporting Design Course (3 credits)**
   - Students must complete one course from the list of approved courses to deepen their education in socially engaged design practices.

3. **Breadth Course (3 credits)**
   - Students must complete one course from the list of approved courses to broaden their education outside of the College of Engineering. Students are encouraged to choose a course in the thematic area of a design project they are engaging in at the curricular or co-curricular level.

4. **SEDA Learning Blocks (For completion – not credit bearing)**
   - Students must complete two Socially Engaged Design Academy (SEDA) learning blocks from the list of approved learning blocks. SEDA blocks will serve to round out a student’s knowledge and skills by providing instruction and assessment on topics that are currently not covered or are covered in a limited manner at a curricular level within the CoE.

The program can be completed without exceeding the 128 credits required for a B.S./B.S.E. and provides students the opportunity to organize their elective courses around the theme of socially engaged design. Students from all disciplines are invited to complete the program.

For more information, visit http://csed.engin.umich.edu/program-in-socially-engaged-design
Program in Global Health Design (PGHD)

The Specialized Study Program in Global Health Design (PGHD) allows undergraduate students to focus their elective courses and upper-level design coursework on the topic of global health.

To complete the program and earn the “Specialized Study in Global Health Design” notation on their transcript, students must complete the following three requirements:

1. Project-based Design Foundations Course with Global Health Themed Project (3 credits)
   - Students must complete a design course at the 300 or higher level in which they work on a project that falls within the theme of global health. The course should expose students to problem definition, concept generation, analysis, prototyping, and/or evaluation.

2. Global Health Foundations Course (3 credits)
   - Students must complete one course from the list of approved global health courses. The global health foundations course is meant to broaden the student’s knowledge of global health outside of a design context. This requirement must be fulfilled by completing a course outside of the College of Engineering.

3. Depth Course (3 credits)
   - The depth course is meant to deepen the student’s understanding of the thematic area of their Design Foundations Course project and/or to strengthen their global health design skillset. This requirement can be fulfilled with courses both within and outside of the College of Engineering.

The specialized study program can be completed without exceeding the 128 credits required for a BS/BSE/BA. Students from all disciplines are invited to complete the program.

For more information, visit [https://globalhealthdesign.engin.umich.edu/opportunities/program-in-global-health-design-pghd](https://globalhealthdesign.engin.umich.edu/opportunities/program-in-global-health-design-pghd)

Fundamentals of Public Health Supplemental Studies

The Fundamentals of Public Health Supplemental Studies (FPHSS) program is a 10-credit course sequence that provides students a formal academic structure to gain an understanding of public health, including the mission and evolution of the field as well as an appreciation of its key methods and applications. FPHSS courses will focus on the basic knowledge and skills used to address complex public health issues related to the prevention and management of chronic and infectious diseases; and will introduce students to concepts specific to the social and environmental determinants of health, promotion of healthy behaviors, and public policies influencing population health status.

**Student must have:**

- Obtained sophomore status (+25 credits)
- Attained a minimum GPA of 3.0
- Completed PUBHLTH 200 with 3.0 (B) or better
Requirements:

- PUBHLTH 200: Health and Society: Introduction to Public Health (4 credits)
- Public Health Sciences elective (minimum of 3 credits)
- Community and Global Public Health elective (minimum of 3 credits)

Students will be able to petition to the Director of Undergraduate Education for consideration in counting courses not on the approved lists for inclusion in B and C above if they believe that these courses offer an opportunity to pair their disciplinary mindset with the learning outcomes of the program. At least one of the courses must be 300-level or above for consideration. ***Starting in Fall 2018: Students who declare their intent to participate in FPHSS must complete 7 of the 10 credits by taking School of Public Health classes (PUBHLTH, NUTR, or EPID). Three (3) credits can be taken outside the School of Public Health, as listed in the Approved Course List.

APPROVED COURSE LIST

Public Health Sciences

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Credits</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANTHRIBIO 363</td>
<td>Genes, Disease, Culture</td>
<td>4</td>
<td>Fall</td>
</tr>
<tr>
<td>BIOSTAT 449</td>
<td>Topics in Biostatistics</td>
<td>3</td>
<td>Winter</td>
</tr>
<tr>
<td>ENVIRON 310</td>
<td>Environmental Chemicals and Disease</td>
<td>3</td>
<td>Winter</td>
</tr>
<tr>
<td>HISTORY 285/RCSCI 275</td>
<td>Science, Technology, Medicine and Society</td>
<td>4</td>
<td>Winter</td>
</tr>
<tr>
<td>MOVESCI 471</td>
<td>Physical Activity Epidemiology</td>
<td>3</td>
<td>Fall &amp; Winter</td>
</tr>
<tr>
<td>PUBHLTH 305</td>
<td>The Environment and Human Health</td>
<td>3</td>
<td>Winter</td>
</tr>
<tr>
<td>PUBHLTH 310</td>
<td>Nutrition in the Life Cycle</td>
<td>3</td>
<td>Winter</td>
</tr>
<tr>
<td>PUBHLTH 311</td>
<td>Introduction to Public Health Genetics</td>
<td>3</td>
<td>Fall</td>
</tr>
<tr>
<td>PUBHLTH 370</td>
<td>Public Health Biology and Pathophysiology</td>
<td>3</td>
<td>Fall</td>
</tr>
<tr>
<td>PUBHLTH 383</td>
<td>Data Driven Solutions in Public Health</td>
<td>4</td>
<td>Winter</td>
</tr>
<tr>
<td>PUBHLTH 401</td>
<td>Exploring the Public Health Spectrum of Cancer: From Prevention to Survivorship</td>
<td>3</td>
<td>Fall</td>
</tr>
<tr>
<td>PUBHLTH 403</td>
<td>Obesity: From Cells to Society</td>
<td>3</td>
<td>Fall</td>
</tr>
<tr>
<td>Number</td>
<td>Name</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PUBHLTH 413</td>
<td>Vaccines in Public Health</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PUBHLTH 460</td>
<td>Introduction to Bacterial Pathogenesis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Winter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Community and Global Public Health

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANTHRCUL 344</td>
<td>Medical Anthropology</td>
</tr>
<tr>
<td>ANTHRCUL 356/DAAS 358</td>
<td>Topics in Sociocultural Anthropology – section specific</td>
</tr>
<tr>
<td>ANTHRCUL 458</td>
<td>Topics in Sociocultural and Linguistic Anthropology – section specific</td>
</tr>
<tr>
<td>PSYCH 211.004</td>
<td>Project Outreach – section specific, only Health, Illness and Society</td>
</tr>
<tr>
<td>PUBHLTH 300</td>
<td>Behavioral and Social Science Foundations for the Health Profession</td>
</tr>
<tr>
<td>PUBHLTH 308</td>
<td>Black American Health: A Focus on Children, Youth, and Families</td>
</tr>
<tr>
<td>PUBHLTH 350</td>
<td>Global Public Health: Challenges and Transformations</td>
</tr>
<tr>
<td>PUBHLTH 360</td>
<td>Community, Culture, and Social Justice in Public Health</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>PUBHLTH 382</td>
<td>Population Health Determinants and Disparities</td>
</tr>
<tr>
<td>PUBHLTH 400</td>
<td>Race and Racism in Public Health</td>
</tr>
<tr>
<td>PUBHLTH 402</td>
<td>Changing Health Behaviors: What Works</td>
</tr>
<tr>
<td>PUBHLTH 405</td>
<td>Social History of Infectious Disease</td>
</tr>
<tr>
<td>PUBHLTH 410</td>
<td>Making Change: public health policy advocacy in principle and practice</td>
</tr>
<tr>
<td>PUBHLTH 414</td>
<td>Mental Health</td>
</tr>
<tr>
<td>PUBPOL 475.005</td>
<td>Improving Public Health</td>
</tr>
<tr>
<td>SOC 475</td>
<td>Introduction to Medical Sociology</td>
</tr>
<tr>
<td>WGS 319</td>
<td>Race, Class and Reproductive Health</td>
</tr>
<tr>
<td>WGS 365</td>
<td>Global Perspectives on Gender, Health, and Reproduction</td>
</tr>
<tr>
<td>WGS 400</td>
<td>Women’s Reproductive Health</td>
</tr>
</tbody>
</table>

For more information please visit the School of Public Health website on the Fundamentals of Public Health Supplemental Studies program: https://sph.umich.edu/undergrad/fph.html
Naval Architecture & Marine Engineering
Naval Architecture and Marine Engineering Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: [https://bulletin.engin.umich.edu/courses/course-info/](https://bulletin.engin.umich.edu/courses/course-info/)

100 Level Courses

**NAVARCH 102 (NS 201). Introduction to Ship Systems**  
*Prerequisite: none. (3 credits) (Not open for credit to students in NAME.)*  
Types, structures and purposes of ships. Ship compartmentation, propulsion systems, auxiliary power systems, interior communications and ship control. Elements of ship design to achieve safe operations and ship stability characteristics. [CourseProfile (ATLAS)]

200 Level Courses

**NAVARCH 203. The Physics of Sailing**  
*Advisory prerequisite: MATH 115, PHYSICS 140. (2 credits)*  
Balance of forces and moments, generation of hydrostatic, hydrodynamic, and aerodynamic forces, adjusting the sails and rubber to efficiently travel through water. Course includes laboratory exercises in the Marine Hydrodynamics Laboratory (MHL). Course culminates with the student sailing a radio-controlled model sailboat around a course. [CourseProfile (ATLAS)]

**NAVARCH 210. Introduction to Solid Mechanics and Marine Structures**  
*Advisory prerequisite: PHYSICS 140/141; preceded or accompanied by MATH 216. (3 credits)*  
Fundamentals of mechanics of solids: stress, strain and equilibrium concepts used in the analysis of deformable materials and structures. Idealizations of marine structures including bars, beams, and frames; deflections due to bending and torsion. Methods of structural analysis including equilibrium and strength requirements in consideration of stresses, forces and moments. [CourseProfile (ATLAS)]

**NAVARCH 235. Marine Thermodynamics**  
*Advisory prerequisite: CHEM 130 and CHEM 125; or CHEM 210 and CHEM 211; and MATH 116. (3 credits)*  
Introduction to marine thermodynamics. First law, second law of thermodynamics. System and control volume analyses. Energy and entropy. Heat transfer. Thermodynamic analysis of representative power producing cycles and refrigerators. Applications to marine systems. [CourseProfile (ATLAS)]

**NAVARCH 270. Introduction to Vessel/Platform Design**  
*Advisory prerequisite: Math 116. (4 credits)*  
Introduction to the marine industries, ships and platforms. Engineering economics as applied in marine design decision making. Overview of preliminary ship design with brief team design project. Hydrostatics, stability and trim of ships, boats, and marine platforms. [CourseProfile (ATLAS)]

**NAVARCH 280. Introduction to Probability for Marine Engineers**  
*Advisory prerequisite: Math 116. (3 credits)*  
Introduction to the fundamentals of probability theory, statistics and random processes with marine applications. Events, Probabilities, Combinatorics, Independence, Bayes Theorem; Discrete and Continuous Random Variables, Central Limit Theorem, Elements of Engineering Statistics,
300 Level Courses

**NAVARCH 310. Marine Structures I**  
*Prerequisite: MECHENG 211 or NAVARCH 210, NAVARCH 270.* (4 credits)  
Structural analysis of ship hulls and offshore structures. Loading, material and fabrication considerations. Hull primary bending and midship section analysis. Framing systems. Secondary and tertiary stresses in stiffened plate components. Energy methods. Introduction to Finite Element Analysis. Failure theories for buckling; combined stress states; brittle fracture and fatigue. [CourseProfile (ATLAS)]

**NAVARCH 320. Marine Hydrodynamics I**  
*Advisory prerequisite: MATH 215, and NA 210 or MECHENG 211 or MECHENG 240, or permission of instructor.* (4 credits)  
Concepts and basic equations of marine hydrodynamics. Similitude and dimensional analysis, basic equations in integral form, continuity, and Navier-Stokes equations. Ideal fluid flow, Euler's equations, Bernoulli equation, free surface boundary value problems. Laminar and turbulent flows in pipes and around bodies. [CourseProfile (ATLAS)]

**NAVARCH 321. Marine Hydrodynamics II**  
*Prerequisite: NAVARCH 320.* (4 credits)  
Ideal and viscous fluid theory applied to marine systems. Ship resistance components. Resistance prediction from model testing and standard series. Two-dimensional and three-dimensional airfoil theory. Propeller geometry, design and matching. Hull-propeller interaction, propeller charts, powering prediction. Unsteady marine hydrodynamics: wave loads, seakeeping and transport of pollutants. [CourseProfile (ATLAS)]

**NAVARCH 331. Marine Power and Energy I**  
*Advisory prerequisites PHYS 240 (“C” or better).* (3 credits)  
Marine electrical power and energy systems. AC and DC power networks, analysis techniques and transformations. Principles, characteristics, and properties of power converters, transformers, and DC AC motors. Shipboard energy storage systems. Basic control theory. Power and energy system modeling and control. Design of boat and ship electric power systems. [CourseProfile (ATLAS)]

**NAVARCH 332. Marine Power and Energy II**  
*Advisory prerequisites: NAVARCH 235 and 331; co-requisite NAVARCH 321.* (3 credits)  
Marine diesel engines, steam turbines, gas turbines, combines cycle power plants. Marine fuels, emission control and environmental compliance. Power transmission and reduction gears. Propeller selection and engine-propeller matching. Design of mechanical, integrated electric and hybrid propulsion systems. Boat and ship auxiliary systems including fluid systems, HVAC and heat exchangers. [CourseProfile (ATLAS)]

**NAVARCH 340. Marine Dynamics I**  
*Prerequisites: MECHENG 240. Co-requisite: NAVARCH 321.* (4 credits)  
Structural vibration; one and multi-degree of freedom models. Forced steady state response. Fourier series; definition and application to frequency response. Introduction to random processes and applications in linear systems. Rigid body motion of floating structures. Sea wave excitation. Hydrodynamic added mass and damping; anti-roll tanks. Ship maneuvering; directional stability and steady turning. [CourseProfile (ATLAS)]

**NAVARCH 370. Conceptual Vessel/Platform Design**  
*Advisory prerequisites: NAVARCH 270; Co-requisite: NAVARCH 321.* (3 credits)
Small teams will design a small planning vessel and an offshore platform to understand design interdependencies. Preliminary design methods for sizing, powering, performance and form for planning hulls and floating offshore structures. CourseProfile (ATLAS)

400 Level Courses

**NAVARCH 401. Small Craft Design**  
*Prerequisite: preceded or accompanied by NAVARCH 321 and NAVARCH 340. (4 credits)*  

**NAVARCH 403. Sailing Craft Design Principles**  
*Prerequisite: preceded or accompanied by NAVARCH 321. (3 credits)*  

**NAVARCH 410 (MFG 410). Marine Structures II**  
*Prerequisite: NAVARCH 310 advised. (4 credits)*  
Structural modeling and analysis techniques applied to ship and marine structure components. Equilibrium and energy methods applied to elastic beam theory; static bi-axial bending, torsion and buckling. Shear flow in multicell cross sections. Stiffened and composite plates. Plastic analysis of beams and plates. Structural limit states and introduction to structural reliability. CourseProfile (ATLAS)

**NAVARCH 416 (AEROSP 416). Theory of Plates and Shells**  
*Prerequisite: NAVARCH 310 or AEROSP 315. (3 credits)*  

**NAVARCH 420 (ENSCEN 420) (CLIMATE 420). Environmental Ocean Dynamics**  
*Prerequisites: NAVARCH 320 or AOSS 305 or CEE 325. (4 credits)*  
Physical conditions and physical processes of the oceans; integration of observations into comprehensive descriptions and explanations of oceanic phenomena. Emphasis on wave and current prediction, optical and acoustical properties of sea water, currents, tides, waves and pollutant transport. CourseProfile (ATLAS)

**NAVARCH 423. Introduction to Numerical Hydrodynamics**  
*Prerequisite: NAVARCH 320, NAVARCH 321. (4 credits)*  
Numerical integration, uncertainty analysis and solution of PDE’s using finite differences and finite volume methods. Turbulence modeling and algorithms for solving the Navier-Stokes equations and introduction to solution of air-water flows. Computer lab sessions introduce the student to the computing environment for source-code development, mesh generation, simulation and post-processing. CourseProfile (ATLAS)

**NAVARCH 424. Hydrofoils, Propellers and Turbines**  
*Advised Prerequisite: NAVARCH 320 or equivalent. (4 credits)*
Introduction to the fundamentals of lifting surfaces related to the selection, design, experimental and numerical modeling, as well as optimization of hydrofoils, propellers, and turbines.  

**NAVARCH 431. Marine Engineering II**  
*Prerequisite: NAVARCH 310, NAVARCH 331, NAVARCH 332, NAVARCH 340. (3 credits)*  

**NAVARCH 440. Marine Dynamics II**  
*Prerequisite: NAVARCH 321, NAVARCH 340. (4 credits)*  

**NAVARCH 461 (MFG 462). Marine Structures Construction**  
*Prerequisite: NAVARCH 260 and NAVARCH 310. (3 credits)*  
Principles and applications of modular construction and assembly, major manufacturing processes, thermo-mechanical interactions and contributions to quality and dimensional accuracy, accuracy control methods and practices.  

**NAVARCH 470 (MFG 470). Foundations of Ship Design**  
*Prerequisite: NAVARCH 321, NAVARCH 332, NAVARCH 340. Co-requisites: NAVARCH 310. I (4 credits)*  
Organization of ship design. Preliminary design methods for sizing and form; powering, maneuvering, seakeeping estimation; arranging; propulsion; structural synthesis; and safety and environmental risk of ships. Extensive use of design computer environment. Given owner’s requirements, students individually create and report the conceptual/preliminary design for a displacement ship.  

**NAVARCH 471. Advanced Ship Design**  
*Advised Prerequisite: NA 471, accepted into CoE Honors Program. (3 credits)*  
Individual or team-based design capstone course for NAME majors participating in the COE Honors Program. Students create, develop, modify and document original marine designs. Projects typically involve economic feasibility study of ship, yacht, submersible, or offshore system. Involves project planning and weekly progress reporting.  

**NAVARCH 475. Capstone Design Project**  
*Advisory prerequisite: NAVARCH 470. (4 credits)*  
Small teams of up to 4 students create, develop, and document original marine designs to contract design level. Projects typically involve a ship, yacht, submersible, or offshore system. Involves extensive project planning and weekly progress reporting. Extensive written and oral presentation of the project. Significant design CAD effort.  

**NAVARCH 483. Marine Control Systems**  
*Prerequisite: NAVARCH 331, NAVARCH 332 or permission of instructor. (3 credits)*  
This course covers the theoretical foundation and practical design aspects of marine control systems. Students will be exposed to important system concepts and available analysis and design tools. Fundamental concepts of dynamic behavior and feedback design will be emphasized in the context marine control system applications.  

**NAVARCH 490. Directed Study, Research and Special Problems**  
*Prerequisite: undergraduate only and permission. (to be arranged)*
Individual or team project, experimental work or study of selected topics in naval architecture or marine engineering. Intended primarily for students with senior standing. 

**NAVARCH 491. Marine Engineering Laboratory I**  
*Prerequisite: NAVARCH 310, NAVARCH 320, NAVARCH 321, NAVARCH 331, NAVARCH 332, NAVARCH 340. (3 credits)*  
Instruction in laboratory techniques and instrumentation. Use of computers in data analysis that includes Fast Fourier transforms. Technical report writing. Investigation of fluid concepts, hydroelasticity, marine dynamics, propeller forces, wave mechanics, ship hydrodynamics and extrapolation of model tests to full scale. **CourseProfile (ATLAS)**

**NAVARCH 492. Marine Engineering Laboratory II**  
*Prerequisite: NAVARCH 310, NAVARCH 320, NAVARCH 321, NAVARCH 331, NAVARCH 332, NAVARCH 340. (3 credits)*  
Instruction in experimental techniques, data analysis, and technical communication. Students will conduct experiments with instructional aid, as well as, process and analyze data collected. Results will then be summarized and presented in a technical report. Experimental concepts investigated, include: fundamental fluids, fundamental structures, marine dynamics, propeller testing, wave machines, and model testing. **CourseProfile (ATLAS)**

**NAVARCH 499. Special Topics in Naval Architecture and Marine Engineering**  
*(1-6 credits)*  
Special topics in Naval Architecture and Marine Engineering for Undergraduates. **CourseProfile (ATLAS)**

### 500 Level Courses

**NAVARCH 500. Mathematics for Naval Architects**  
*Advisory Prerequisite: Senior or graduate standing. (3 credits)*  
First and Second Order ODE's Systems of ODE's. Linear Algebra, solving linear systems by Gaussian elimination, inverting matrices by Gauss-Jordan elimination. Eigenvalues, Eigenvectors. Vector Differential and Integral Calculus, including the three major theorems (Gauss Divergence, Green's and Stokes'). Fourier Series, Integral and Transforms. Complex number, Cauchy-Riemann equations, analytic functions. **CourseProfile (ATLAS)**

**NAVARCH 510. Marine Structural Mechanics**  
*Prerequisite: NAVARCH 410. (4 credits)*  
Failure modes encountered in ship and offshore structures. Von Karman plate equations. Geometric and material nonlinear analyses of beams and stiffened plates. Calculus of variations. Effective width and breadth of stiffened plates. Introduction to structural reliability theory with applications to marine structural design. **CourseProfile (ATLAS)**

**NAVARCH 511. Special Topics in Ship Structure**  
*Prerequisite: prior arrangement with instructor. (to be arranged)*  
Individual or team project, experimental work, research or directed study of selected advanced topics in ship structure. Primarily for graduate students. **CourseProfile (ATLAS)**

**NAVARCH 512 (CEE 510). Finite Element Methods in Solid and Structural Mechanics**  
*Prerequisite: Graduate Standing. (3 credits)*  
NAVARCH 513. Defect Assessment for Marine Structures  
*Prerequisite: NAVARCH 461 or permission of instructor. (3 credits)*  
Engineering-Critical-Assessment (ECA) is about providing a quantitative evaluation of a structure’s fitness for service (FFS) when a flaw or damage is detected either in service or during construction. This course discusses basic mechanics principles and the state of the art methodologies for establishing the integrity of a structure containing crack-like defects. [CourseProfile](ATLAS)

NAVARCH 514 (MFG 515). Fatigue of Structures  
*Prerequisite: none. (3 credits)*  
Fundamental concepts associated with fatigue damage and failure in engineering structures and contemporary design and analysis procedures with an emphasis on fatigue of welded structures, including most recent developments in finite element based fatigue design and analysis procedures, e.g., mesh-insensitive structural stress method and master S-N curve approach. [CourseProfile](ATLAS)

NAVARCH 515. Residual Stresses & Distortions in Modern Manufacturing  
*Advisory Prerequisite: Mechanics of materials or strengths of materials courses recommended. (3 credits)*  
Modern approaches to residual stress and distortion control are presented with a focus on design and manufacture of lightweight structures, involving plate processing, laser cutting/forming, welding/joining, and 3D printing. Basic thermo-plasticity phenomena are treated through a series of 1D analytical models and followed by modern finite element stimulation procedures. [CourseProfile](ATLAS)

NAVARCH 520. Intermediate Hydrodynamics  
*Prerequisite: none. (4 credits)*  
Computation of wave loads on marine vehicles and offshore structures including resistance, diffraction, viscous and radiation forces. Linear theory using panel methods and Green functions. Forces on cylindrical bodies. Morison’s Equation. Nonlinear computation using desingularized method for inviscid flow and Reynold’s averaged Navier-Stokes equation (RANS) for viscous flow. [CourseProfile](ATLAS)

NAVARCH 523. Numerical Marine Hydrodynamics  
*Prerequisite: NA 423. (3 credits)*  
Develop the necessary skills to numerically predict the hydrodynamic performance of bodies that move in the marine environment. Topics include numerical uncertainty analysis, panel methods for the free-surface Green function and Michell’s integral, discretization fundamentals for unstructured finite-volume methods, interface capturing methods and turbulence modeling for ship flows. [CourseProfile](ATLAS)

NAVARCH 525. Drag Reduction Techniques  
*Prerequisite: NAVARCH 320 (3 credits)*  
Course addresses active and passive techniques of friction drag reduction. Active methods discussed include air layers and cavities, polymer and gas/bubble injection, and super-hydrophobic and other coating technologies. Passive techniques covered include hull form optimization and appendages such as stem flaps, lifting bodies and bulbous bows. [CourseProfile](ATLAS)

NAVARCH 528 (CLIMATE 528)(ENSCEN 529). Remote Sensing of Ocean Dynamics  
*Prerequisite: NAME/AOSS 420 or permission of instructor. (3 credits)*  
The dynamics of ocean wave motion, both surface and internal waves, and ocean circulation are explored utilizing active and passive remote sensing techniques. Emphasis is placed upon the synoptic perspective of ocean dynamics provided by remote sensing which is not obtainable by conventional means. [CourseProfile](ATLAS)

NAVARCH 540. Marine Dynamics II  
*Prerequisite: NAVARCH 340 (4 credits)*

**NAVARCH 542. Stochastic Dynamics of Marine Systems**
*Advisory Prerequisite: Graduate student or permission of instructor (3 credits)*
Response of systems to stochastic excitation with marine applications. Linear dynamical systems, probability, stochastic processes, stationarity and ergodicity, spectral analysis, stochastic response, time series analysis, statistics of extremes. Applications from floating body dynamics, random sea representation and design of marine structures. Workshop on stochastic analysis, design of offshore wind turbines.

**NAVARCH 551. Offshore Engineering I**
*Prerequisite: Graduate student standing or permission of instructor. (3 credits)*

**NAVARCH 552. Offshore Engineering II**
*Advised Prerequisite: NAVARCH 551. (3 credits)*

**NAVARCH 562 (MFG 563). Marine Systems Production Business Strategy and Operations Management**
*Advised Prerequisite: NAVARCH 260 or permission of instructor or graduate standing. (3 credits)*
Examination of business strategy development, operations management principles and methods and design-production integration methods applied to the production of complex marine systems such as ships, offshore structures, and yachts. Addresses shipyard and boat yard business and product strategy definition, operations planning and scheduling, performance measurement, process control and improvement.

**NAVARCH 565 (ROB 535). Self Driving Cars: Perception and Control**
*Advised prerequisite: Students are recommended to have a background in linear algebra & differential equations. Programming skills in Python & MATLAB, Some C++. (3 credits)*
Self-driving cars are a transformative technology for society. This course covers the underlying technologies in perception and control. Topics include deep learning, computer vision, sensor fusion, localization, trajectory optimization, obstacle avoidance, vehicle dynamics. Course includes theoretical underpinnings of self-driving car algorithms and practical application of the material in hands-on labs.

**NAVARCH 568 (EECS 568 & ROBOTICS 530). Mobile Robotics: Methods and Algorithms**
*Advised Prerequisite: Graduate Standing or permission of instructor. (4 credits)*
Theory and application of probabilistic techniques for autonomous mobile robotics. This course will present and critically examine contemporary algorithms for robot perception (using a variety of modalities), state estimation, mapping, and path planning. Topics include Bayesian filtering; stochastic representations of the environment; motion and sensor models for mobile robots; algorithms for mapping, localization, planning and control in the presence of uncertainty; application to autonomous marine, ground, and air vehicles.
NAVARCH 570 (MFG 572). Advanced Marine Design
Prerequisite: Graduate Standing required. (4 credits)
Organization of marine product development; concurrent marine design. Shipbuilding policy and build strategy development. Group behaviors; leadership and facilitation of design teams. General theories and approaches to design. Conceptual design of ships and offshore projects. Nonlinear programming, multicriteria optimization, and genetic algorithms applied to marine design. Graduate standing required. CourseProfile (ATLAS)

NAVARCH 580 (MFG 580). Optimization and Management of Marine Systems
Prerequisites: none. (4 credits)
Optimization methods (linear, integer, nonlinear, deterministic and stochastic sequential optimization concepts and applications in the operations of marine systems. Elements of maritime management. Risk analysis and utility theory. Fleet deployment optimization for major ocean shipping segments. Forecasting concepts and applications to shipping and shipbuilding decisions. CourseProfile (ATLAS)

NAVARCH 582 (MFG 579). Reliability, Risk and Safety Analysis
Prerequisite: EECS 401 or Math 425 or Stat 412. (3 credits)

NAVARCH 583. Adaptive Control
Prerequisite: Graduate standing or permission of instructor. Not Offered On Regular Basis (3 credits)

NAVARCH 590. Directed Study, Research and Special Problems
Prerequisite: permission of instructor. (1-6 credits)
Individual or group study, design, or laboratory research in a field of interest to the student. Topics may be chosen from any of the areas of Naval Architecture and Marine Engineering. CourseProfile (ATLAS)

NAVARCH 592. Master’s Thesis
Prerequisite: Graduate Standing. (1-6 credits)
To be elected by Naval Architecture and Marine Engineering students pursuing the master’s thesis option. May be taken more than once up to a total of 6 credit hours. CourseProfile (ATLAS)

NAVARCH 599. Special Topics in Naval Architecture and Marine Engineering
Prerequisite: Graduate standing or permission of instructor. (1-6 credits)
Special topics in Naval Architecture and Marine Engineering. CourseProfile (ATLAS)

600 Level Courses

NAVARCH 615. Special Topics in Ship Structure Analysis II
Prerequisite: NAVARCH 510, prior arrangement with instructor. (to be arranged)
Advances in specific areas of ship structure analysis as revealed by recent research. Lectures, discussions and assigned readings. CourseProfile (ATLAS)
NAVARCH 620. Computational Fluid Dynamics for Ship Design  
*Advised Co-requisite: NAVARCH 500 (3 credits)*  
Development of the necessary skills for the hydrodynamic design of hull shapes based on available Computational Fluid dynamics (CFD) tools. Topics: Potential Flows (Deeply submerged, Free-surface treatments, Status of CFD solvers), Viscous flows (Basics, Turbulence modeling, Grid generation, Discretization, Numerical methodologies (Strategies for Wave Resistance, Viscous flows, Total resistance and Optimization work).  
[CourseProfile (ATLAS)](ATLAS)

700 Level Courses

NAVARCH 792. Professional Degree Thesis  
*(2-8 credits); (1-4 credits)*  
[CourseProfile (ATLAS)](ATLAS)

900 Level Courses

NAVARCH 990. Dissertation/Pre-Candidate  
*(2-8 credits); (1-8 credits)*  
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.  
[CourseProfile (ATLAS)](ATLAS)

NAVARCH 995. Dissertation/Candidate  
*Prerequisite: Graduate School authorization for admission as a doctoral candidate. (1-8 credits); (4 credits)*  
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.  
[CourseProfile (ATLAS)](ATLAS)
Nuclear Engineering & Radiological Sciences
Nuclear Engineering and Radiological Sciences Courses

For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: https://bulletin.engin.umich.edu/courses/course-info/

200 Level Courses

NERS 201. Survey of Nuclear Engineering and Radiological Sciences
No Prerequisite (1 credit)
An introduction to the fields of nuclear engineering and radiological sciences. Special emphasis is placed on emerging topics and research in fields of (i) fission systems and radiation transport, (ii) nuclear materials and radiation effects, (iii) radiation measurements and imaging, and (iv) plasmas and nuclear fusion.

NERS 211 (ENSCEN 211). Introduction to Nuclear Engineering and Radiological Sciences
Prerequisite: preceded or accompanied by Math 216. (4 credits)
This course will discuss different forms of energy, the history of nuclear energy, the fundamentals of fission and fusion nuclear power, radiological health applications and electromagnetic radiation in the environment. Current topics in the media such as radon, radioactive waste and nuclear proliferation will also be covered.

NERS 250. Fundamentals of Nuclear Engineering and Radiological Sciences
Prerequisite: preceded or accompanied by Math 216 and Physics 240. (4 credits)
Technological, industrial and medical applications of radiation, radioactive materials and fundamental particles. Special relativity, basic nuclear physics, interactions of radiation with matter. Fission reactors and the fuel cycle.

NERS 290. Special Topics for Nuclear Engineering and Radiological Sciences
Prerequisite: permission of instructor. (1-3 credits)
Special topics offered at the first and second year level. The subject matter may change from term to term.

NERS 299. Directed Study in Nuclear Engineering and Radiological Sciences
Prerequisite: none. (1-3 credits)
Offers a direct study experience to 1st and 2nd year students in an area of interest to the student and faculty member. (Each hour of credit requires 3 – 4 hours of work per week. An oral presentation and/or written report is due at the end of the term.)

300 Level Courses

NERS 311. Elements of Nuclear Engineering and Radiological Sciences I
Advisory Prerequisites: concurrent enrollment in NERS 320.
Enforced Prerequisites: Physics 240. Minimum grade of “C”. (3 credits)
Photons, electrons, neutrons and protons. Particle and wave properties of radiation. Introduction to quantum mechanics. Properties and structure of atoms.

NERS 312. Elements of Nuclear Engineering and Radiological Sciences II
Prerequisite: NERS 250. Minimum grade of “C”. (3 credits)

NERS 315. Nuclear Instrumentation Laboratory
Prerequisites: EECS 215 or EECS 314, preceded or accompanied by NERS 312. (4 credits)
An introduction to the devices and techniques most common in nuclear measurements. Topics include the principles of operation of gas-filled, solid state and scintillation detectors for charged particle, gamma ray and neutron radiations. Techniques of pulse shaping, counting and analysis for radiation spectroscopy. Timing and coincidence measurements.

NERS 320: Applied Mathematics for Engineering Physics
Advisory Prerequisites: MATH 216 or equivalent. (4 credits)
This course provides an overview of applied linear algebra, systems of ordinary differential equations, basic numerical methods, vector calculus with curvilinear coordinates, partial differential equations, and fundamentals of probability applied to applications including fluid mechanics, heat transfer, electromagnetism, quantum mechanics, medical physics, radiological engineering, nuclear reaction physics, radiation transport, and reliability analysis.

NERS 344. Fluid Mechanics for Nuclear Engineers
Prerequisite: NERS 311 and MECHENG 235. (3 credits)

400 Level Courses

NERS 421. Nuclear Engineering Materials
Prerequisites: MATSCIE220 or MATSCIE 250, NERS 312. (3 credits)
An introduction to materials used in nuclear systems and radiation effects in materials (metals, ceramics, semiconductors, organics) due to neutrons, charged particles, electrons and photons.

NERS 425. Application of Radiation
Prerequisite: NERS 312. (4 credits)
Applications of radiation interaction with matter using various forms (neutrons, ions, electrons, photons) of radiation, including activation analysis, neutron radiography, nuclear reaction analysis, Rutherford backscattering analysis, proton-induced x-ray emission, plasma-solid interactions and wave-solid interactions. Lectures and laboratory.

NERS 441. Nuclear Reactor Theory I
Prerequisite: NERS 312, Math 454. (4 credits)
An introduction to the theory of nuclear fission reactors including neutron transport theory, the P1 approximation, diffusion theory, criticality calculations, reactor kinetics, neutron slowing down theory and numerical solution of the diffusion equation.

NERS 442. Nuclear Power Reactors
Prerequisite: NERS 441 or graduate status. (2 credits)
Analysis of nuclear fission power systems including an introduction to nuclear reactor design, reactivity control, steady-state thermal-hydraulics and reactivity feedback, fuel cycle analysis and fuel management, environmental impact and plant siting and transient analysis of nuclear systems.

NERS 444. Thermal-hydraulics for Nuclear Systems
Prerequisite: NERS 344; or graduate standing; or permission of instructor. Minimum grade of a “C” required for enforced prerequisites. (3 credits)
Mass, momentum, and energy balance in lumped-parameter and differential forms for two-phase
flows. Heat conduction, convective heat transfer, heat transfer by radiation. Flow regime maps and thermal hydraulics phenomena in nuclear applications, e.g. counter-current flow limitation and critical heat flux. Best-estimate thermal hydraulic systems codes for nuclear power plan transients.

**NERS 462. Reactor Safety Analysis**  
*Prerequisite: preceded or accompanied by NERS 441. (3 credits)*  
Analysis of design and operational features of nuclear reactor systems that are relevant to safety. Topics include radiation sources and exposure, engineered safety features, system reliability, transient and accident analysis, reactor containment and radionuclide source term, and NRC regulations and licensing. Emphasis will be placed on probabilistic risk assessment for representative nuclear power plants.

**NERS 471. Introduction to Plasmas and Fusion**  
*Prerequisite: preceded or accompanied by Physics 240 or 260. (3 credits)*  
Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Wave phenomena in plasmas. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices and applications, including fusion. Introduction to plasma kinetic theory.

**NERS 472. Fusion Reactor Technology**  
*Prerequisite: NERS 471. (3 credits)*  
Study of technological topics relevant to the engineering feasibility of fusion reactors as power sources. Basic magnetic fusion and inertial fusion reactor design. Problems of plasma confinement. Energy and particle balances in fusion reactors, neutronics and tritium breeding, and environmental aspects. Engineering considerations for ITER and NIF.

**NERS 484. (BIOMEDE 484) Radiological Health Engineering Fundamentals**  
*Prerequisite: MATH 216 or MATH 256 or MATH 286; or graduate standing. Minimum grade of a “C” required for enforced prerequisite. (4 credits)*  
Fundamental physics behind radiological health engineering and topics in quantitative radiation protection. Radiation quantities and measurement, regulations and enforcement, external and internal dose estimation, radiation biology, radioactive waste issues, radon gas, emergencies and wide variety of radiation sources from health physics perspective.

**NERS 490. Special Topics in Nuclear Engineering and Radiological Sciences**  
*Prerequisite: permission of instructor. (1-4 credits)*  
Selected topics offered at the senior or first-year graduate level. The subject matter may change from term to term.

**NERS 491. Nuclear Engineering and Radiological Sciences Design 1**  
*Co-requisite: NERS 441. Minimum grade of “C”. (1 credit)*  
Preparation of a proposal for the senior design project (NERS 492). The tasks include the selection of teams, background literature review, identification and familiarization with necessary computational tools, writing short reports, making presentations, writing a final report, and giving a final oral presentation.

**NERS 492. Nuclear Engineering and Radiological Sciences Design 2**  
*Prerequisite: NERS 491. Minimum grade of “C”. (3 credits)*  
Carry out the design projects proposed in NERS 491 with advice/assistance from faculty advisors and outside mentors and present results in oral and written progress reports including a final presentation to the NERS community.

**NERS 499. Research in Nuclear Engineering and Radiological Sciences**  
*Prerequisite: permission of instructor. Junior or senior status required. (1-3 credits)*  
This course offers research or directed study experience to 3rd or 4th year students in an area of interest to the student and faculty member.
500 Level Courses

**NERS 511. Quantum Mechanics in Neutron-Nuclear Reactions**  
*Prerequisite: NERS 312, Math 454. (3 credits)*  
An introduction to quantum mechanics with applications to nuclear science and nuclear engineering. Topics covered include the Schrödinger equation and neutron-wave equations, neutron absorption, neutron scattering, details of neutron-nuclear reactions, cross sections, the Breit-Wigner formula, neutron diffraction, nuclear fission, transuranic elements, the deuteron problem, masers and lasers.

**NERS 512. Interaction of Radiation and Matter**  
*Prerequisite: NERS 511. (3 credits)*  

**NERS 515. Nuclear Measurements Laboratory**  
*Prerequisite: permission of instructor. (4 credits)*  
Principles of nuclear radiation detectors and their use in radiation instrumentation systems. Characteristics of important devices with applications in nuclear science. Gamma ray spectroscopy, fast and thermal neutron detection, charged particle measurements, pulse analysis, nuclear event timing and recent development in nuclear instrumentation.

**NERS 518. Advanced Radiation Measurements and Imaging**  
*Prerequisite: NERS 315 or NERS 515. (2 credits)*  
Detection and imaging of ionizing radiation that builds on a basic course in radiation measurements. Topics include statistical limits on energy and spatial resolution, analog and digital pulse processing, pulse shape analysis and discrimination, position sensing techniques, application of Ramo theorem for calculating induced charge and the use of statistical methods in data analysis. Specific devices used as examples of evolving technology include newly-developed scintillators and wave-shifters, optical sensors, gas-filled imaging and spectroscopic detectors, semiconductor spectrometers from wide bandgap materials, gamma ray/neutron imaging systems and cryogenic spectrometers.

**NERS 521. Radiation Materials Science I**  
*Prerequisite: NERS 421 permission of instructor. (3 credits)*  
Radiation damage processes; defect production, spike phenomena, displacement cascades, interatomic potential, channeling, focusing, slowing down. Physical effects of radiation damage, radiation induced segregation, dislocations, dislocation loop and void formation, phase stability, unique effects of ion irradiation, comparison between ion and neutron irradiation.

**NERS 522. Radiation Materials Science II**  
*Prerequisite: NERS 421, NERS 521 or permission of instructor. (3 credits)*  
Mechanical and environmental effects of irradiation. Mechanical effects include hardening, embrittlement, fracture and creep. Thermodynamics and kinetics of corrosion, corrosion in high temperature aqueous environments, stress corrosion cracking and effects of irradiation on corrosion and stress corrosion cracking.

**NERS 524. Nuclear Fuels**  
*Prerequisite: permission of instructor. (3 credits)*  
Nuclear reactor fuels and the fuel cycle; mining, processing, isotope separation and fabrication. Fuel/clad behavior; radiation damage, thermal response, densification, swelling, fission gas release, burn-up, clad corrosion, design and modeling. Spent fuel; characterization, performance, reprocessing, disposal.
NERS 531 (EECS529) (ENSCEN529). Nuclear Waste Management  
**Prerequisite:** Senior Standing. (3 credits)  
Based on the nuclear fuel cycle, this course will review the origin, composition, form and volumes of waste generated by commercial reactors and defense programs. The scientific and engineering basis for near-field and far-field containment in a geologic repository will be reviewed in the context of performance assessment methodologies.

NERS 532. Nuclear Safeguards  
**Prerequisite:** NERS 315 or Graduate Standing. Minimum grade of a “C” for enforced prerequisites. (3 credits)  
Students will be introduced to the history of nuclear-material safeguards, nuclear-safeguard techniques, international safeguards policy, and currently used neutron and gamma-ray measurement systems and techniques. Students will attend weekly lectures to prepare for a week-long training offered at the Safeguards Laboratory (SL) at Oak Ridge National Laboratory (ORNL).

NERS 535. Detection Techniques of Nuclear Non-proliferation  
**Prerequisite:** NERS 315 or equivalent. (4 credits)  
Laboratory course covering recent techniques for the detection, identification, and characterization of nuclear materials. It includes the study of Monte Carlo simulation and measurement techniques through hands-on experiments with isotopic gamma ray and neutron sources.

NERS 543. Nuclear Reactor Theory II  
**Prerequisite:** NERS 441 or equivalent. (3 credits)  
A continuation of NERS 441 including neutron resonance absorption and thermalization, perturbation and variational methods, flux synthesis. Analytic and numerical solutions of the neutron transport equation including the S, and B methods, collision probabilities and Monte Carlo methods.

NERS 544. Monte Carlo Methods  
**Prerequisite:** Graduate standing in Engineering, Mathematics or Sciences. (2 credits)  
This course is an introduction to Monte Carlo methods, including basic probability and statistics, random number generation, sampling, scoring and tallies, error estimation, variance reduction and importance sampling. Examples are drawn from Monte Carlo particle transport.

NERS 546. Thermal Fluids for Nuclear Reactor Safety Analysis  
**Prerequisite:** concurrently with or prior to NERS 441, ME 320, or CEE 325 or equivalent, or graduate standing. (3 credits)  
This course gives a broad overview of thermal-hydraulics/fluids for nuclear reactor safety. First, the basic principles of mass energy and momentum are discussed for nuclear applications. Then group projects are performed using NRC computer codes for simulating light water and gas cooled reactors.

NERS 547 (NAVARCH 527, AEROSP 528). Computational Fluid Dynamics for Industrial Applications  
**Advisory Prerequisites:** NERS 344, MECHENG 320, CEE 325 or equivalent. (3 credits)  
Theoretical background on turbulence and modeling for single-phase and two-phase flow, and practical experience on using CFD codes. Evaluate simulations of 3-D flows, applicability/limitations of turbulence models, mesh generation and mesh convergence, numerical methods for solution of Navier-Stokes equation, theoretical exercises, computational project and presentation.

NERS 551. Nuclear Reactor Kinetics  
**Prerequisite:** preceded or accompanied by NERS 441. (3 credits)  
NERS 554. Radiation Shielding  
Prerequisite: NERS 441 or NERS 484; or graduate status. Minimum grade of “C”. (2 credits)  
Neutron and photon transport using Monte Carlo and analytical methods.

NERS 555. Radiological Physics and Dosimetry  
Prerequisite: NERS 312; or graduate standing; or permission of instructor. Minimum grade of a “C” required for enforced prerequisite. (2 credits)  
Radiation physics, theoretical radiation dosimetry, fundamental radiometric quantities, fluence, exposure, kerma, collision kerma and dose for photons and electrons, equilibrium, Fano’s theorem, Monte Carlo methods, convolution method, cavity theory, saturation theory, and other analytic methods in the discipline, the dosimetry chain. Lectures and examples.

NERS 556. Nuclear Core Design and Analysis I  
Prerequisite: NERS 441. (3 credits)  
Analytical investigation of areas of special importance to the design of nuclear reactors. Includes development, evaluation and application of models for the neutronic, thermal-hydraulic and economic behavior of both thermal and fast reactors. Typical problems arising in both design and operation of nuclear reactors are considered. This course includes extensive use of digital computers.

NERS 557. Nuclear Core Design and Analysis II  
Prerequisite: NERS 561. (3 credits)  
Continuation of subject matter covered under NERS 561 with emphasis on applications of analytical models to the solution of current problems in reactor technology.

NERS 570. (ENGR 570) Methods and Practice of Scientific Computing  
Advisory Prerequisite: MATH 371 or MATH 471.  
Enforced Prerequisite: ENGR 101 or 151 or EECS 183 AND MATH 216 or 256 or 286; or Graduate Status. Minimum grade of “C” required for enforced prerequisite. (4 credits)  
Designed for graduate students developing the methods and using the tools of scientific computing. Students learn how to use HPC clusters, and utilize community tools and software engineering best practices to develop their own codes. Students are expected to have had some introduction to programming, linear algebra, and differential equations.

NERS 571. Intermediate Plasma Physics I  
Prerequisite: NERS 471 or Physics 405. (3 credits)  
Single particle motion, collision and transport; plasma stability from orbital considerations; Vlasov and Liouville equations; Landau damping; kinetic modes and their reconstruction from fluid description; electrostatic and electromagnetic waves, cutoff and resonance.

NERS 572. (Appl Phys 672) Intermediate Plasma Physics II  
Prerequisite: NERS 571. (3 credits)  
Waves in non-uniform plasmas, magnetic shear; absorption, reflection and tunneling gradient-driven micro-instabilities; BGK mode and nonlinear Landau damping; macroscopic instabilities and their stabilization; non-ideal MHD effects.

NERS 573. Plasma Engineering  
Prerequisite: NERS 471 or graduate standing. (3 credits)  
This course covers the theory and application of plasma concepts relevant to plasma engineering problems encountered in the workplace. Focus areas addressed include plasma propulsion, semiconductor processing, lighting, and environmental mitigation. Students will accumulate over the term a toolbox of concepts and techniques directly applicable to real world situations.

NERS 574. Introduction to Computational Plasma Physics  
Prerequisite: NERS 471 or 571. Minimum grade of a “B” required for enforced prerequisites. (3 credits)

NERS 575 (EECS 519). Plasma Generation and Diagnostics Laboratory
Prerequisite: preceded or accompanied by a course covering electromagnetism. (4 credits)
Laboratory techniques for plasma ionization and diagnosis relevant to plasma processing, propulsion, vacuum electronics, and fusion. Plasma generation techniques includes: high voltage-DC, radio frequency, and e-beam discharges. Diagnostics include: Langmuir probes, microwave cavity perturbation, microwave interferometry, laser schlieren and optical emission spectroscopy. Plasma parameters measured are: electron/ion density and electron temperature.

NERS 576. Charged Particle Accelerators and Beams
Prerequisite: Physics 240 or 260; or EECS 230. (3 credits)

NERS 577. Plasma Spectroscopy
Prerequisite: introductory courses in plasma and quantum mechanics. (3 credits)
Basic theory of atomic and molecular spectroscopy and its application to plasma diagnostics. Atomic structure and resulting spectra, electronic (including vibrational and rotational) structure of molecules and the resulting spectra, the absorption and emission of radiation and the shape and width of spectral lines. Use of atomic and molecular spectra as a means of diagnosing temperatures, densities and the chemistry of plasmas.

NERS 578 (EECS 517). Physical Processes in Plasmas
Prerequisites: EECS 330. (3 credits)
Plasma physics applied to electrical gas discharges used for material processing. Gas kinetics; atomic collisions; transport coefficients; drift and diffusion; sheaths; Boltzmann distribution function calculation; plasma simulation; plasma diagnostics by particle probes, spectroscopy, and electromagnetic waves; analysis of commonly used plasma tools for materials processing.

NERS 579. Introduction to the Science and Technology of Space Nuclear Power and Propulsion
Prerequisites: None. (3 credits)
Course introduces students to the application of nuclear technology for space power and propulsion. Course provides students with the physics of mission trajectory analysis and the science behind nuclear power systems and propulsion approaches. With this background course surveys the history and state of the art in terms of nuclear space technologies. The course provides background for a team design project where the end goal is the development of an all nuclear mission to the outer planets and beyond. The key design components include nuclear power, propulsion, power conversion and rejection, mission analysis and shielding/life support.

NERS 581. Radiation Therapy Physics
Prerequisite: Physics 240 or 260; or graduate standing. Minimum grade of “C” required for enforced prerequisites. (3 credits)
Covers the physics concepts necessary for the understanding of modern radiation therapy techniques. External beam radiation therapy and brachytherapy fundamentals are covered, including treatment planning, evaluation, and delivery with an emphasis on current developments in the field.
NERS 582 (BIOMEDE 582). Medical Radiological Health Engineering
Prerequisite: MATH 216 or 256 or 286 and Physics 240 or 260; or graduate standing. Minimum grade of "C" required for enforced prerequisites. (3 credits)
This course covers the fundamental approaches to radiation protection in radiology nuclear medicine, radiotherapy, and research environments at medical facilities. Topics presented include health effects, radiation dosimetry and dose estimation, quality control of imaging equipment, regulations, licensing and health physics program.

NERS 583. Radiological Dose Assessment and Response
Prerequisite: MATH 216 or 256 or 286 and Physics 240 or 260; or graduate standing. Minimum grade of "C" required for enforced prerequisites. (3 credits)
This course is structured around an event, such as a medical incident or nuclear accident, which encompasses open-ended problems common in radiological engineering practice. Student teams engage in standardized radiological dose assessment and apply radiation protection approaches culminating in comprehensive oral presentations and written reports.

NERS 584. Radiation Biology
Prerequisite: Senior or graduate standing. (3 credits)
Lecture course covering three main areas of radiation biology: molecular and cellular radiation biology, radiation and human health, principles of radiation therapy.

NERS 585. Physics of Medical Imaging
No Prerequisite (3 credits)
Physics, equipment and techniques basic to producing medical diagnostic images by x-rays, fluroscopy, computerized tomography of x-ray images, mammography, ultrasound, and magnetic resonance imaging systems. Lectures and demonstrations.

NERS 586 Applied Radiological Measurements
Prerequisite: NERS 484, NERS 515 or equivalent. (4 credits)
Instrumentation and applied measurements of interest for radiation safety, environmental sciences, and medical physics. Dosimeters, radon gas, in situ gamma ray spectroscopy, skin dose, bioassay, internal dose evaluation, alpha detection, applied instrumentation and other selected medical physics and health measurements. Includes analytical modeling and computer simulation for comparison with several physical experiments.

NERS 588. Radiation Safety and Medical Physics Practicum
Prerequisite: permission of instructor; mandatory satisfactory/ unsatisfactory. (1-12 credits)
Individuals intern at a medical or industrial facility. Students concentrate on a specific radiological health engineering problem and participate in broader facility activities. Assignments are arranged by agreement among the student, faculty member and facility personnel.

NERS 590. Special Topics in Nuclear Engineering and Radiological Sciences II
Minimum grade of "C". (1-4 credits)
Selected topics offered at the graduate level. The subject matter will change from term to term.

NERS 599. Master's Project
Prerequisite: permission of instructor. (1-3 credits)
Individual or group investigations in a particular field or on a problem of special interest to the student. The course content will be arranged at the beginning of each term by mutual agreement between the student and a staff member. This course may be repeated for up to 6 credit hours.

600 Level Courses

NERS 621 (EES 629) (MATSCIE 621) (ENSCEN 620). Nuclear Waste Forms
Prerequisites: NERS 531 (recommended). (3 credits)
This interdisciplinary course will review the materials science of radioactive waste remediation and disposal strategies. The main focus will be on corrosion mechanisms, radiation effects and the long-term durability of glasses and crystalline ceramics proposed for the immobilization and disposal of nuclear waste.

**NERS 622 (MFG 622) (MATSCIE 622). Ion Beam Modification and Analysis of Materials**  
*Prerequisite: NERS 421, NERS 521 or MATSCIE 351 or permission of instructor. (3 credits)*  
Ion-solid interactions, ion beam mixing, compositional changes, phase changes, micro-structural changes; alteration of physical and mechanical properties such as corrosion, wear, fatigue, hardness; ion beam analysis techniques such as RBS, NRA, PIXE, ion channeling, ion microprobe; accelerator system design and operation as it relates to implantation and analysis.

**NERS 644. Transport Theory**  
*Prerequisite: Math 555. (3 credits)*  
Mathematical study of linear transport equations with particular application to neutron transport, plasma physics, photon transport, electron conduction in solids, and rarefied gas dynamics; one-speed transport theory; Wiener-Hopf and singular eigen function methods; time-dependent transport processes; numerical methods including spherical harmonics, discrete ordinates and Monte Carlo techniques; non-linear transport phenomena.

**NERS 671. Theory of Plasma Confinement in Fusion Systems**  
*Prerequisite: NERS 572 advised. (3 credits)*  
Study of the equilibrium, stability and transport of plasma in controlled fusion devices. Topics include MHD equilibrium for circular and non-circular cross section plasmas; magneto-hydrodynamic and micro-instabilities; classical and anomalous diffusion of particles and energy and scaling laws.

**NERS 673. Electrons and Coherent Radiation**  
*Prerequisite: NERS 471 or Physics 405. (3 credits)*  
Collective interactions between electrons and surrounding structure studied. Emphasis given to generation of high power coherent microwave and millimeter waves. Devices include: cyclotron resonance maser, free electron laser, peniotron, orbitron, relativistic klystron and crossed-field geometry. Interactions between electron beam and wakefields analyzed.

**NERS 674 (Appl Phys 674). High Intensity Laser-Plasma Interactions**  
*Prerequisite: NERS 471, NERS 571 or permission of instructor. (3 credits)*  
Coupling of intense electromagnetic radiation to electrons and collective modes in time-dependent and equilibrium plasmas, ranging from underdense to solid-density. Theory, numerical models and experiments in laser fusion, x-ray lasers, novel electron accelerators and nonlinear optics.

### 700 Level Courses

**NERS 799. Special Projects**  
*(1-6 credits)*  
Individual or group investigations in a particular field or on a problem of special interest to the student. The project will be arranged at the beginning of the term by mutual agreement between the student and a staff member.

### 900 Level Courses

**NERS 990. Dissertation/Pre-Candidate**  
*Prerequisite: (2-8 credits); (1-4 credits)*  
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
NER 995. Dissertation/Candidate

Prerequisite: Graduate School authorization for admission as a doctoral candidate. (8 credits); (4 credits)

Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
Robotics
Robotics Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under “How to Read a Course Description”, in the CoE Bulletin Website: https://bulletin.engin.umich.edu/courses/course-info/

100 Level Courses

ROB 101. Computational Linear Algebra
(3 credits)

ROB 102. Introduction to AI and Programming
Advisory Prerequisite: ROB 101 (Computational Linear Algebra) or ROB 103 (Robotic Mechanisms). (4 credits)
Algorithms and programming for robotics and artificial intelligence in C++ and high-level scientific programming languages; autonomous navigation and search algorithms; introduction to models of computing through graphs and graph algorithms. CourseProfile (ATLAS)

ROB 103. Robotics Mechanisms
Advisory Prerequisite: ROB 101. (4 credits)
Hands-on design, build, and operations of robotic systems. Students, in teams, will build a mobile manipulation robot that can be teleoperated. Students will develop maker-shop skills (3D printing, laser cutting, mill, etc.), programming (C++) and controls, system design and integration, and technical writing. Culmination in friendly competition and final report. CourseProfile (ATLAS)

400 Level Courses

ROB 422. (EECS 465) Introduction to Algorithmic Robotics
Prerequisite: EECS 280 and MATH 215 and (junior standing or senior standing) or graduate standing. Minimum grade of “C” for enforced prerequisite. Advisory Prerequisite: EECS 281 and (MATH214 or MATH 217 or MATH 417 or MATH 419 or ROB 101) or permission of instructor. (3 credits)
An introduction to the algorithms that form the foundation of robot planning, state estimation, and control. Topics include optimization, motion planning, representations of uncertainty, Kalman and particle filters, and point cloud processing. Assignments focus on programming a robot to perform tasks in simulation. CourseProfile (ATLAS)

ROB 464 (EECS 464). Hands-on Robotics
Prerequisite: EECS 216 or EECS 281 or ME 360 or CEE 212 or IOE 333 or Grad Standing. Minimum grade of “C” required for enforced prerequisites. (4 credits)
A hands-on, project based introduction to the principles of robotics and robot design. Multiple team projects consisting of design and implementation of a robot. Theory: motors, kinematics & mechanisms, sensing/filtering, planning, pinhole cameras. Practice: servo control, project management; fabrication; software design for robotics. Significant after hours lab time investment. CourseProfile (ATLAS)
500 Level Courses

ROB 501. Mathematics for Robotics
Prerequisite: Graduate standing or permission of instructor. Advisory: differential equations and matrix algebra recommended. (4 credits)
Applied mathematics for robotics engineers. Topics include vector spaces, orthogonal bases, projection theorem, least squares, matrix factorizations, Kalman filter and extensions, particle filters, underlying probabilistic concepts, norms, convergent sequences, contraction mappings, Newton Raphson algorithm, nonlinear constrained optimization, local vs global convergence, convexity, linear and quadratic programs, and randomized search strategies. CourseProfile (ATLAS)

ROB 502. Programming for Robotics
Prerequisite: None. (3 credits)
Graduate level project-based programming and computer science course for Robotic engineers. Topics include data representation, memory concepts, debugging, recursion, search, abstractions, threading, and message passing. The average student will have already written MATLAB programs about 250-500 lines long and will have basic familiarity with C syntax. CourseProfile (ATLAS)

ROB 511. Robot Operating Systems
Advisory Prerequisite: Linear Algebra (Math 214, 217, 417, 419 or equivalent) and Programming (EECS 280, 402, or equivalent). (3 credits)
An Introduction to computational models, algorithms, and software systems for autonomous robot control that generalizes across a wide variety of machines. Topics covered include path and motion planning, reactive control, forward and inverse kinematics, numerical integration for dynamics, and robot middleware [design]. Significant programming. CourseProfile (ATLAS)

ROB 520. Motion Planning
Advisory Prerequisite: Undergraduate linear algebra (e.g. MATH 214) and significant programming experience (e.g. EECS 281). (3 credits)
Focuses on algorithms that reason about the movement of robots. These algorithms can be used to generate sequences of motions for cars, arms, and humanoids. Students will implement motion planning algorithms in open-source frameworks, read recent literature in the field, and complete a project that draws on the course material. CourseProfile (ATLAS)

ROB 550. Robotic Systems Laboratory
Prerequisite: Graduate standing or permission of instructor. (4 credits)
Multidisciplinary laboratory course with exposures to sensing, reasoning, and acting for physically-embodied systems. Intro to kinematics, localization and mapping, planning, control, user interfaces. Design, build, integration, and test of mechanical, electrical, and software systems. Projects based on a series of robotic platforms: manipulators, mobile robots, aerial or underwater vehicles. CourseProfile (ATLAS)

ROB 590. Directed Study
Prerequisite: Permission of instructor. Mandatory Satisfactory/Unsatisfactory. (1-6 credits)
Individual study of specialized aspects of robotics. Graduate students only. CourseProfile (ATLAS)

ROB 599. Special Topics in Robotics
Advisory Prerequisite: Graduate standing or permission of instructor. (1-6 credits)
Special topics in Robotics. CourseProfile (ATLAS)

600 Level Courses

ROB 690. Master's Advanced Research
Prerequisite: Graduate standing; 1 previous election of ROB 590 (min 3 credits); AND Corequisite: 1
additional election of ROB 590 (min 3 credits) which may be elected concurrently with ROB 690. Minimum grade requirement: S
Faculty-supervised research that culminates in a submitted and graded document. Expectation is that student will write and submit an original conference style paper based on their advanced research that builds on earlier research completed in three to six credits of ROB 590. Specific expectations determined by advisor. Course will be letter graded. 2 different options each with a maximum of 9 credits of research that can count toward the MS: (see pre-req and co-req for details). CourseProfile (ATLAS)

900 Level Courses

ROB 990. Dissertation/Pre-Candidate
Prerequisite: None. (1-8 credits)
Dissertation work by doctoral student not yet admitted to status as candidate. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment. CourseProfile (ATLAS)

ROB 995. Dissertation/Candidate
Prerequisite: Doctoral candidacy. (8 credits); (4 credits)
Election for dissertation work by a doctoral student who has been admitted to candidate status. The defense of the dissertation, that is, the final oral examination, must be held under a full-term candidacy enrollment.
Engineering Division Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: https://bulletin.engin.umich.edu/courses/course-info/

100 Level Courses

ENGR 100. Introduction to Engineering
(4 credits)
Focused team projects dealing with technical, economic, safety, environmental and social aspects of a real-world engineering problem. Written, oral and visual communication required within the engineering profession; reporting on the team engineering projects. The role of the engineer in society; engineering ethics. Organization and skills for effective teams. CourseProfile (ATLAS)

ENGR 101. Introduction to Computers and Programming
Prerequisite: prior or concurrent enrollment in MATH 115 or equivalent. Credit for only one: EECS 180, EECS 183, ENGR 101, or ENGR 151. (4 credits)
Algorithms and programming in C++ and MATLAB, computing as a tool in engineering, introduction to the organization of digital computers. CourseProfile (ATLAS)

ENGR 110. Design Your Engineering Experience
Prerequisite: none. (2 credits)
In this elective course, you explore the breadth of opportunities available to engineers in both their education and their career. You will have a chance to explore the foundations of the field, and its influence on ourselves and the world we live in. You will learn about the engineering majors offered at Michigan, and the types of career paths available as an engineer. You will identify your own interests and goals, and discover the broader opportunities available through academic minors and co-curricular opportunities that align with your passions. And, you will actively incorporate this information into a plan for your educational experience in Michigan Engineering. CourseProfile (ATLAS)

ENGR 151. Accelerated Introduction to Computers and Programming
Prerequisite: permission of instructor. Credit for only one: EECS 180, EECS 183, ENGR 101, or ENGR 151. (4 credits)
Algorithms and programming in C++ and MATLAB. Procedural and object-oriented algorithm design, implementation and testing. Emphasis on engineering analysis and embedded computing application. This course is an advanced alternative to ENGR 101. Cannot take both ENGR 101 and 151. CourseProfile (ATLAS)

ENGR 190. Special Topics
Prerequisite: none. (1-6 credits)
Special topics of current interest selected by faculty. CourseProfile (ATLAS)

ENGR 196. Outreach Internship
Prerequisite: none. (1 credit)
Practical work experience related to the student's field of study in consultation with an academic advisor. CourseProfile (ATLAS)
200 Level Courses

**ENGR 255. Introductory Multidisciplinary Engineering Project**  
*Prerequisite: None. (1-3 credits)*  
Intro course in which students acquire, develop, and refine skills for success in the modern engineering design process using mentored, multidisciplinary, team-based, project work. Students will integrate: (1) knowledge from previous courses; (2) knowledge of engineering design process; and (3) professional skills (e.g., teamwork, project planning, communications, etc.). [CourseProfile](ATLAS)

**ENGR 256. Peer Mentorship in Engineering Design**  
*Prerequisite: permission of instructor. (1-2 credits)*  
Peer mentorship of design-build-test engineering team projects at the first year level. Mentors assist teams on technology issues associated with design or production phases of the projects. Faculty oversight guides mentors in the development of leadership skills associated with design team project management. [CourseProfile](ATLAS)

**ENGR 260. Engineering Across Cultures I**  
*Prerequisite: none. (1 credit)*  
This course explores the role of culture and context in identifying and solving engineering problems. Lectures, guest speakers and group discussions focus on intercultural knowledge and case studies of engineering projects in a global context. The final project is a culture-specific needs assessment of a technical product/service. [CourseProfile](ATLAS)

**ENGR 280. Undergraduate Research**  
*Prerequisite: permission of instructor. (1-4 credits)*  
This course offers research experience to first- and second-year Engineering students in an area of mutual interest to the student and to a faculty member within the College of Engineering. For each hour of credit, it is expected that the student will work three hours per week. The grade for the course will be based on a final project/report evaluated by the faculty sponsor and participation in other required UROP activities, including bimonthly research group meetings and submission of a journal chronicling the research experience. [CourseProfile](ATLAS)

**ENGR 290. Special Topics in Engineering**  
*Prerequisite: none. (1-6 credits)*  
Special topics of current interest selected by faculty. [CourseProfile](ATLAS)

300 Level Courses

**ENGR 301. Engineering Undergraduate Study Abroad**  
*Prerequisite: student must meet any other prerequisites designated by the host university. (1-16 credits)*  
Students planning to study abroad for fall, winter, spring, summer or spring/summer on College of Engineering Study Abroad programs should register under Engineering Division (course #301). Separate course sections will be listed for each different study abroad destination. [CourseProfile](ATLAS)

**ENGR 345. Introduction to Design Processes**  
*Prerequisite: permission of instructor. (2 credits)*  
Processes of design, focusing on front-end strategies, including opportunity discovery, problem definition, developing robust mechanisms to gather information from users and other stakeholders, data synthesis methods for translating user data into design requirements, creating innovative
solutions during concept generation, and decision-making systems for evaluating possible solutions. [CourseProfile (ATLAS)]

ENGR 350. International Laboratory Experience for Engineers  
**Prerequisite:** ENGR 100, permission of instructor (3 credits)  
This course provides practical laboratory experience at a partner institute abroad. Students work on small project teams with local students to design and conduct experiments, analyze results and present reports to faculty and industry representatives. Students gain international perspectives on the engineering field and develop intercultural communication and problem-solving skills. [CourseProfile (ATLAS)]

ENGR 354. Engineering Design Practice  
**Prerequisite:** permission of instructor (1 credit)  
Lectures are structured around the modern design process common to all engineering disciplines. The importance of the development of clear and traceable requirements, analysis ranging from scaling and order-of-magnitude calculations to sophisticated simulations and tests. Project scoping exercise. Synthesis of solutions and trades are studied in detail. Students are encouraged to take ENGR 354 and 355 simultaneously. [CourseProfile (ATLAS)]

ENGR 355. Intermediate Multidisciplinary Engineering Project  
**Enforced Prerequisite:** Permission of instructor (1 -4 credits)  
Intermediate course in which students acquire, develop, and refine skills for success in the modern engineering design process using mentored, multidisciplinary, team-based, project work. Students will integrate: (1) knowledge from previous courses; (2) knowledge of engineering design process; and (3) professional skills (e.g., teamwork, project planning, communications, etc.). [CourseProfile (ATLAS)]

ENGR 371 (MATH 371). Numerical Methods for Engineers and Scientists  
**Advised Prerequisite:** ENGR 101, one of MATH 216, 256, 266 or 316, and one of MATH 214, 217, 417, or 419. (3 credits)  
This is a survey course of the basic numerical methods which are used to solve scientific problems. In addition, concepts such as accuracy, stability and efficiency are discussed. The course provides an introduction to MATLAB, an interactive program for numerical linear algebra as well as practice in computer programming. [CourseProfile (ATLAS)]

ENGR 390. Special Topics in Engineering  
**Prerequisite:** none. (1-6 credits)  
Special topics of current interest selected by faculty. [CourseProfile (ATLAS)]

ENGR 391. Directed Overseas Study  
**Prerequisite:** foreign language skills as necessary; sophomore standing. (1-3 credits)  
Directed overseas study in an industrial placement that is overseen by a faculty member at host institution in conjunction with academic courses taken as part of a study abroad program. [CourseProfile (ATLAS)]

ENGR 399. Directed Study in Science and Technology Policy  
**Prerequisite:** Permission of Instructor. (1-4 credits)  
Directed study that involves a strong technical element that is combined with policy aspects of interest to the student. The content may be based on research performed during participation in the Michigan in Washington or Public Service Intern Program. The course of study will be supervised by a faculty member in Washington DC, or in the student’s home department. [CourseProfile (ATLAS)]
ENGR 400. Engineering Cooperative Education  
Prerequisite: permission of program director. (no credit)  
Off-campus work under the auspice of the cooperative education program. Engineering work experience in government or industry. CourseProfile (ATLAS)

ENGR 403. Scientific Visualization  
Prerequisite: Upper division or Graduate Standing. (3 credits)  
Introduces engineering and science students to scientific visualization principles of data display. Use of color to encode quantitative information. Display of 2- and 3-D scalar and vector data. Interactive computer techniques emphasized. Extensive hands-on practice. Project or research paper required. CourseProfile (ATLAS)

ENGR 405 (CHE 405). Problem Solving and Troubleshooting in the Workplace  
Prerequisite: senior standing. (3 credits)  
The course goals are to help students enhance their problem solving, critical thinking, creative thinking and troubleshooting skills and to ease the transition from college to the workplace. The course includes a few speakers from the industry. Students work in teams to complete the home problems and the term project. CourseProfile (ATLAS)

ENGR 406 (EECS 406). High-Tech Entrepreneurship  
Prerequisite: none. (4 credits)  
Four aspects of starting high-tech companies are discussed: opportunity and strategy, creating new ventures, functional development and growth and financing. Also, student groups work on reviewing business books, case studies, elevator and investor pitches. Different funding models are covered, including angel or VC funding and small business (SBIR) funding. CourseProfile (ATLAS)

ENGR 410 (EECS 410). Patent Fundamentals for Engineers  
Prerequisite: junior or senior standing or graduate standing. (4 credits)  
This course covers the fundamentals of patents for engineers. The first part of the course focuses on the rules and codes that govern patent prosecution, and the second part focuses on claim drafting and amendment writing. Other topics include litigation, ethics and licensing. CourseProfile (ATLAS)

ENGR 450. Multidisciplinary Design  
Prerequisite: must meet individual engineering departmental requirements for senior design. (4 credits)  
A senior capstone interdisciplinary engineering design experience. The student is exposed to the design process from concept through analysis to system integration, prototyping, testing and report. Interdisciplinary projects are proposed from the different areas within engineering. Two hours of lecture and two laboratories. CourseProfile (ATLAS)

ENGR 455. Advanced Multidisciplinary Engineering Project  
Enforced Prerequisite: Permission of instructor. (2-5 credits)  
Advanced course in which students acquire, develop, and refine skills for success in the modern engineering design process using mentored, multidisciplinary, team-based, project work. Students will integrate: (1) knowledge from previous courses; (2) knowledge of engineering design process; and (3) professional skills (e.g., teamwork, project planning, communications, etc.) CourseProfile (ATLAS)

ENGR 456. Mentorship-Leadership in Multidisciplinary Design  
Enforced Prerequisite: Permission of instructor. (2 credits)  
Mentoring and/or leadership of engineering team projects for multidisciplinary design at junior or senior level. Students participate in reflective and integrated learning exercises while simultaneously providing guidance based on previous participation in team based multidisciplinary engineering
projects. Students offer technical knowledge, interpersonal/group dynamics, and project management skills to teams. CourseProfile (ATLAS)

ENGR 460. Engineering Across Cultures II
Prerequisite: ENGR 260, minimum grade of C. (1 credit)
This course is the second of a 2-course sequence for the students enrolled in the International Minor for Engineers. It is designed to help students reflect on their international/intercultural experience leveraging the Intercultural Development Inventory, the Experiential Learning Framework and its related competencies. CourseProfile (ATLAS)

ENGR 480. Global Synthesis Project
Prerequisite: admitted to Tauber Institute for Global Operations. (4 credits)
Students will work on global operations or industry-relevant projects. Students will work on multi-disciplinary teams with business students, under faculty supervision. CourseProfile (ATLAS)

ENGR 490. Special Topics in Engineering
Prerequisite: none. (1-6 credits)
Special topics of current interest selected by faculty. CourseProfile (ATLAS)

500 Level Courses

ENGR 520. Entrepreneurial Business Fundamentals for Engineers & Scientists
Prerequisite: senior or graduate standing. (3 credits)
This course provides students with a perspective in looking to form or join startup companies and those that are looking to create corporate value via industrial research. The students are taught the entrepreneurial business development screening tools necessary to translate opportunities into businesses with focus on: strategy, finance and market positioning. CourseProfile (ATLAS)

ENGR 521. Clean Tech Entrepreneurship
Advised Prerequisite: Senior and Graduate Standing. (1.5 credits)
The course teaches the students how to screen venture opportunities in various clean tech domains. Venture assessments are approached through strategic, financial and market screens, and consider the impact of policy and regulatory constraints on the business opportunity. There is a term project with two milestone deliverables. CourseProfile (ATLAS)

ENGR 523 (BA 518). Business of Biology
Advances in life science research have enhanced our understanding of the human genome, human genetic variation, and the role that genes play in our everyday health, response to treatment and susceptibility to disease. This new frontier in genomic medicine ushers in both opportunity and peril for individuals, companies and societies. The objective in this interdisciplinary graduate course is to explore the intersections between science, technology, commerce and social policy as they come together to advance (and in some cases retard) progress toward more-personalized health care. The course is intended for graduate students in medicine, biomedical and health-related science, public health, law, engineering, and business interested in the future of health care. Due to variation in student backgrounds coming into the course, efforts are made to establish a shared vocabulary and knowledge base across the disciplines. Interdisciplinary student teams are assigned to a group research project which is presented at the end of the course. CourseProfile (ATLAS)

ENGR 580. Teaching Engineering
Prerequisite: doctoral candidate. (3 credits)
Aimed at doctoral students from all engineering disciplines interested in teaching. Topics include educational philosophies, educational objectives, learning styles, collaborative and active learning, creativity, testing and grading, ABET requirements, diversity, equity and inclusion issues. CourseProfile (ATLAS)
ENGR 590. International Experience in Engineering
Prerequisite: seniors and grad students of engineering only. (2-8 credits)
This independent study course covers selected research areas in engineering. The topic and research plan must be approved by the instructor. A student is expected to participate in the planning of the course, visit a foreign research institution, participate in a research project (analytical and/or experimental) and write a report. The course may continue for more than one semester. CourseProfile (ATLAS)

ENGR 591. Engineering Graduate Study Abroad
Prerequisite: student must have 4-5 semesters of foreign language for immersion programs and fulfill any other prerequisites designated by the host university. (1-16 credits)
Students planning to study abroad for fall, winter, spring, summer or spring/summer on College of Engineering Study Abroad programs should register under Engineering Division (course #591). Separate course sections will be listed for each different study abroad destination. CourseProfile (ATLAS)

ENGR 599. Special Topics in Engineering
Prerequisite: graduate standing or permission of instructor. (1-4 credits)
Special topics in interdisciplinary engineering. CourseProfile (ATLAS)

600 Level Courses

ENGR 600. Engineering Practicum Projects
Prerequisite: graduate standing and permission of the department. (8 credits)
This practice-oriented course is intended to provide students with industrial work experience in their academic discipline. Students may participate in individual or team projects in an industrial setting. CourseProfile (ATLAS)

900 Level Courses

ENGR 996. Responsible Research Practices
(1-2 credits)
The Research Responsibility Program introduces concepts and policies relating the responsible practice of research. It does not provide opportunities for students to put what they are learning into practice in a scholarly context. The course is designed to provide the opportunity to apply what students are learning to the scholarly analysis of an issue that raises questions about responsible research practices. Attendance required. CourseProfile (ATLAS)

ENGR 998. Curriculum Practical Project
No Prerequisites (1 credit)
Practical work experience related to graduate student’s field of study in consultation with the student’s department/program, cognizant faculty, and the Engineering Career Resource Center.
Military Officer Education Program

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: https://bulletin.engin.umich.edu/courses/course-info/

AERO (Air Force Officer Education Program)

AERO 101. Air Force Today I
Prerequisite: none. (1 credit)
Examines the growth and development of the United States Air Force; covers Presidential, Secretary of Defense and JCS roles in the defense posture, and the national and U.S. military strategic concepts; studies the Air Force contribution to strategic offensive and defensive and General Purpose Forces and Air Force supporting forces. Compares the dynamics and interaction of all U.S. military forces in the General Purpose role and their cooperative efforts in the national security posture.

AERO 102. Air Force Today II
Prerequisite: AERO 101. (1 credit)
This course is a continuation of the study of the growth and development of the United States Air Force begun in AERO 101. The course relates the mission and responsibilities of the various Air Force major commands to the U.S. defense posture and the U.S. military strategy. Emphasis is placed on the Air Force contribution to General Purpose forces and the dynamics, interactions, and cooperative efforts of all the Services in the General Purpose role for the national security posture.

AERO 201 (UC 201). U.S. Aviation History & Its Development into Air Power
Prerequisite: AERO 102. (1 credit)
This course traces the development of aviation from the 18th century — a time of balloons and dirigibles — to the present, and examines how technology has affected the growth and development of air power. In addition, this course traces the use and development of air power through World War I and World War II, the Korean and Vietnamese conflicts, employment in relief missions and civic action programs in the late 1960s, and employment in military actions concluding with Desert Shield/Desert Storm.

AERO 202 (UC 202). U.S. Aviation History & Its Development into Air Power
Prerequisite: AERO 201. (1 credit)
Examines the development of aviation from the 18th century, from balloons and dirigibles, to the present, and how technology has affected growth and development of air power; traces use and development of air power through WW's I and II, the Korean and Vietnamese conflicts, employment in relief missions and civic action programs in the late 1960s, and employment in military actions concluding with Desert Shield/Desert Storm. Continuation of AERO 201.

AERO 310 (UC 309). Air Force Leadership and Management
Prerequisite: AERO 202. (3 credits)
The concepts, principles, and techniques of leadership are presented within the framework of behavioral theories. Emphasis on the leader, group, situation, and their interaction as dynamic factors in an organizational environment. Historical overview of managerial development throughout recorded history with emphasis on the social and physical setting in which the manager operates. The curriculum includes effective communications, decision making, planning, and strategic management.
AERO 311. Management & Af Appl  
*Prerequisite: AERO 310. (3 credits)*  
An integrated management course emphasizing the concepts and skills required by the successful manager and leader. Organizational and personal values (ethics), management of change, organizational power, politics, and managerial strategy and tactics are discussed within the context of the military organization. Actual Air Force case studies are used throughout the course to enhance the learning and communication process (lecture and seminar).

AERO 410. National Security Forces in Contemporary American Society  
*Prerequisite: AERO 311. (3 credits)*  
Focuses on the Armed Forces as an integral element of society. Provides examination of a broad range of American civil-military relations, and the environmental context in which defense policy is formulated. Special themes include: societal attitudes toward the military; the role of the professional military leader-manager in a democratic society; the fundamental values and socialization processes associated with the Armed Services; the requisites for maintaining adequate national security forces; policy, economic, and social constraints on the national defense structure; the impact of technological and international developments on strategic preparedness; the manifold variables involved in the formulation and implementation of national security policy.

AERO 411. National Security Forces in Contemporary American Society  
*Prerequisite: AERO 410. (3 credits)*  
This course is a continuation of AERO 410 which examines the role of the military in contemporary American society. The course covers current issues affecting the military in the aftermath of the end of the Cold War and the lessons learned from the recent war in the Persian Gulf. Finally, AERO 411 prepares officer cadets for future active duty services by explaining what is expected of them as professional military officers and how to prepare for the transition into the Air Force. Instruction is conducted via lecture and discussion.

MILSCI (Army Officer Education Program)

MILSCI 101. Introduction to Officership  
*Prerequisite: none. (1 credit)*  
Develops an understanding of the U.S. Army. Introduces the critical military leadership skills used by the Officer Corps of the Army. Topics include: customs and traditions of the service, organization of the Army, and the officer corps’ role in the service of the country. Students have the opportunity to participate in various military skills training such as rappelling, land navigation, orienteering, briefing techniques, and physical fitness classes. There is no obligation to the military associated with this class.

MILSCI 102. Introduction to Leadership  
*Prerequisite: none. (1 credit)*  
Learn/apply principles of effective leading. Reinforce self-confidence through participation in physically and mentally challenging exercises with upper division ROTC students. Develop communication skills to improve individual performance and group interaction. Relate organizational ethical values to the effectiveness of a leader. Participation in a weekend exercise is optional, but highly encouraged.

MILSCI 201 (UC 203). Innovative Tactical Leadership  
*Prerequisite: none. (1 credit)*  
The focus of this course is to develop the students’ basic understanding of military leadership. The course focuses on current military leadership theory and its organizational application. It includes discussions of leadership styles, principles of leadership, human behavior, principles of motivation, ethics, counseling, communications and the military problem solving process. It also incorporates
leadership assessment training and discussions of how leadership influences the achievement of organizational goals.

MILSCI 202 (UC 204). Leadership in Changing Environments
Prerequisite: none. (1 credit)
Examines the challenges of leading in complex contemporary operational environments. Dimensions of the cross-cultural challenges of leadership in a constantly changing world are highlighted and applied to practical Army leadership tasks and situations.

MILSCI 301 (UC 301). Leading Small Organizations I
Prerequisite: permission of Chairman. (2 credits)
Series of practical opportunities to lead small groups, receive personal assessments and encouragement, and lead again in situations of increasing complexity. Uses small unit tactics and opportunities to plan and conduct training for lower division students both to develop such skills and as vehicles for practicing leading. Two hours and a required leadership lab, plus required participation in three one-hour sessions for physical fitness. Participation in one weekend exercise is also required.

MILSCI 302 (UC 302). Leading Small Organizations II
Prerequisite: MILSCI 301/UC 301; permission of Chairman. (2 credits)
Continues methodology of MILSCI 301/UC 301. Analyze tasks; prepare written or oral guidance for team members to accomplish tasks. Delegate tasks and supervise. Plan for and adapt to the unexpected in organizations under stress. Examine and apply lessons from leadership case studies. Examine importance of ethical decision making in setting a positive climate that enhances team performance. Two hours and a required leadership lab, plus required participation in three one-hour sessions for physical fitness. Participation in one weekend exercise is required.

MILSCI 401 (UC 401). Leadership and Management
Prerequisite: MILSCI 302/UC 302; permission of Chairman. (2 credits)
Plan, conduct, and evaluate activities of the ROTC cadet organization. Articulate goals and put plans into action to attain them. Assess organizational cohesion and develop strategies to improve it. Develop confidence in skills to lead people and manage resources. Learn/apply various Army policies and programs in this effort.

MILSCI 402 (UC 402). Military Professionalism and Professional Ethics
Prerequisite: MILSCI 401/UC 401. (2 credits)
MILSCI 402 is an interdisciplinary course that integrates history, political science, ethics and morality, law, leadership and management. The course helps prepare students to ethically lead and manage complex organizations by focusing on the moral, ethical, legal and regulatory aspects of being a commissioned officer in the US Army.

MILSCI 499. Independent Study-Directed Readings
Prerequisite: permission of instructor. (1-4 credits)
Directed reading or research in consultation with a member of the Army Officer Education faculty.

NAVSCI (Navy Officer Education Program)

NAVSCI 101. Introduction to Naval Science
Prerequisite: none. (2 credits)
An introductory look at the organizational structure of the naval service. Attention is concentrated on leadership and management principles as they apply to the naval service and the shipboard organization. Additional subjects to be covered are military justice, and Navy policies and procedures.
NAVSCI 102 (UC 101). Seapower and Maritime Affairs  
*Prerequisite: none. (2 credits)*  
This course focuses on the historical role of sea power, emphasizing the U.S. Navy. Topics include: development of naval power and applications as an instrument of foreign policy; historical relationship of navies with their respective domestic, political, and economic environment; and the rise of U.S. as a maritime power.

NAVSCI 201 (NAVARCH 102). Introduction to Ship Systems  
*Prerequisite: none. (3 credits)*  
Types, structures and purposes of ships. Ship compartmentation, propulsion systems, auxiliary power systems, interior communications, and ship control. Elements of ship design to achieve safe operations, and ship stability characteristics. The course is taught in a lecture format with limited discussion. In addition to class sessions, there are several laboratory sessions which illustrate applications of the theories and concepts learned in the classroom.

NAVSCI 202 (EECS 250). Electronic Sensing Systems  
*Prerequisite: Prior or concurrent enrollment in Physics 240 (or 260) or EECS 230. (3 credits)*  
Introduction to properties and behavior of electromagnetic energy as it pertains to naval applications of communication, radar, and electro-optics. Additional topics include sound navigation and ranging (SONAR) tracking and guidance systems, and computer controlled systems. Several laboratory demonstrations will illustrate applications of the theories and concepts learned in the classroom.

NAVSCI 203 (UC 205). Leadership and Management  
*Prerequisite: NAVSCI 101 & 102 or Permission of Instructor. (3 credits)*  
This course is specifically designed to teach introductory-level leadership and management concepts and applications to sophomore-level university students. The course starts with a basic overview of leadership and management, and then moves into basic skills including professional reading, writing, briefings, problem solving, team building, situational leadership, morality, ethics, and communications. After the basic skills are covered, the curriculum explores leader-subordinate and peer relationships, while taking an in-depth look at professional and unprofessional relationships. The course emphasized ethics in leadership and management and explores subjects in power and influence, counseling, supervision, accountability, responsibility, and core values.

NAVSCI 301 (ASTRO 261). Navigation  
*Prerequisite: none. (3 credits)*  
The purpose of this course is to educate students in all aspects of marine navigation, from getting a vessel underway from port through open ocean navigation using both celestial and electronic means. The content of the course is divided into three major areas. The first section focuses on piloting, emphasizing the safe navigation of vessels in coastal waters. This section provides an introduction to navigational instruments and aids to navigation. The second section concerns celestial navigation, the ability to determine position through observation of celestial bodies. Students learn how to determine position based on the use of the sextant and various almanacs and mathematical tables. The third section of the course considers electronic navigation.

NAVSCI 302. Naval Operations  
*Prerequisite: NAVSCI 301. (3 credits)*  
A study of the international and inland rules of the nautical road, relative motion vector analysis, relative motion problems at sea, formation tactics, and ship employment. Also included is an introduction to naval operations and operations analysis, ship behavior and characteristics in maneuvering, applied aspects of shiphandling, seamanship, and afloat communications.

NAVSCI 310 (UC 310). Evolution of Warfare  
*Prerequisite: none. (3 credits)*  
Introduction to the history, development and innovations in warfare. The student acquires a general background and insight into the effect that society and technology has had on the evolution of
warfare. There is a critical analysis of the changes in warfare, the changes in the views on war, and the thoughts and actions of military leaders and writers.

**NAVSCI 402 (UC 403). Leadership and Ethics**

*Prerequisite: NAVSCI 203 or Permission of Instructor. (2 credits)*

Exploration of Western moral traditions and ethical philosophy in topics to include military leadership, core values, and professional ethics. NAVSCI 410 (UC 410). Amphibious Warfare Prerequisite: none. I (3 credits) (Offered Fall of odd years) Exploration of the history, development, and techniques of amphibious operations to enable the student to acquire a general background in amphibious operations.
Technical Communications Courses

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin Website: [https://bulletin.engin.umich.edu/courses/course-info/](https://bulletin.engin.umich.edu/courses/course-info/)

200 Level Courses

**TCHNCLCM 215. Technical Communication for Electrical and Computer Engineering**  
Prerequisite: Engineering 100, Corequisite: EECS 215. (1 credit)  
Professional communication to the general public, managers and other professionals about electrical and computer engineering ideas. Functional, physical and visual/diagrammatic description. Report writing about circuits, signals and systems, including description and analysis. Job letters and resumes. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

**TCHNCLCM 281. Technical Communication for Computer Science and Engineering**  
Prerequisite: Engineering 100, Corequisite: EECS 281. (1 credit)  
Introduction to professional communication for computer scientists and engineers. Communication to managers and programmers about data structures, algorithms and programs. Coding conventions and documentation. Functional and visual/diagrammatic descriptions. Letters of transmittal and reports on software systems. Job letters and resumes. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

300 Level Courses

**TCHNCLCM 300. Technical Communication for Electrical and Computer Science**  
Prerequisite: Engineering 100. (1 credit)  
Professional communication to the general public, managers and other professionals about electrical and computer engineering ideas as presented in written reports and oral presentations. Functional, physical and visual/diagrammatic description; job letters and resumes. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

**TCHNCLCM 380. Technical Communication in IOE**  
Prerequisite: preceded or accompanied by IOE 366 and 373. (2 credits)  
Successful professional and technical communication commands a wide range of skills, including critical inquiry, analysis and collaboration. Through regular practice, feedback, reflection and revision, this course examines technical communication principles and how to apply them in IOE environments. Specifically, the course emphasizes strategies for effective argumentation and persuasion as well as effective language use and style in written reports and oral presentations intended for IOE audiences. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)

400 Level Courses

**TCHNCLCM 401. Special Topics Strategic Planning & Proposal Writing**  
Prerequisite: junior or senior standing. (4 credits)  
Student teams provide expert consulting services to community service organizations. Team assignments include preparing an environmental scan, a strategic plan and a grant proposal. Special emphasis is given to oral communication, writing to effect organizational change, design and management of large documentation projects, major designs reviews and creative thinking. [CourseProfile (ATLAS)](https://bulletin.engin.umich.edu/courses/course-info/)
TCHNCLCM 450. Web Page and Site Design  
*Prerequisite: junior or senior standing. (4 credits)*
Practical skills and theoretical principles necessary to design effective WWW pages and sites, including HTML, tools for creating Web pages, graphics, scripting, animation, multimedia (practical skills) and information design, visual design and theoretical principles (theory). Design and analysis of Web sites. [CourseProfile (ATLAS)]

TCHNCLCM 496. Advanced Technical Communication for Electrical Engineering and Computer Engineering  
*Requisites: TC 300 Co-Requisites: Senior Design Course. (2 credits)*
Development of advanced communication skills required of electrical and computer engineers and managers in industry, government and business. Design and writing of reports, proposals and memoranda on complex technical material for diverse organizational audiences. Preparation and delivery of organizational oral presentations and briefings. [CourseProfile (ATLAS)]

TCHNCLCM 497. Advanced Technical Communication for Computer Science  
*Prerequisite: TechComm 300 Co-Requisites: Major Design Experience Course in Computer Science. (2 credits)*
Advanced technical communication for computer science. Design and writing of user and task analysis, requirements documents, specifications, proposals, reports and documentation, all aimed at diverse organizational audiences. Preparation and delivery of final oral presentations and written project reports. [CourseProfile (ATLAS)]

TCHNCLCM 498. Technical and Professional Writing for Industry, Government, and Business  
*Prerequisite: senior or graduate standing. (3 credits)*
Development of the communication skills required of engineers and managers in industry, government and business. Focus on (1) the design and writing of reports and memoranda that address the needs of diverse organizational audiences and (2) the preparation and delivery of organizational oral presentations and briefings. Writing and speaking about design and research problems in terms that will satisfy both specialists and non-specialists. A series of short explanatory papers and speeches leading up to a final formal report and public lecture. [CourseProfile (ATLAS)]

TCHNCLCM 499. Scientific and Technical Communication  
*Prerequisite: permission of Technical Communication faculty. (elective credit only)*
Conferences and tutorial sessions that provide opportunities for students with special interests to work on a tutorial basis with a member of the Technical Communication faculty. Not intended as substitutes for regularly scheduled courses. Conference and signed contract required with an instructor about the proposed study before enrollment possible. (Directed Study contract forms and additional information are available from the Technical Communication office.) [CourseProfile (ATLAS)]

500 Level Courses

TCHNCLCM 575. Directed Study  
*Prerequisite: permission of instructor. (to be arranged)*
Conferences and tutorial sessions for students with special interests. May be taken for 1-4 credit hours as arranged by the instructor. [CourseProfile (ATLAS)]

600 Level Courses

TCHNCLCM 610. Technical & Professional Communication For Graduate Students  
*Advisory Prerequisite: Graduate Standing. (3 credits)*
Writing instruction and tailored one-on-one support for students’ specific writing projects and needs.
Recent projects include dissertation proposals and chapters, postdoctoral applications, journal articles, and conference presentations. Students will bring materials to workshop; this course does not have separate deliverables. CourseProfile (ATLAS)

**TCHNCLCM 675. Directed Study**  
*Prerequisite: graduate standing, permission of instructor. (to be arranged)*  
Conferences and tutorial sessions for students with special interests. May be taken for 1-4 credit hours as arranged by the instructor. CourseProfile (ATLAS)

**UARTS Courses**

*For more information regarding course equivalencies please refer to the Course Equivalency section, under "How to Read a Course Description", in the CoE Bulletin*  
Website: https://bulletin.engin.umich.edu/courses/course-info/

### 100 Level Courses

**UARTS 150. Introduction to the Creative Process**  
*Prerequisite: None. (4 credits)*

Introduction to Creative Process is a 4 credit hour project-based and writing course for first-year students who are residents of Living Arts. This course affords students the opportunity to understand how the creative process manifests across disciplines and provides students with the opportunity to work on a collaborative, multi-disciplinary project that leverages multiple fields of study toward the production of a short video game. Each team member will be encouraged to use this opportunity to both hone their existing forms of expertise as well as explore less familiar disciplines. Students will gain an understanding of the creative process through readings; reflect on those readings in writing; and experiment with creative processes first-hand under the tutelage of experts.

This course also fulfills the First Year Writing requirement with an emphasis on argumentative-based writing in a number of modalities. The writing assignments offer students the opportunity to deepen their creative practice by exploring ideas related to creativity through close-reading skills, research in various disciplines, and reflection.

### 200 Level Courses

**UARTS 250. Creative Process**  
*Prerequisite: None. (4 credits)*

Process is to de-mystify creativity for students in all U-M units and years: to teach students that creativity is not a character trait or an event, but a process — one that will challenge their sense of competence and mastery, but that they can understand and eventually master, transforming both themselves and their work.

**UARTS 260. Introductory ArtsEngin Project**  
*Prerequisite: None. (2-5 credits)*

Team-based exploration of innovation, creativity and collaboration using mentored interdisciplinary project, research, or studio work. Students from different disciplines will integrate knowledge from their previous courses, knowledge of the design, creative process or research of their respective disciplines, and professional skills (e.g., teamwork, project planning, communications, etc.).
UARTS 290. Special Topics in University Arts  
*Prerequisite: None. (1-4 credits)*  
Special topics of current interest selected by faculty.

### 300 Level Courses

UARTS 360. Intermediate ArtsEngin Project  
*Prerequisite: None. (2-5 credits)*  
Team-based exploration of innovation, creativity and collaboration using mentored interdisciplinary project, research, or studio work. Students from different disciplines will integrate knowledge from their previous courses, knowledge of the design, creative process or research of their respective disciplines, and professional skills (e.g., teamwork, project planning, communications, etc.).

UARTS 390. Special Topics in University Arts  
*Prerequisite: None. (1-4 credits)*  
Special topics of current interest selected by faculty.

### 400 Level Courses

UARTS 460. Advanced ArtsEngin Project  
*Prerequisite: None. (2-5 credits)*  
Team-based exploration of innovation, creativity and collaboration using mentored interdisciplinary project, research, or studio work. Students from different disciplines will integrate knowledge from their previous courses, knowledge of the design, creative process or research of their respective disciplines, and professional skills (e.g., teamwork, project planning, communications, etc.).

UARTS 490. Special Topics in University Arts  
*Prerequisite: None. (1-4 credits)*  
Special topics of current interest selected by faculty.

### 500 Level Courses

UARTS 550. Creative Process  
*Prerequisite: None. (4 credits)*  
This course provides a conceptual and experiential foundation for the cultivation of creativity within and across academic disciplines. It is designed to prepare UM students to recognize, understand, articulate, and utilize their creative abilities in their chosen field.

UARTS 560. Graduate ArtsEngin Project  
*Prerequisite: None. (2-5 credits)*  
Team-based exploration of innovation, creativity and collaboration using mentored interdisciplinary project, research, or studio work. Students from different disciplines will integrate knowledge from their previous courses, knowledge of the design, creative process or research of their respective disciplines, and professional skills (e.g., teamwork, project planning, communications, etc.).
UARTS 590. Creative Process

Prerequisite: None. (4 credits)
Special topics of current interest selected by faculty.