College of Engineering
at the
University of Michigan

BULLETIN
2024-2025

MICHIGAN ENGINEERING
UNIVERSITY OF MICHIGAN

As part of one of the nation's leading public research universities, our engineering programs, students, instructors, and collaborations have a world-class reputation.

Our academic approach combines technical depth with lateral thinking and collaboration across disciplines. We want our graduates to embody **equity-centered values** – seeking out different perspectives and global worldviews. We are committed to engaging our entire community, learning and growing together.

The online Michigan Engineering Bulletin is an academic resource that reflects the most up-to-date information available and is updated as changes are made to the curriculum.

Bulletin Resources

- **Academic Calendar & Deadlines**
- **Introduction and General Information**
- **Admissions**
- **Academic Rules**
- **Undergraduate Education**
- **Graduate Education**
- **Course Guide**
- **Departments & Units**

Archived Bulletins

About the Bulletin

The 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 may follow a subsequent Bulletin. This determination, however, should be made in conjunction with the program advisor.

To view past versions of the Michigan Engineering 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 any questions.

Contact

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

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Academic Calendar

Academic Calendar

*Please note, the academic calendar for the 2023-2024 academic year can be found on the 2023-2024 Archived Bulletin.

The action of updating a class grading basis from Graded to Audit is unavailable via the Late Drop/Add/Edit/Swap System and must be done prior to the third week deadline using a Late Drop/Add/Edit/Swap Form found on the Forms page.

*Were you looking for deadlines?

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

Fall 2024

Classes Begin	Aug 26, Monday
Labor Day (holiday)	Sept 2, Monday
Fall Break	Oct 14-15, Monday-Tuesday
Thanksgiving Recess	Nov 27, Wednesday
Classes resume 8:00am	Dec 2, Monday
Classes end	Dec 9, Monday
Study Days	Dec 10, Tuesday and Dec 14-15, Saturday-Sunday
Examinations	Dec 11-13, Wednesday-Friday and Dec 16-18, Monday-Wednesday
Fall Term ends	Dec 18, Wednesday
Commencement	Dec 15, Sunday

Winter 2025

Classes Begin	Jan 8, Wednesday
Martin Luther King, Jr. Day (University Symposia, No regular classes)	Jan 20, Monday
Winter Vacation begins at 12:00 noon	Mar 01, Saturday
Classes resume 8:00am	Mar 10, Monday
University Honors Convocation	Mar 16, Sunday
Classes end	Apr 22, Tuesday
Study Days	Apr 23, Wednesday; Apr 26-27, Saturday-Sunday
Examinations	Apr 24-25, Thursday-Friday; & Apr 28-May 1, Monday-Thursday
Winter Term Ends	May 1, Thursday

Commencement Activities	May 2-4, Friday-Sunday

Spring/Summer 2025

Classes begin	May 6, Tuesday
Memorial Day (holiday)	May 26, Monday
Juneteenth (holiday)	June 19, Thursday
Classes end (Spring Half Term)	June 20, Friday
Study Days	June 21-22, Saturday-Sunday
Examinations	June 23-24, Monday-Tuesday
Spring Half Term ends	June 24, Tuesday
Classes begin (Summer Half Term)	June 26, Thursday
Independence Day (holiday observed)	July 4, Friday
Classes end 5:00pm	Aug 12, Tuesday
Study Day	Aug 13, Wednesday
Examinations	Aug 14-15, Thursday-Friday
Full & Summer Half Terms end	Aug 15, Friday

*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 the Office of the Provost website.

Dearborn Campus – for registration and academic calendar information, visit the University of Michigan-Dearborn Registration website.

Flint Campus – for registration and academic calendar information, visit the University of Michigan-Flint Office of the Registrar website.

Deadlines

Undergraduate

Click here for **2024-2025** downloadable version.

The action of updating a class grading basis from Graded to Audit is unavailable via the Late Drop/Add/Edit/Swap System and must be done prior to the third week deadline using a Late Drop/Add/Edit/Swap Form found on the Forms page.

Fall Term 2024 *(2510)*

Student online submission–Deadline ends at 11:59 PM!

Fall First 7 week classes begin — Monday, August 26
Fall First 7 week classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Monday, September 09
Fall First 7 week classes drop and pass/fail deadline without SSC Petition — Monday, September 30
Fall First 7 week classes end — Friday, October 11

Fall Full term classes begin — Monday, August 26
Fall Full Term classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Monday, September 16
Fall Full term classes drop and pass/fail deadline without SSC Petition — Monday, October 28
Fall Full term classes end — Monday, December 09

Fall Second 7 week classes begin — Wednesday, October 16
Fall Second 7 Week classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Wednesday, October 30
Fall Second 7 week classes drop and pass/fail deadline without SSC Petition — Wednesday, November 20
Fall Second 7 week classes end — Monday, December 09

Winter Term 2025 *(2520)*

Student online submission–Deadline ends at 11:59 PM!

Winter First 7 week classes begin — Wednesday, January 08
Winter First 7 week classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Wednesday, January 22
Winter First 7 week classes drop and pass/fail deadline without SSC Petition — Wednesday, February 12
Winter First 7 week classes end — Friday, February 28

Winter Full term classes begin — Wednesday, January 08
Winter Full term classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Wednesday, January 29
Winter Full term classes drop and pass/fail deadline without SSC Petition — Wednesday, March 19
Winter Full term classes end — Tuesday, April 22

Winter Second 7 week classes begin — Monday, March 10
Winter Second 7 week classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Monday, March 24
Winter Second 7 week classes drop and pass/fail deadline without SSC Petition — Monday, April 14
Winter Second 7 week classes end — Tuesday, April 22

Spring Term 2025 *(2530)*

Student online submission–Deadline ends at 11:59 PM!

Spring Half term classes begin — Tuesday, May 6
Spring Half term classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Tuesday, May 20
Spring Half term classes drop and pass/fail deadline without SSC Petition — Tuesday, June 10
Spring Half term classes end — Friday, June 20

Spring/Summer Term 2025 *(2540)*

Student online submission–Deadline ends at 11:59 PM!

Spring/Summer Full term classes begin — Tuesday, May 6
Spring/Summer Full term classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Tuesday, May 27
Spring/Summer Full term classes drop and pass/fail deadline without SSC Petition — Tuesday, July 8
Spring/Summer Full term classes end — Tuesday, August 12

Summer Term 2025 *(2550)*

Student online submission–Deadline ends at 11:59 PM!

Summer Half term classes begin — Thursday, June 26
Summer Half term classes last day to audit/drop without "W" on official transcript and without need for Late/Drop/Add/Swap/Edit — Thursday, July 10
Summer Half term classes drop and pass/fail deadline without SSC Petition — Thursday, July 31
Summer Half term classes end — Tuesday, August 12

These deadlines are subject to change. 04.02.24

The academic calendar and course registration dates are the same for CoE and Rackham and can be viewed at the Office of the Registrar Calendars website.

Graduate

The academic calendar and course registration dates are the same for CoE and Rackham and can be viewed at the Office of the Registrar Calendars website.

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

College of Engineering's Master of Engineering (MEng) Apply for Graduation and Graduation Deadlines

Rackham Master's and Certificate Apply for Graduation and Graduation Deadlines

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

About the 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.

Archived Bulletins

About the College

Engineers for a better world

As part of the nation's number one public research university, our engineering programs, students, instructors, and collaborations have a world-class reputation.

Our academic approach combines technical depth with lateral thinking and collaboration across disciplines. We want our graduates to embody equity-centered values – seeking out different perspectives and global worldviews. We are committed to engaging our entire community, learning and growing together.

Highlights of our unique academic environment

- Fourteen highly ranked engineering departments with growing faculty headcount and student enrollment
- On a campus with leading business, medical and liberal arts colleges, we share buildings with social scientists, auto manufacturers, doctors and artists
- The country's first engineering/arts living-learning community
- Hundreds of student organizations and competitive teams
- 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

- Partnership with Shanghai Jiao Tong University, and other academic institutions on six continents
- One of the nation's most successful centers of entrepreneurship
- Numerous student research opportunities across the university

More Michigan Engineering facts and figures.

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.

Read more about our vision, mission, and values.

A community where everyone can be heard

We are committed to creating an environment where all members of our community enjoy a high-quality educational experience – where personal interactions, classroom experiences, and research activities are free from harassing and discriminatory behaviors.

We are determined to investigate and address any allegations of misconduct that might occur.

For more information and to learn how to report an incident, please contact our Office of Student Affairs and explore these U-M resources.

- Report a Concern
- Report Sexual and Gender-Based Misconduct.
- The University of Michigan Non-discrimination Policy

Information about in-state tuition rates

The University of Michigan's tuition structure is two-tiered, reflecting resident and nonresident rates. To be eligible to pay in-state tuition rates, a student must demonstrate compliance with the University's Residency Classification Guidelines.

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

The University of Michigan, Michigan Engineering 2023-2024

The University of Michigan

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Donna Fry, *Interim Chancellor, University of Michigan-Flint*

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Kevin Pipe, *Associate Dean for Undergraduate Education*

Mingyan Liu, *Associate Dean for Academic Affairs*

The Regents of the University of Michigan

Jordan B. Acker, Huntington Woods

Contacts

University of Michigan Offices (area code 734)

Admissions, Undergraduate, 1220 Student Activities Bldg. (SAB)	764-7433
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	764-8312
Employment:	
Student, 2500 Student Activities Building (SAB)	763-4128 936-4000
Hospital, 2901 Hubbard, Suite 1100	615-2000
Recruitment and Employment, G250 Wolverine Tower	
Temporary Staffing Services, G250 Wolverine Tower	
Financial Aid, 2500 SAB	763-6600
Graduate School, Rackham Bldg., 915 E. Washington	764-8129
Rackham Admissions	764-4400
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, 3190 Ruthven Bldg.	764-6270
Office of Student Conflict Resolution, 100 SAB	763-3000
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	763-5900
Student Legal Services, 715 N. University, Suite 202	763-9920
University Health Service, 207 Fletcher	764-8325
University Health Service: **Appointments** **Information**	764-8320
Veterans and Military Services Program (VMSP), 1100 LSA	764-6413
Veterans Benefits, Office of the Registrar, 1207 LSA	763-9066

Michigan Engineering Offices (area code 734)

General Information	647-7000
Academic Records and Services (Withdrawal/Disenrollment), 145 A Chrysler Center	647-7111
CAEN (Computing & IT), Main Office, 2161 Duderstadt Center	764-CAEN
CAPS Embedded Counselor, Engineering, 145 B Chrysler Center, 145 C Chrysler Center	764-8312
Counseling, Assistance and Resources in Engineering Center (C.A.R.E Center), 129 Chrysler Center	615-1405
Office of Culture, Community and Equity (OCCE), 1101 LEC	647-7120
Center for Entrepreneurship (CFE), 3350 Duderstadt Center	763-1021

Engineering Career Resource Center (students and alumni), 230 Chrysler Center	647-7160
Engineering Center for Academic Success (ECAS), 273 Chrysler Center	615-8438
Engineering Advising Center (EAC), 230 Chrysler Center	647-7106
Engineering Scholarship Office, 143 Chrysler Center	647-7113
Engineering Student Organizations, 143 Chrysler Center	615-5728
Integrative Systems + Design, 2214 SI-North	647-7024
International Programs in Engineering Office (IPE), 245 Chrysler Center	647-7129
Multidisciplinary Design Program (MDP), 203 Gorguze Family Laboratory	763-7421
Office of Student Affairs (OSA), 143 Chrysler Center	647-7118
Office of Recruitment, 153 Chrysler Center	647-7101
Scholastic Standing Committee, 230D Chrysler Center	647-7106
Undergraduate Education, 1261 LEC	647-7150
Wilson Student Team Project Center	615-6400
Women in Science & Engineering Program (WISE), 3236 Undergraduate Science Building	615-4455

All Department & Program Course Guides

How to Read a Course Description

Course Guides:

- Aerospace Engineering (AEROSP)
- Applied Physics (APPPHYS)
- Biomedical Engineering (BIOMEDE)
- Chemical Engineering (CHE)
- Civil and Environmental Engineering (CEE)
- Climate and Space Sciences and Engineering (CLIMATE & SPACE)
- Electrical Engineering and Computer Science (EECS)
  - Electrical & Computer Engineering (ECE)
  - Computer Science & Engineering (CSE)
- Engineering Division (ENGR)
- Entrepreneurship (ENTR)
- Industrial and Operations Engineering (IOE)
- Integrative Systems + Design (AUTO, DESCI, ESENG, ISD, MFG)
- Macromolecular Science and Engineering (MACROMOL)
- Materials Science and Engineering (MATSCIE)
- Mechanical Engineering (MECHENG)
- Military Officer Education Program (AERO, MILSCI, & NAVSCI)
- Naval Architecture and Marine Engineering (NAME)
- Nuclear Engineering and Radiological Sciences (NERS)
- Robotics (ROB)
- Technical Communications (TCHNCLCM)
- UARTS (UARTS)

Archive

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.

100	First-year-level courses
200	Sophomore-level courses
300	Junior-level courses
400*	Senior-level courses
500	Predominantly Graduate-level courses
600	Graduate-level courses and above

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 their 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

The phrase "or equivalent" may no longer be considered as part of any prerequisite for any course. The specific courses must be listed. 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 no longer be considered as part of the statement of prerequisites for any course. 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.

Representative 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.

Archived Bulletins

- 2023-2024 Bulletin (PDF)
- 2022-2023 Bulletin (PDF)
- 2021-2022 Bulletin (PDF)
- 2020-2021 Bulletin (PDF)
- 2019-2020 Bulletin (PDF)
- 2018-2019 Bulletin (PDF)
- 2017-2018 Bulletin (PDF)
- 2016-2017 Bulletin (PDF)
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- 2007-2008 Bulletin (PDF)
- 2006-2007 Bulletin (PDF)
- 2005-2006 Bulletin (PDF)
- 2004-2005 Bulletin (PDF)
- 2003-2004 Bulletin (PDF)

Admissions

Admissions

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.

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

Graduate Admissions

Admission is competitive for all master's and doctoral programs. Among other criteria, admission is determined by:

- Department, degree and concentration of interest
- Transcripts of an applicant's academic record
- Graduate Record Examination (GRE) general test scores
- Letters of recommendation
- An applicant's Grade Point Average (GPA)

For detailed admission criteria and information on how to apply, visit the Graduate Recruiting and Admissions website.

Accepted Credit

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
AP Student College Board website (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 the 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.*

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**.

Foreign Languages

Credit by test (e.g. Advanced Placement, A-Level and International Baccalaureate) can be used to satisfy Intellectual Breadth requirements. Foreign language credit by test at the 200- level or higher counts toward the Liberal Arts Course (LAC) 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.

The CoE no longer grants 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.

"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 know.

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. toward a minor with a language requirement).

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.

Second Bachelor's Degree

Students already in possession of a bachelor's degree should consider a master's degree or Ph.D. in engineering. The College of Engineering will admit second bachelor's degree students in very rare and exceptional circumstances and if there is room at the transfer level. The College of Engineering prioritizes 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 has the 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.

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 Undergraduate Recruitment 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.

Note: International students are not eligible for the NCFD process.

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 Undergraduate Recruitment. 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.

Readmission

A student who is not enrolled for 12 months or more must apply for readmission through the Office of Undergraduate Recruitment, 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 who left the College of Engineering in good academic standing and have not been enrolled for more than 5 years must create and have approved a re-entry plan prior to being readmitted. If the student was undeclared at the time of last enrollment, the re-entry plan should be developed in consultation with the Engineering Advising Center. If the student was declared at the time of last enrollment, the re-entry plan should be developed in consultation with a departmental advisor. All re-entry plans must be approved by the ADUE.

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 Undergraduate Recruitment, 153 Chrysler Center, 2121 Bonisteel Boulevard, Ann Arbor, MI 48109-2092 at engin-our@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 Undergraduate Recruitment.

A student whose enrollment has been withheld because of poor academic performance must first petition for Reinstatement to the Scholastic Standing Committee. Petitions are available on the ECAS Petitions website.

Note: Students that transfer to another 4-year institution to pursue a bachelors degree do not retain their right as a Michigan Engineering student to return. They will be considered as a transfer student when they reapply for readmission.

Academic Rules

Academic Definitions

Visit/Audit

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, tests, 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 is the third week for full term courses, second week for half-term courses, as well as 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. Petitions are available online. 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:

Term	Months
Fall	Sept., Oct., Nov., Dec.
Winter	Jan., Feb., Mar., Apr.
Spring/Summer	May, June, July, Aug.

The Spring-Summer term may be scheduled as two half terms, approximately as follows:

Term	Months
Spring	May, June
Summer	July, Aug.

Course Offerings

The appropriate Bulletin and the Schedule of Classes 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.

Work Load

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

The College expects students to attend courses regularly and arrive on time. Unexcused absences can negatively affect the final course 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.

Registration

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 according to the polices outlined in the "Term Withdrawal'' section of the CoE Bulletin page for Transferring Out, Withdrawals, Readmission. 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 or submit an email to engineering-ro@umich.edu:

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

Indebtedness to the University

Students shall pay all accounts due to 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 periods. 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. See the Deadlines CoE Bulletin page for further information.

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 deadline. Fee adjustments are finalized through the University of Michigan Registrar's Office.

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

Updated deadlines regarding Course Withdrawals and the usage of the Add/Drop/Edit/Swap system may be viewed on the Undergraduate Drop/Edit Deadlines page of the CoE Bulletin.

Declare/Change Major

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, with the exception of Computer Science & Engineering. Please see the below section titled, “Declaring a Computer Science & Engineering Major” for further information. 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.

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.

Declaring a Computer Science & Engineering Major

In addition to the criteria for major declaration mentioned in the above section, due to capacity constraints, students who are admitted to the University of Michigan for Fall 2023 or later must also be selected for the Computer Science major before they can declare that major. Students admitted to enroll prior to Fall of 2023 will be able to declare a major in Computer Science without the need for the additional selection process.

Please review the CS Majors Selection Process FAQs for further information. You may also contact csugadmissions@umich.edu.

Transferring Out, 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 Rm 2200 Student Activities Building; via e-mail (WolverineServices@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 the Third-week deadline*****:** Students must report to the College Registrar's Office (145A Chrysler Center) or submit an email to engineering-ro@umich.edu from their student email account, which requests a term withdrawal and includes the student's name and UMID number. The term is fully removed from the academic record. No documentation is needed.
- ***Third-week deadline to the Ninth-week deadline in Fall/Tenth-week deadline in Winter*****:** Students must report to the College Registrar's Office (145A Chrysler Center), or submit an email to engineering-ro@umich.edu from their student email account, which requests a term withdrawal and includes the student's name and UMID number; a "W" will appear for each course. No documentation is needed.
- ***Ninth-week deadline in Fall/Tenth-week deadline in Winter to the last day of classes*****:** Students must report to the Scholastic Standing Committee Office (273 Chrysler Center) or email SSCResponse@umich.edu from their student email 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 the 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)*****:** Students 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. To review Incomplete Grading policies, see the Grades and Scholastic Standing page of the Bulletin.
- 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 drop. You must petition the Scholastic Standing Committee to drop a class after the ninth week of a Fall term, tenth week of a Winter term, or fifth week for a half term, which can be accessed **here**.

Students withdrawing after the ninth-week deadline in Fall, tenth-week deadline in Winter 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 Undergraduate Recruitment, 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 **engin-our@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 Undergraduate Recruitment.

A student whose enrollment has been withheld because of poor academic performance must first petition for Reinstatement to the Scholastic Standing Committee: **Petitions – Engineering Center for Academic Success**.

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.

Academic Rules, Student Conduct and Rights

General Standards of Conduct for Engineering Students

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

Being a successful member of the College of Engineering community involves intense, spirited innovation, and 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 takes the active involvement of all of our community members to create an environment that values our diverse community 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 their 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 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.

The College of Engineering Honor Code

College of Engineering Honor Code Prepared by the Engineering Honor Council and Faculty Committee on Discipline

To the Faculty and Students of the College of Engineering:

The Honor Code is part of our lives in the College of Engineering. The standards for personal integrity demanded by the Honor Code are a reflection of the standards of conduct expected of engineers. These standards allow fairness among students to ensure that no unfair advantage is gained and an equal learning opportunity is given to all students. Not only does the faculty have trust in the students with the implementation of their course policies, but the students have trust in one another. While the College of Engineering is a competitive environment, the College also holds an honorable environment in which students receive credit for their efforts and determination. For over 100 years the Honor code has been an indication of the mutual trust that characterizes student-faculty relationships in the College.

Alumni of the College of Engineering have a truly outstanding record of accomplishments. We are convinced that this is in part due to the professional attitude fostered by the standards of the Honor Code. The Honor Code is a basic part of your everyday life at the College of Engineering, University of Michigan.

In 1915, the students of the College of Engineering petitioned for the establishment of an Honor Code. The Code was promptly adopted with faculty approval in 1916 and has since been basic to life in the College of Engineering. The Honor Code outlines certain standards of ethical conduct for persons associated with the College of Engineering at the University of Michigan. The policies of the Honor Code apply to graduate and undergraduate students, faculty members, and administrators.

The Honor Code is based on these tenets:

i. Engineers must possess personal integrity both as students and as professionals. They must be honorable people to ensure safety, health, fairness, and the proper use of available resources in their undertakings.

ii. Members of the College of Engineering community are honorable and trustworthy persons.

iii. The students, faculty members, and administrators of the College of Engineering trust each other to uphold the principles of the Honor Code. They are jointly responsible for precautions against violations of its policies.

iv. It is dishonorable for students to receive credit for work that is not the result of their own efforts.

I. Responsibilities of the Engineer

Faith of the Engineer, a statement widely accepted by the professional engineering societies, contains pledges that are relevant to the Honor Code of the College of Engineering:

"As an Engineer, I will participate in none but honest enterprise. To those who engage my services, an employer or client, I will give the utmost of performance and fidelity.

"Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

"To my fellows, I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession."

The Fundamental Canons for Engineers, as it appears on the National Society of Professional Engineers website.

Engineers, in the fulfillment of their professional duties shall:

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 reputation and usefulness of the profession.

II. Applications of the Honor Code

The Honor Code is intended to support and enforce course policies in the College of Engineering. Course instructors have exceptional latitude when preparing the policies for their courses. This can lead to variations between policies of different courses. It is the instructor's responsibility to craft the course policies in accordance with the doctrine of the Honor Code.

Students are responsible for understanding the Honor Code and its implementation in the College of Engineering. Because the specific policies of different faculty members can vary significantly, it is the responsibility of faculty members to specify their policies in writing at the beginning of each semester. Students are responsible for understanding these policies and should consult the instructor if they are unclear. The Honor Code supports the individual course policy, whatever it may be.

If a student feels that their instructor is not doing what the Honor Code calls for, the student should contact the instructor or a member of the Honor Council to discuss this, and consider further steps, if needed.

Students of the College of Engineering enrolled in other colleges must abide by the policies of the school or college in which the course is offered. Any suspected policy violations will be referred to the appropriate authorities of the school in question.

Students who are not members of the College of Engineering and who take a course offered by the College are bound by the policies of the Engineering Honor Code. Any suspected policy violations will be referred to the Engineering Honor Council and Faculty Committee on Discipline. The appropriate authorities of the school or college of the students involved will be notified.

All alleged Honor Code violations may be investigated by either a member of the Honor Council or the Honor Council Administrative Team.

When Taking an Examination

The Honor Code holds that students are honorable and trustworthy people and encourages them to behave with integrity in all phases of university life. During examinations, the instructor is available for questions, but the examination is not proctored.

The instructor will announce the time and place of the examination. At the start of the examination, the instructor's whereabouts during the exam will be communicated to the class in case a question arises.

Students have the right to have at least one empty seat between themselves and their neighbors. This helps ensure comfort during the examination and reduces the temptation to cheat. It is the instructor's responsibility to ensure that there is adequate seating beforehand, and to obtain additional rooms if necessary.

During the examination, students are free to leave the room. Minimal essential conversation is allowed. However, no communication regarding the examination is allowed inside or outside the room. All questions about the examination should be directed to the instructor.

It is the instructor's responsibility to inform the class prior to the examination if aids, such as calculators, notes, or textbooks, are allowed during the examination.

After each examination, students must write the Honor Pledge in their test books and sign their names under it. The Honor Pledge is as follows:

"I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code."

Instructors are not required to grade tests in which the signed Honor Pledge does not appear. The Honor Code remains enforced whether or not the student signs the Pledge.

Use of Computers and Other Facilities

Each department in the College of Engineering establishes its own general policies on the use of computers, laboratories, and other facilities. In addition, students should observe any specific instructions appearing in computer rooms, laboratories, or libraries.

Students may not submit as their own work a computer program or part thereof which is not the result of their own thought and efforts. Contributions to a program from external sources must be acknowledged and properly documented in accordance with the course policies.

Students may not attempt to access or tamper with the class account of another student unless permission to do so has been given by both the class instructor and the student to whom the account is assigned.

Computers available for students to use are the property of the University of Michigan. Software available for students to use is the property of the University of Michigan or is licensed to the University of Michigan. Any unauthorized attempt to copy software or to tamper with computers or software is a violation of federal law, as well as the Honor code.

All laboratories, classrooms, office equipment, and libraries are meant for instruction and learning. Misuse of these facilities is a violation of the Honor Code.

Homework and Laboratory Assignments

The principles of the Honor Code apply to homework and laboratory assignments as well as to examinations. The instructor may allow collaboration among students on such assignments. The instructor is to make clear how much, if any, collaboration is permissible. The instructor may also require that students write and sign the Honor Pledge on their homework and lab reports.

It is a violation of the Honor Code for students to submit, as their own, work that is not the result of their own labor and thoughts. Work that includes material derived in any way from the efforts of another author, either by direct quotation or paraphrasing, should be fully and properly documented. To avoid plagiarism, it is necessary to cite all sources of both ideas and direct quotations, including those found on the internet. The basic principle is to provide enough information so that the original source of the material can be located. The University of Michigan English Language and Literature Department website provides a thorough discussion of plagiarism.

University Documents

Official academic forms and records are the property of the College of Engineering and/or the University of Michigan. Tampering, alteration, or other misuse of these documents is a violation of the Honor Code, as is submitting falsified or altered documents.

Course Registration

The University Registrar's Office provides students with a registration date in accordance with their own policies. Registering for a course, or asking another student to register for a course, in order to hold a seat for yourself or someone else is a violation of the Honor Code.

III. The Engineering Honor Council

The Engineering Honor Council is composed of students from the College of Engineering. The primary purpose of the Honor Council is to investigate suspected violations of the Honor Code.

Members of the Engineering Honor Council also visit classes every year to answer questions about the Honor Code and acquaint students with its ideals. Openings may occur on the Honor Council as members graduate and leave the University. At such times, the Honor Council accepts membership applications from students, and arranges interviews with prospective members. The Honor Council can be contacted at coehcmembers@umich.edu Also, see the Honor Council website.

IV. Reporting Honor Code Violations

The Honor Code works to the benefit of students, instructors, and administrators in the College of Engineering at the University of Michigan. It is based on the mutual trust that all those bound by it will uphold its principles and enforce its policies.

However, this makes it the duty and responsibility of students and instructors to report promptly any suspected violations of the Honor Code. The College of Engineering Honor Code requires that students take the following steps if a violation of the Honor Code is observed:

1) Obtain the names of the people involved.

2) Inform the instructor of the incident. To ensure uniformity and fairness, the instructor is required to take the appropriate actions in accordance with the Honor Code if the instructor feels there is just cause to do so.

3) If the instructor refuses to submit the case for an investigation, the student may contact the Associate Dean for Undergraduate Education who will refer the case to the Honor Council.

If the instructor becomes aware of the possible violation of the Honor Code, it is their responsibility to contact the Associate Dean for Undergraduate Education (273 Chrysler Center 2121 Bonisteel Blvd, Ann Arbor, Michigan; honorcouncil-admin@umich.edu) to report this accusation. **Suspected Honor Code violations must be reported no later than two months after the end of the term in which the potential violation occurred**.

The Honor Council will investigate the suspected violation. The student and any witnesses to the incident may be asked to recall their impressions and thoughts concerning the case when they appear at the inquiry. The Honor Council will report its findings and make a recommendation to the Faculty Committee on Discipline.

NOTE: The proceedings of the Honor Council are confidential. Therefore, the students and faculty involved are obligated to refrain from discussing the case with persons not directly involved in the case. Disclosure of confidential information is a violation of the Honor Code.

V. Being Accused of an Honor Code Violation

If a student is suspected of an Honor Code violation, the following steps will be taken:

1) The instructor is instructed to report a grade of 'I' to the accused student while the student is under investigation. Once the case has been resolved, a final grade will be assigned.

2) If the violation is reported while the full Honor Council is adjourned for the Spring and Summer terms a case may be processed via a shortened traditional process by meeting directly with the Faculty Committee on Discipline. Respondents who elect to not participate in this abridged Spring/Summer process will have their cases handled as soon as possible when cases resume being heard in the Fall semester.

3) An Honor Council member will be assigned to investigate the allegations. At this time, the accused student is given written notice of the suspected violation. The investigating member will go over the evidence with the accused student and ask for an explanation of the incident. The accused student has the right to request another investigator if the student feels uncomfortable with the investigator originally assigned to the case.

4) Accused students are invited to prepare a brief written statement for use in their defense, if they feel that this is necessary.

5) The Honor Council will invite the student to appear before the Council when it considers all the evidence. At that time, the student will be given a second written notice of the suspected violation. The student will be asked to describe actions and motivations relevant to the incident. If the student fails to appear for the hearing, the Honor Council has the right to pass judgment in their absence.

The accused student has the right to waive the Honor Council hearing and go directly to the Faculty Committee on Discipline. The student must first meet with their assigned Honor Council investigator before this option is available.

6) The Honor Council will make a recommendation to the Faculty Committee on Discipline regarding the responsibility of the accused, and a suitable sanction, if applicable. The student will be notified of the recommendation and the reasons for the decision.

7) The Faculty Committee on Discipline will review the recommendation made by the Honor Council. The Committee will ask the student to appear for the hearing. If the student fails to appear for the hearing, the Committee has the right to pass judgment in the absence of the student. The Faculty Committee will render a decision and will notify the student by written communication. The student may appeal the Committee's decision to the Executive Committee of the College.

8) 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.

9) Missed deadlines for community service sanctions can result in withholding your registration and/or your diploma.

VI. Decision of an Honor Code Violation

The Honor Council investigates each suspected violation of the Honor Code and recommends action to the Faculty Committee on Discipline. Appointments to the Committee are rotated to ensure representation of all Engineering departments. The Faculty Committee considers the recommendations of the Honor Council and follows up with appropriate disciplinary action. The decision of the Committee is ordinarily final. It may, however, be appealed to the Executive Committee of the College of Engineering on the following grounds:

- Proper procedures were not followed;
- Sanctions are not consistent with past practice;
- There is new evidence not reasonably available at the time of hearing before the Faculty Committee on Discipline.

The College of Engineering Executive Committee shall not review findings of fact made by the Faculty Committee on Discipline.

The College of Engineering Executive Committee has sole discretion to determine if sufficient grounds exist for consideration of an appeal.

If the request for appeal has merit, the College of Engineering Executive Committee shall review the appeal as soon as practical after it has been filed and will give the student, along with the Chair/Associate Chair of FCD, an opportunity to address the Committee in person.

Following the review, the College of Engineering Executive Committee may sustain or reverse the finding of an Honor Code violation. If the finding of academic dishonesty stands, the Committee may sustain, modify, or increase the sanction imposed. The student will be informed by email/letter of the Committee's decision.

Students have 1 week from the receipt of their Honor Code decision to submit their letter of appeal to the Executive Committee.

Completed appeal letters should be emailed to the Honor Council Administrator at honorcouncil-admin@umich.edu and should be addressed c/o: Professor Kevin Pipe Associate Dean for Undergraduate Education College of Engineering University of Michigan

Cases involving suspected violations on the part of students registered in another school taking an Engineering course, or involving Engineering facilities, will be reviewed by the Engineering Honor Council and Faculty Committee on Discipline. The appropriate authorities of the school or college of the students involved will be notified.

When graduate students are suspected of Honor Code violations, the College of Engineering Honor Code process will be followed. In addition, communications will be sent to the Dean of Rackham School or Graduate Studies.

Protection of the Suspected Student

During the Honor Council hearing, the suspected student deals at first only with other students. This creates an atmosphere where the case can be stated fully without any inhibitions caused by the presence of faculty members or administrators. Although the hearings are confidential, the suspected student may bring a friend or advisor. The College of Engineering maintains records of all Honor Code convictions. However, all Honor Council and Faculty Committee on Discipline records are strictly confidential and are kept separate from the student's regular file.

Conclusion

The students, faculty, and administrators of the College of Engineering believe that living under the guidance of the Honor Code contributes to the success of engineers from the University of Michigan. Each student admitted to the College of Engineering is subject to the tenets of the Honor Code. Students are reminded that the principles on which the Honor Code rests apply to life in the professional world as well as on campus. Students enrolled in the College of Engineering are expected to conduct themselves in such a manner as to be a credit to the University and to the community, and most importantly, to themselves.

A student who wishes 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, which means that the final class grade would be lowered by a third of a grade, such as going from a B+ to a C-.)
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 Engineering Center for Academic Success, 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 actions.
8. Expedited review of potentially "Not Responsible" respondents as the result of expedited hearing information collected.

- In a case with multiple students, the respondent may identify those students they believe to be potentially not responsible.
- 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.
- 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.
- 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 Engineering Center for Academic Success, 273 Chrysler Center and on the College of Engineering website: Honor Code Pamphlet.

Sanctioning Policies

To have consistency among decisions rendered by either the expedited or traditional Honor Code case proceedings, the following guidelines represent previous case precedent in assigning sanctions. These are considered to be the minimally punitive actions by the College of Engineering and are dictated as such for consistency in sanctioning. Additional restorative sanctioning including but not limited to reflective essays, letters of apology, and educational seminars are considered to be appropriate additional restorative actions for all violations of *The Honor Code*.

Home programs of any student taking a College of Engineering class will be notified providing the program has a Memorandum of Understanding with the College of Engineering. Home programs may increase or add sanctions.

Sanctions for common first-time violations:

This category of sanctioning represents the most common responses to violations of *The Honor Code* that do not directly violate *The Statement,* described in the next section*.* These sanctions are to be prescribed as they are considered the minimum punitive actions in the scenarios below. In most cases, a first-time violation does not result in a notation on a respondent's transcripts. Please note this is not an exhaustive list but covers the most common responses for actions of inappropriate collaboration, copying/plagiarism, or seeking an unfair advantage.

If a respondent **was enrolled** in the course during the term in which the violation occurred the following sanctions are considered standard minimum sanctions.

- A grade/score of a zero for the entirety of any homework, assignment, project, or test where the submitted product was not entirely of the respondent's creation.
- A ⅓ letter grade decrement on the respondent's final course grade (eg. a grade reduction from an "A-" to a "B+").

If the respondent was **not enrolled** in the course during the term in which the violation occurred the following sanctions are considered standard minimum sanctions.

- 10 hours of community service to be completed before graduation.

If the respondent has graduated, was **not enrolled** in the course during the term in which the violation occurred, and assisted in the resolution of the case (eg: by providing an admission of responsibility, removing their work from public forums, or assisting investigators in identifying the distribution of work to resolve a case) no further sanctions are required.

Supplemental sanctions can be assigned when the student admits to actions that otherwise may have infringed upon the rights of another student. In these occurrences, a student may have gained access to another student's work without their explicit permission (eg. looking at another student's work, copying or taking files without permission, or photographing/ screen capturing work without the other party's permission).

- A 1,000 word reflective essay on a topic most closely related to the offense in question.
- A letter of apology to the aggrieved party.

Sanctions for common second-time violations:

This category of sanctioning represents the most common responses to violations of *The Honor Code* that do not directly violate *The Statement* when a student has been found responsible for a second separate course or case.

A second incident is defined as any action deemed in violation of *The Honor Code* that a respondent engages in after having had the opportunity to meet with a member of *The Honor Code* stakeholder team (the Honor Council, Faculty Committee on Discipline, or the Engineering Center for Academic Success). For example, a student meets with a member of the ECA Steam to admit responsibility for a violation of *The Honor Code*. Any act that violates *The Honor Code* after that meeting would be considered a second offense. However, an act that violates *The Honor Code* that has occurred prior to that meeting but reported after that meeting would be collectively considered a first-time offense for sanctioning purposes.

These sanctions are to be prescribed as they are acceptable punitive actions in the scenarios below. Please note this is not an exhaustive list but covers the most common responses for actions of inappropriate collaboration, copying/ plagiarism, or seeking an unfair advantage.

- A notation of the respondent's transcript indicating that they have been found responsible for violating *The Honor Code*.
- Public disclosure of their current and previous violations upon request by 3rd parties.

If a respondent **was enrolled** in the course during the term in which the violation occurred the following sanctions are considered standard minimum sanctions.

- A grade/score of a zero for the entirety of any homework, assignment, project, or test where the submitted product was not entirely of the respondent's creation.
- A 2/3 letter grade decrement on the respondent's final course grade (eg. a grade reduction from an "A" to a "B+").

If the respondent was **not enrolled** in the course during the term in which the violation occurred the following sanctions are considered standard minimum sanctions.

- 20 hours of community service to be completed before graduation.

Guidelines for acceptable administrative actions for second violations.

- Probationary status placed on the respondent's records if the action was not a repeated offense.
- Suspension: repeating violations but repentant actions displayed by the respondent.
- Expulsion: repeating violations and unrepentant actions displayed by the respondent.

Sanctions for violations that explicitly violate *The Statement* and/or for those who have violated *The Honor Code* more than two times:

This category of sanctioning represents the most common responses to violations of *The Honor Code* that also directly violate *The Statement.* These are acts that are beyond a simple occurrence of copying or misinterpretation of class policy wherein a respondent is accused of actions that directly infringe upon the rights of others or have become habitual (eg: threats towards, forcibly taking another student's work through malicious means such as hacking or theft, fabrication of records, assuming another individuals identity, violating *The Honor Code* more than twice). This is a similar sanctioning standard by LSA's conduct teams.

If a respondent were to deny a specific action that is potentially a violation of *The Statement*, the action itself should be reported to the Office of Student Conflict Resolution for an impartial review. Honor Code case proceedings may continue in parallel up to the Faculty Committee on Discipline. Final FCD determinations should be postponed until a determination is made by OSCR so all evidence can be considered.

These sanctions are to be prescribed as they are considered the minimum punitive actions in the scenarios below.

- A notation of the respondent's transcript indicating that they have been found responsible for violating *The Honor Code*.
- Public disclosure of their current and previous violations upon request by 3rd parties.

If a respondent **was enrolled** in the course during the term in which the violation occurred the following sanctions are considered standard minimum sanctions.

- A grade/score of a zero for the entirety of any homework, assignment, project, or test where the submitted product was not entirely of the respondent's creation.

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 of Michigan-Ann Arbor (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, and must also take responsibility for according the same right to others.

Students have the right to be treated fairly and with dignity regardless of race, color, national origin, age, marital status, sex, sexual orientation, gender identity, gender expression, disability, religion, height, weight, or veteran status, and as revised in the University of Michigan Nondiscrimination Policy. The University has a long-standing tradition of commitment to pluralistic education. Accordingly, the University, through this Statement of Student Rights and Responsibilities (the Statement), will not unlawfully discriminate on the basis of protected 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, the Division of Student Life will proactively inform new students of the Statement, including, 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. Related procedures are outlined in VI.2.B. Adaptable Conflict Resolution.

Student Responsibilities

Along with rights come certain responsibilities. Students at the University of Michigan-Ann Arbor (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.

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 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:

Letter Grades	Honor Points
A+	4.0
A (excellent)	4.0
A-	3.7
B+	3.3
B (good)	3.0
B-	2.7
C+	2.3
C (satisfactory)	2.0
C-	1.7
D+	1.3
D	1.0
D-	0.7
E (not passed)	0.0
ED (unofficial drop)	0.0

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, a notation of "I," if not replaced by an I plus the passing grade, lapses to "E" the last day of classes for the next full term and, for graded elections, is computed into the term and cumulative grade point average.
    - Requests for Incompletes must meet both of the following criteria:
      - Request is made *before* the end of the term (last day of classes) *(Exceptions are possible for extenuating circumstances that occur after the last day of classes.)*
      - Student has already finished at least 70% of coursework
  - 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 the 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)

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 academic term order of election. Any course that is offered only on a pass/fail basis will not be counted in the above totals.

1. 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 passing 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).
2. 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.
3. 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.
4. 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 with the exception of a course with a minimum grade of "C" for an enforced prerequisite (See CoE Course Guide for these courses).
   - 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:
   - The course is not required for any program or department.
   - 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.

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 ENGR 100, ENGR 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

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

Incompletes (denoted on the transcript as "I") may be reported to indicate that the course has not been completed. Situations can include:

- Student is unable to complete any assignment/exam assigned in the course (due to illness or cause beyond the student's control)
- Final grade is temporarily withheld by the instructor

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."

Requests for Incompletes **must** meet both of the following criteria:

- Request is made *before* the end of the term (last day of classes) *(Exceptions are possible for extenuating circumstances that occur after the last day of classes.)*
- Student has already finished at least 70% of coursework

Instructors are not obligated to grant the request and should only give consideration if the above criteria is met and they are willing to support the student to completion of the requirements.

If an Incomplete is agreed upon, both the student and instructor should mutually understand the reasons for the "I" mark and methods and timelines for completion of work, using the Student-Instructor Incomplete Agreement Form, to be filed with the student's academic advisor.

The required work may be completed and the grade submitted by the instructor whether or not the student is enrolled in the subsequent term. (**Students do not need to re-enroll in the course to finish an Incomplete. If the student chooses to retake the class in its entirety rather than finish the Incomplete, they are encouraged to submit a retroactive withdrawal petition).**

The student should plan to complete the work as soon as possible. To secure credit, the required work must be completed no later than 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, with an "I" remaining next to the grade. 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 lapsed to an E), which factors into the grade point average as a failing grade and no credit is received. Incomplete extensions must be arranged with the instructor. Forms are available on the College of Engineering Registrar's Office website.

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.****Graduation:** If a student has an Incomplete the term they are expected to graduate, the student will need to complete the work by the degree conferral date. 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

Unless a course is designated as repeatable, a student CANNOT repeat a course for credit that they have already passed (A+ through C, P, CR or S grade was earned). In exceptional cases, this rule may be waived by submitting a Petition for an Exception to College Rules through the Scholastic Standing Committee. If waived, and the student received a grade of C or above, a NFC (Not For Credit) code will be applied to the second attempt, unless the course is approved for repetition. Students will have no MSH, CTP, MHP, or GPA. If a student receives an NFC code for a course, there will be no financial aid.

For students with a grade of C- through D- letter grade, then the repetition of this course will receive a REP code. (No CTP, yes MSH, MHP). Grades of E, F, NC, or U will receive a REP code. (Yes CTP, MSH, MHP).

Grade Earned in Prior Attempt	Code associated with repeat	Will a repeat attempt count toward CTP?	Will a repeat attempt count toward MSH & MHP?	Will a repeat attempt count toward GPA?	Will a repeat attempt count toward Financial Aid?
A+ through C (may not be repeated unless approved)	NFC (Not for Credit)	No	No	No	No
C- through D-	REP (Repeat)	No	Yes	Yes (P/F – No)	Yes*
E, F, NC, or U	REP (Repeat)	Yes	Yes	Yes (P/F – No)	Yes*
Repeatable course which has exceeded the credit limit rule (maximum number of times it can be taken)	NDC (Not for degree credit)	No	Yes	Yes	No

***Please note:** Financial Aid will cover one REP attempt of a course (not NDC or NFC), but not additional attempts beyond that. Please see details on Repeated Classes and Financial Aid.

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.

Honor Point Deficit Calculator

(Michigan Semester Hours x 2) – Michigan Honor Points = 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): 25.6 MHP / 16.00 MSH = 1.600 GPA.

The term honor point deficit is calculated by multiplying MSH by 2 and subtracting MHP: (16.00 MSH x 2) – 25.60 MHP = 6.4 honor point deficit.

Thus, this student needs 6.4 credits of "B" grades to raise their term GPA above 2.00.

Academic Honors and 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.

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 and Professional 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 student success and the 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

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 their 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

A student will have the notation "Enrollment Withheld" placed on 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 – Engineering Center for Academic Success) requesting reinstatement. The student must meet with 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 – Engineering Center for Academic Success.

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 **ECAS Progress Report website**. 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 – Engineering Center for Academic Success**. 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 – Engineering Center for Academic Success**.

* 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.

Deadlines

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 their 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:
   - 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.)
   - By Advanced Placement Program examination for college-level work completed in high school (See "Advanced Placement," under "Admission.")
   - By an examination regularly offered by a department of the University, or by a recognized testing service
   - By transfer of equivalent credit from another recognized college (See "Adjustment of Advanced Credit.")
   - By demonstrating competence in a higher-level course or series covering similar material (e.g., honors-level)
   - 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 their 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 toward the 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 Credit 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 a 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 their 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:
   - 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 one year on the Ann Arbor campus (one term if originally admitted as an external transfer student)
   - 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. The minimum of 14 additional credit hours in pertinent technical subjects must be beyond the requirements of each individual degree separately, not 14 additional credit hours on top of the requirements of both degrees. Students can

double count some courses as specified in the below section titled, "Double Counting Courses." The 14 additional technical subject credits do not need to be upper-level (300+), they can be any level (100+). Technical electives must be taken as a graded option and cannot be taken as P/F.

3. Students are encouraged to carefully consider whether a relevant graduate degree would be more appropriate than a second undergraduate degree. To obtain both a B.S.E. and M.S.E. degree from the College of Engineering, refer to the program requirements under **Combined Bachelor's and Master's Programs** for details. 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 bachelor's degree with a school or college outside of the College of Engineering on the University of Michigan – Ann Arbor campus, refer to the guidelines under Multiple Dependent Degree Programs (MDDP) section on the **Degree Options** page of the Bulletin.

Please note: A dual major combination of CS-Eng with DS-Eng is not allowed.

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. No course can count towards more than one requirement within a BSE program. Double counting a course for credit towards more than one requirement is not allowed. A single course can qualify to meet the requirements of multiple sections of the BSE, but must formally count towards one requirement.
4. 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.
5. 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.
6. 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
Information about Degree Options

Fees & Debt

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 Fall, Winter and Spring/Summer semester, or 6 hours per Spring or Summer 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.

Withdrawal

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.

Transfer Credit

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. 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. **CoE will evaluate future transfer courses based on content and not format (i.e. stop disqualifying courses simply because they are online). Pre-approved courses that are taught online will be accepted without further evaluation.** Transfer evaluations are generally conducted by the Department that owns the equivalent course.

For CoE undergraduate enrolled students, please send your official transcript to:

College of Engineering, Office of Undergraduate Recruitment

153 Chrysler Center
2121 Bonisteel Boulevard
Ann Arbor, MI 48109-2092

Electronic transcripts can be emailed directly to **engincredit@umich.edu**. These PDF transcripts must be sent directly from an institution or third-party vendor such as Parchment. Transcripts cannot come from the student directly as they would not be considered official. Electronic transcripts can be emailed directly to **engincredit@umich.edu**.

Please note that students who are **transferring in credit for their final term prior to graduation** must be active participants 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 Chrysler Center 143H.

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

LSA Policy on Transfer General Credit

This credit type, TRGENCR departmental level does not meet any specific degree requirements but does apply to the overall number of credits required for a degree.

This type of credit is given to LSA students (and students in some other undergraduate programs) when a course does not directly match a U-M Ann Arbor course or match departmental credit or interdepartmental credit. This credit type does not meet any specific degree requirements but does apply to the overall number of credits required for a degree. More information can be found on the LSA transfer credit website.

CoE is NOT accepting these courses. These courses will be listed as not transferable, effective May 2024, and will affect CoE transfer students as well as CoE cross campus students.

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 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.
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.

Undergraduate Transfer

Undergraduate Education

Undergraduate Education

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.

Objectives

A University of Michigan undergraduate engineering graduate will be prepared to generate value for society through a lifetime of technical and professional creativity. Our graduates will display reasoning skills and proficiency in problem definition, problem-solving and quantitative expertise, a respect for measurement and data and the wisdom of experience. Our graduates will use these skills to achieve the following objectives within a few years of graduation:

- Contribute to technical engineering practice.
- Pursue graduate education in engineering or science, either following a path towards a professional masters degree and practice, or a doctoral degree.
- Pursue careers in business, education, medicine, law or other fields, bringing engineering problem solving skills—honed through practice in problem definition and quantitative problem solving—to bear in those disciplines.

Michigan Engineers will excel in all of these areas of endeavor. They will also be prepared to become successful leaders, managers, entrepreneurs and humanitarians.

Our graduates must understand that solutions, especially for society's most critical needs, are not just technical in scope but depend on many disciplines working together, and that as engineers their core contribution will include bringing data-driven, quantitative problem solving skills to the table. We also understand that our students have many varied aspirations and that our primary duty is to provide them with a foundational education that they can carry forward into any of the career paths they may follow over the decades of their careers.

To prepare our students for the careers of the 21st century, whether they continue in engineering or pursue other paths after graduation, our undergraduate programs support our students in developing:

- An understanding of the fundamental knowledge in a discipline.
- An ability to recognize and define a problem, and the vision to see a solution.
- An ability to identify, understand, and solve ill-defined problems even in the face of uncertainty and imperfect information.
- Strong quantitative and qualitative problem-solving skills.
- A mindset and skills that support continued learning both during and long after their CoE career.
- Personal attributes of success including the following professional skills:
    - Communication
    - Creativity
    - Empathy
    - Entrepreneurial Mindset
    - Ethics
    - Global & Cultural Awareness
    - Grit, Persistence, Resilience
    - Leadership
    - Lifelong Learning
    - Risk – Ability to Accept and Manage
    - Systems Thinking – Authentic Problem Solving
    - Teamwork
- An understanding of the human, social and environmental dimensions of engineering practice.
- A drive and capability to make a difference by bringing their solutions into production.
- An understanding that Engineering, as a discipline that seeks to improve the common good, should be inclusive and equitable not only in its engineering outcomes but also its participants.

Many of the College's undergraduate degree programs are accredited by the Accreditation Board for Engineering and Technology (ABET). Each such program has statements of educational objectives and outcomes that are based on the College's mission and on the needs of its constituents. Those constituents include our alumni, students, employers of our students and the graduate schools at which many of our students later study.

Student Outcomes

Graduates of the College's undergraduate programs will possess an ability to (Engineering Accreditation Commission Student Outcomes):

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
- 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.
- Communicate effectively with a range of audiences.
- 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.
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
- Acquire and apply new knowledge as needed, using appropriate learning strategies.

Curricular Information in the Bulletin

In this edition of the College of Engineering *Bulletin*, our traditional "Sample Schedule for Required Programs" has been updated to reflect the current undergraduate engineering curriculum and curricular plans in each department and program. It is important to note that the curriculum revision process is an ongoing one; therefore, the program requirements and specific course requirements, especially upper-division courses, listed here should be viewed as works-in-progress. Always confirm your course plan with your academic advisor. Upon entering the College, undeclared students will be assigned an advisor in the Engineering Advising Center. After declaring a degree program, a student's advising home moves to that program's Advising Office. Each department's Program Advising Office and website information has been provided for your assistance in determining specific program changes.

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

Core Courses and 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 their 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.)
4. Engineering 101 or Engineering 151 (ENGR 151 is an approved alternative to ENGR 101 for all College of Engineering (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. No course can count towards more than one requirement within a BSE program. Double counting a course for credit towards more than one requirement is not allowed. A single course can qualify to meet the requirements of multiple sections of the BSE, but must formally count towards one requirement.
4. 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.
5. 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.

6. 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.

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.

***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).** *Be sure to consult with the Office of Recruitment 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

Engineering 101 focuses on using your computer to solve engineering problems through computer programming. Many engineering problems involve repetition – getting data and doing the same calculations over and over again. Automating this process, using programming, saves time and minimizes errors in these calculations. Engineers have more and more data to work with, so developing computer programs is now a part of almost every modern engineering project.

One of the core concepts of the course is the concept of an algorithm: a well-defined set of steps that achieves a particular goal. Constructing an algorithm for a given purpose is fundamental in every engineering design task. Algorithms help us break down large, complex problems into smaller problems that we can solve separately and then weave back together to give us a final answer.

In this course, you will learn how to create algorithms for solving engineering problems, and then how to write those algorithms in a programming language that the computer can understand. In this course, we will use two different programming languages: MATLAB for numerical analysis and generating plots of data; and C++ for processing textual data and implementing more complex algorithms that require more decision-making.

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 more information.

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" (some departments are now requiring a C in all math, science, and engineering core courses) 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, PHYSICS 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 Physics 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 (Physics 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 30 credits of college level math and basic sciences, some with an experimental experience. They must also have 45 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

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:

- **16 Intellectual Breadth Credits:** Comprised of Liberal Arts Courses (LACs — defined in the following section of the Bulletin titled, "Definition of Liberal Arts Courses"), including:
  - **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
  - **300-level LAC:** At least 3 credits of LAC must be at the 300 level or higher. Students *may* satisfy the Humanities and 300-level requirements with a single course
  - **(Optional) PCDC** – no more than 4 credits of PCDC (defined in the following section of the Bulletin titled, "Professional or Creative Development Courses"

Professional or Creative Development Courses (PCDC)

Professional and creative development courses are optional and 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 (Bachelor of Science) or NS (Natural Science) 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 Environment and Sustainability (EAS)
- 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)

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 (Humanities) or SS (Social Science) 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 (Bachelor of Science), NS (Natural Science), QR/1 or QR/2 in the LSA course guide.
- A course can count as an LAC or HU if it is not marked BS, NS, QR/1 or QR/2, despite being marked SS or HU, in the LSA course guide. (Note: ECON 101 and ECON 102 are both exceptions to this rule)
- 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.

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****.*

Afroamerican & African Studies	*(AAS)*	*Latin American & Caribbean Studies*	*(LACS)*
Applied Liberal Arts	*(ALA)*	*Linguistics*	*(LING)*

Arab and Muslim American Studies	*(AMAS)*	*Lloyd Hall Scholars for Writing and the Arts*	*(LSWA)*
American Culture	*(AMCULT)*	*Medieval & Early Modern Studies*	*(MEMS)*
Anthropological Archaeology	*(ANTHRARC)*	*Middle Eastern & North African Studies*	*(MENAS)*
Archaeology: Ancient Mediterranean	*(ARCHAM)*	*Middle East Studies*	*(MIDEAST)*
Arabic Language	*(ARABIC)*	*Modern Greek*	*(GREEKMOD)*
Armenian Language	*(ARMENIAN)*	*Museum Studies*	*(MUSEUMS)*
Asian Languages	*(ASIANLAN)*	*Music History and Musicology*	*(MUSICOL)*
Asian Studies	*(ASIAN)*	*Native American Studies*	*(NATIVEAM)*
Asian/Pacific Islander American Studies	*(ASIANPAM)*	*Nursing*	*(NURS)*
Bosnian, Croatian and Serbian	*(BCS)*	*Organizational Studies*	*(ORGSTUDY)*

Classical Archaeology	*(CLARCH)*	*Persian Language*	*(PERSIAN)*
Classical Civilization	*(CLCIV)*	*Philosophy*	*(PHIL)*
College Honors	*(HONORS)*	*Polish*	*(POLISH)*
Communication Studies	*(COMM)*	*Political Science*	*(POLSCI)*
LSA Computation for Arts and Sciences	*(COMPFOR)*	*Portuguese*	*(PORTUG)*
Comparative Literature	*(COMPLIT)*	*Psychology*	*(PSYCH)*
Complex Systems	*(CMPLXSYS)*	*RC Creative Writing and Literature*	*(RCCWLIT)*
Comprehensive Studies Program	*(CSP)*	*RC Humanities*	*(RCHUMS)*
Cultural Anthropology	*(ANTHRCUL)*	*RC Social Sciences*	*(RCSSCI)*
Czech	*(CZECH)*	*RC Social Theory and Practice*	*(RCSTP)*
Digital Studies	*(DIGITAL)*	*Religion*	*(RELIGION)*

Dutch	*(DUTCH)*	*Romance Languages and Literatures*	*(ROMLANG)*
Economics	*(ECON)*	*Romance Linguistics*	*(ROMLING)*
Education	*(EDUC)*	*Russian*	*(RUSSIAN)*
English Language and Literature	*(ENGLISH)*	*Russian, East European & Eurasian Studies*	*(REEES)*
Environment	*(ENVIRON)*	*Scandinavian*	*(SCAND)*
French	*(FRENCH)*	*Slavic*	*(SLAVIC)*
Film, Television, and Media	*(FTVM)*	*Sociology*	*(SOC)*
Geography	*(GEOG)*	*South Asian Studies*	*(SAS)*
German	*(GERMAN)*	*Southeast Asian Studies*	*(SEAS)*
Greek	*(GREEK)*	*Information*	*(SI)*
History	*(HISTORY)*	*Slavic Languages and Literatures*	*(SLAVIC)*
History of Art	*(HISTART)*	*Sociology*	*(SOC)*

Institute for the Humanities	*(INSTHUM)*	*Spanish*	*(SPANISH)*
International Studies	*(INTLSTD)*	*Science, Technology & Society*	*(STS)*
Islamic Studies	*(ISLAM)*	*Music Theory*	*(THEORY)*
Italian	*(ITALIAN)*	*Theatre and Drama*	*(THTREMUS)*
Judaic Studies	*(JUDAIC)*	*Turkish Language*	*(TURKISH)*
Korean Studies	*(KRSTD)*	*University Courses*	*(UC)*
Latin	*(LATIN)*	*Ukrainian*	*(UKR)*
Latina/o American Studies	*(LATINOAM)*	*Women's Studies*	*(WGS)*

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.

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

The CoE no longer grants 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 have 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.

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

Degree Program	Credits of General Electives
Aerospace Engineering	9
Biomedical Engineering	9
Chemical Engineering	12
Civil Engineering	11
Climate and Meteorology	9
Computer Engineering	13-16
Computer Science	16

Data Science	15
Electrical Engineering	11
Engineering Physics	12
Environmental Engineering	12
Industrial and Operations Engineering	9-12
Materials Science Engineering	12
Mechanical Engineering	9
Naval Architecture and Marine Engineering	8-9
Nuclear Engineering and Radiological Sciences	12
Space Science and Engineering	12

Degree Options

Undergraduate Engineering Degrees

The College of Engineering offers 18 undergraduate programs of study, all of which lead to a Bachelor of Science in Engineering (B.S.E.) degree. Twelve of these programs have specialized accreditation by ABET.

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

Degree Program	Major Department	ABET Accreditation
B.S.E. in Aerospace Engineering	Aerospace Engineering (AEROSP)	EAC
B.S.E. in Biomedical Engineering	Biomedical Engineering (BME)	EAC
B.S.E. in Chemical Engineering	Chemical Engineering (ChE)	EAC
B.S.E. in Civil Engineering	Civil and Environmental Engineering (CEE)	EAC
B.S.E. in Climate and Meteorology	Climate and Space Sciences and Engineering (CLaSP)	No
B.S.E. in Computer Engineering	Electrical Engineering & Computer Science (EECS)	EAC
B.S.E. in Computer Science	Electrical Engineering & Computer Science (EECS)	CAC
B.S.E. in Data Science	Electrical Engineering & Computer Science (EECS)	No
B.S.E. in Electrical Engineering	Electrical Engineering & Computer Science (EECS)	EAC

B.S.E. in Engineering Physics	Nuclear Engineering and Radiological Sciences (NERS)	No
B.S.E. in Environmental Engineering	Civil and Environmental Engineering (CEE)	EAC
B.S.E. in Industrial and Operations Engineering	Industrial and Operations Engineering (IOE)	EAC
B.S.E. in Materials Science and Engineering	Materials Science and Engineering (MSE)	EAC
B.S.E. in Mechanical Engineering	Mechanical Engineering (ME)	EAC
B.S.E. in Naval Architecture and Marine Engineering	Naval Architecture and Marine Engineering (NAME)	EAC
B.S.E. in Nuclear Engineering and Radiological Sciences	Nuclear Engineering and Radiological Sciences (NERS)	EAC
B.S.E. in Robotics	Robotics (ROB)	No
B.S.E. in Space Science and Engineering	Climate and Space Sciences and Engineering (CLASP)	No

EAC: These programs are accredited by the Engineering Accreditation Commission of ABET.

CAC: This program is accredited by the Computing Accreditation Commission of ABET.

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 Registration, Declarations, and Transfer Credit section of the *Bulletin*.

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 Degree Requirements section of the *Bulletin*. The College generally recommends that students consider pursuing some of the many co- and extracurricular activities offered as an alternative to a second College of Engineering 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 one year on the Ann Arbor campus (one term if originally admitted as an external transfer student)
- 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.

Please note: A dual major combination of CS-Eng with DS-Eng is not allowed.

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 engin-our@umich.edu for the required MDDP Form
2. The CoE Office of Undergraduate Recruitment 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.

Please note: The following MDDP combinations are not allowed:

- CS-Eng with DS-LSA
- DS-Eng with CS-LSA

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 year. 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.
8. The following MDDP combinations are not allowed: CS-Eng with DS-LSA, DS-Eng with CS-LSA.

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 Information

Students originally enrolled in an undergraduate degree program in the College of Engineering (CoE) who are admitted to the School of Information (UMSI) 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 unit or the other. These combined degrees are open to students initially enrolled in Engineering who are accepted into the School of Information BSI program.

Students are required to meet regularly with advisors in both UMSI 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 *UMSI BSI Student Handbook* and *CoE Bulletin*. In order to remain in good academic standing in both UMSI 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 Information (B.S.I.) in the School of Information. 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.

Students who are admitted to the BSI program and wish to pursue the MDDP must make this clear to both academic units. Unless this is done, admission to the BSI program can result in the student being disenrolled from the College of Engineering. Like most other dual degree programs, this program will generally require 10 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.

Information about Degree Requirements

Degree Programs

Michigan 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.

Our graduate students have access to nearly 60 master's and doctoral degree programs.

There are 18 courses of study that lead to the Bachelor of Science in Engineering degree (B.S.E.). With 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 additional year.

Engineering students can also explore earning both a bachelor's and a master's degree in approximately five years.

Areas of undergraduate study at Michigan Engineering

- 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
- Robotics

Degrees awarded at the graduate level of study

- 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)
- View the available graduate degrees by discipline.

Departments

- Aerospace Engineering
- Biomedical Engineering
- Chemical Engineering
- Civil and Environmental Engineering
- Climate and Space Sciences & Engineering
- Computer Science & Engineering
- Electrical & Computer Engineering
- Industrial & Operations Engineering
- Integrative Systems + Design
- Materials Science & Engineering
- Mechanical Engineering
- Naval Architecture & Marine Engineering
- Nuclear Engineering & Radiological Sciences
- Robotics

Programs & Units:

- Integrative Systems and Design
- Automotive Engineering
- Design Science
- Energy Systems Engineering
- Global Automotive and Manufacturing Engineering
- Manufacturing Engineering
- Systems Engineering and Design
- Applied Physics
- Engineering Sustainable Systems Dual Degree Program
- Macromolecular Science and Engineering
- Robotics
- Engineering Education Research

Accreditation

The Computer Science program is accredited by the Computing Accreditation Commission of ABET.

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.

Combined Bachelor's and Master's 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)

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

The Sequential Undergraduate/Graduate Study (SUGS) Program is a uniquely cost-effective and efficient way to earn a master's degree. Eligible students enter the program in the first term of their senior year to receive their 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) by double counting and/or transferring courses.

Students complete both degrees in about 5 years, which is significantly shorter than the average time it takes to complete a bachelor's and master's degree separately—usually 6-7 years.

Students apply to the SUGS program at the end of their junior year or early in the first semester of their senior year, and must be enrolled in a minimum of two graduate semesters. The baccalaureate may be awarded upon completion of the undergraduate requirements or concurrently with the master's degree.

Requirements: 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, and can also refer to the Integrative Systems and Design page for MEng programs or the Rackham graduate school page for MSE programs. For a list of SUGS programs by department, please refer to the degree program listings under the B.S.E. home department. Learn more about SUGS and hear from SUGS alumni.

Engineering Global Leadership Honors Program (EGL)

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 required 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.

The EGL program is a specialization offered through the **CoE Honors Program**. Students admitted to the CoE Honors Program who choose a global business/operations focus are eligible to apply to EGL.

Engineering Minors

College of Engineering Policy for Engineering Minors

Undergraduate students enrolled in a College of Engineering (CoE) 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 a 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.
12. Students may not add, complete, or declare a minor after graduation.

Climate and Space Sciences and Engineering Minor

The primary goal of the Climate and Space Sciences and Engineering (Climate and 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 and 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 their program of study for the minor to the Climate and Space undergraduate advisor
- Attained a minimum GPA of 2.0 in the designated courses
- Completed the Climate and 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)
3. 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

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 ancient/extinct language) equivalent to fourth-semester college-level (max of 6 language credits can be counted towards the Minor).
  - 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 (min. 1 credit). 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 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 the IPE International Minor for Engineers website.

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: EECS 216, 230, 270, 320
- Two electives from among the following courses: EECS 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

Paths Option	Required Core	Path Preparation Core	Elective 1	Elective 2
Systems	215	216	351, 455, 460	351, 452, 455, 460, 461 (no duplicates)
Electromagnetics and Optics	215	230	330,334	411, 430, 434, 438, 530
Circuits & Solid State	215	216	311, 312, 320	411, 413, 414, 420, 421, 423, 425, 427, 429

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 decision making. 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.

To declare, please visit the advising calendar.

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 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 "Electives" 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 is built upon participation in multi-term, on-campus, immersive design team experiences for academic credit. This minor is not completed via 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, MRover, M-HEAL, etc.) with permission from the team's faculty advisor and MDP

The Multi-term Design Project can yield degree credit 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 the MDP website.

Other 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)

- Afroamerican 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
- Social Media Analysis and Design
- Sociology of Health and Medicine
- Spanish Language, Literature, and Culture
- Statistics
- Sustainability
- Theatre Design & Production
- Translation Studies
- Ukrainian Language, Literature and Culture
- Urban Studies

- User Experience Design
- 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)
- Minor in Community Action and Social Change (School of Social Work)
- Minor in Education for Empowerment (School of Education)
- Minor in Public Policy (Ford School of Public Policy)
- 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)
- Minor in School of Information
  - Minor in User Experience Design
  - Minor in Social Media Analysis and Design
- Minor in School of Music, Theatre & Dance
  - Minor in Music
  - Minor in Performing Arts Management
  - Minor in Design and Production
  - Minor in Playwriting
  - Minor in Dance

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. Failure to submit a release prior to the deadline will result in removal of the minor/supplemental studies during the graduation clearance process. Incomplete minors/supplemental studies **cannot** be finished after graduation.

Concentrations and Supplemental Studies

College of Engineering Policy for Engineering Concentrations

A concentration within a program allows students in that program to gain recognition for choosing a set of electives that make up a coherent area of study within their program. This takes advantage of the flexibility of elective choices to allow students to focus their educational experience in a way that prospective employers can more easily recognize.

Policies involving Concentrations include:

1. The term “Concentration in <identifier>” will appear in the student’s transcript, but not the diploma.
2. It consists of an approved sequence of courses that are a minimum of 12 credit hours. Courses taken as elective requirements of a program, including general electives may be included in the 12 credit minimum. The 12 credit hours must include at least one course at the 300 or 400 level.
3. A student must earn an overall GPA of at least 2.0 in courses taken to meet the requirements of a concentration.
4. The administrative responsibility for a concentration rests solely with the program advisor for the degree. The program advisor for the degree is responsible for advising and auditing the degree and concentration requirements.
5. The creation of a concentration is a program change, which requires the approval of the faculty.
6. It is recommended that the number of credit hours to obtain a concentration be contained within a usual degree. A concentration that requires additional coursework requires justification.
7. In keeping with the College’s double-counting policy, a course can count toward a concentration regardless of how many majors or minors it is already counting towards.

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 coursework, 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 programs.
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 into 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 an 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.

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 the Program in Global Health Design website.

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 the Associate Dean for 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. Students who declare their intent to participate in FPHSS must fulfill 7 of the 10 credits with courses from the School of Public Health classes. 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

Data-Driven Solutions in Public Health	Name	Credits	Term
ANTHRBIO 363	Genes, Disease, Culture	4	Fall
BIOSTAT 449	Topics in Biostatistics	3	Winter

ENVIRON 310	Environmental Chemicals and Disease	3	Winter
HISTORY 285/ RCSCI 275	Science, Technology, Medicine and Society	4	Winter
MOVESCI 471	Physical Activity Epidemiology	3	Fall & Winter
PUBHLTH 305	The Environment and Human Health	3	Winter
PUBHLTH 310	Nutrition in the Life Cycle	3	Winter
PUBHLTH 311	Introduction to Public Health Genetics	3	Fall
PUBHLTH 370	Public Health Biology and Pathophysiology	3	Fall
PUBHLTH 383	Data Driven Solutions in Public Health	4	Winter
PUBHLTH 401	Exploring the Public Health Spectrum of Cancer: From Prevention to Survivorship	3	Fall
PUBHLTH 403	Obesity: From Cells to Society	3	Fall
PUBHLTH 413	Vaccines in Public Health	3	Winter
PUBHLTH 460	Introduction to Bacterial Pathogenesis	3	Winter

Community and Global Public Health

Number	Name	Credits	Term
ANTHRCUL 344	Medical Anthropology	4	Winter
ANTHRCUL 356/DAAS 358	Topics in Sociocultural Anthropology – section specific	3	Fall & Winter
ANTHRCUL 458	Topics in Sociocultural and Linguistic Anthropology – section specific	3	Fall & Winter
PSYCH 211.004	Project Outreach – section specific, only Health, Illness and Society section counts	3	Fall & Winter
PUBHLTH 300	Behavioral and Social Science Foundations for the Health Professions	4	Winter
PUBHLTH 308	Black American Health: A Focus on Children, Youth, and Families	3	Winter
PUBHLTH 313	LGBTQ+ Health Promotion: Local and Global Strategies	3	Winter
PUBHLTH 350	Global Public Health: Challenges and Transformations	4	Fall
PUBHLTH 360	Community, Culture, and	3	Fall

	Social Justice in Public Health		
PUBHLTH 382	Population Health Determinants and Disparities	3	Winter
PUBHLTH 400	Race and Racism in Public Health	4	Winter
PUBHLTH 402	Changing Health Behaviors: What Works	3	Winter
PUBHLTH 405	Social History of Infectious Disease	3	Fall
PUBHLTH 410	Making Change: public health policy advocacy in principle and practice	3	Winter
PUBHLTH 414	Mental Health	3	Fall
PUBHLTH 450	Critical Reflections on Global Public Health	3	Fall
PUBPOL 475.005	Improving Public Health	3	Fall
SOC 295.002	Topics in Sociology – Epidemics of Inequality: Sociological Dimensions of HIV/AIDS and Covid-19	3	Winter
SOC 475	Introduction to Medical Sociology	3	Fall & Winter

WGS 319	Race, Class and Reproductive Health	3	Winter
WGS 365	Global Perspectives on Gender, Health, and Reproduction	3	Fall
WGS 400	Women's Reproductive Health	3	Winter

For more information please visit the School of Public Health website on the Fundamentals of Public Health Supplemental Studies program.

Experiential Learning

Practice Your Purpose

At Michigan Engineering, a first-rate engineering education is just the beginning.

We have a rich variety of experiential learning opportunities to help you find your niche, connect with people who share your passion and gain hands-on experience that'll set your resumé apart from the stack.

Experiential learning crosses disciplines, crosses oceans, crosses social divides, builds on your classroom skills and puts it all to work in real-world situations. For more information, see the Immersed website.

Opportunities

Arts & Engineering

Engineering Abroad

Human-centered Design

Leadership Development

Organizations and Teams

Research and Teaching

Work Experience

ArtsEngine

ArtsEngine is an interdisciplinary initiative for students and faculty supported by the five North Campus schools and colleges (Engineering; Architecture & Urban Planning; Art & Design; Music, Theatre & Dance; Information). We provide grant funding for interdisciplinary projects and research, co-sponsor campus-wide programs, such as the MPowered Innovation Challenge and the Science as Art competition. We also offer co-taught courses on creativity and collaboration through our UARTS courses, and support the Living ArtsEngine residential community.

ArtsEngine Website

Talk to a human: artsengine@umich.edu | (734)763-2318

Semesters Offered/Recommended: Year Round

Financial: Funding Available

Engineering Abroad

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 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
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 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.

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.

Global Health Design Initiative (GHDI)

The Global Health Design Initiative provides curricular and co-curricular opportunities for undergraduate students to collaborate with stakeholders to define problems and develop and implement solutions to address essential health care challenges.

Global Health Design Initiative (GHDI) Website

Talk to a human: globalhealthdesign@umich.edu | (734) 764-9366

Semesters Offered/Recommended: Year Round

Financial: Assistance available, Some paid opportunities

Human-centered Design

Center for Socially Engaged Design (C-SED)

The Center for Socially Engaged Design empowers students and practitioners with perspectives and skills needed to design effective, socially conscious technology interventions. We believe this requires designers to take into account the fullest social, cultural, economic, and environmental contexts of their design process and to analyze how their own biases shape their approach.

Center for Socially Engaged Design (C-SED) website

Talk to a human: c-sed-info@umich.edu | (734) 764-5298

Semesters Offered/Recommended: Year Round

Financial: No Extra Fees, Funding Available, Paid Experience

Center for Healthcare Engineering & Patient Safety (CHEPS)

CHEPS brings together students from many different backgrounds to collaboratively solve real-world problems in healthcare. Visit our project page for examples of the types of projects that students at CHEPS have the opportunity to work on. We hire students of all degree levels and majors, which include (but are not limited to) engineering, computer science, pre-med, nursing, public health, informatics, business, and humanities.

Center for Healthcare Engineering & Patient Safety (CHEPS) website

Talk to a human: cheps-contact@umich.edu | (734) 763-0799

Semesters Offered/Recommended: Year Round

Financial: Paid Experience

Leadership Development

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**; students with a GPA below 3.6 meet with an honors advisor to establish academic success plans.
- Complete 9 credits of advanced electives in an identified **focus area**, selected in consultation with the capstone supervisor and approved by the Honors Faculty Advisor.
- 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; **students with a GPA below 3.6 are encouraged to apply and will be considered holistically by the admissions committee**
- Submit a portfolio, including an individual development plan.
- Be interviewed and recommended for admission by an admission committee (composed 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 U-M 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**

Organizations and Teams

Student Organizations

University of Michigan Engineering supports 150+ engineering affiliated student organizations. These organizations provide an amazing opportunity to advance leadership, team development, technical skills and engineering knowledge through a wide-variety of hands-on activities, outreach events, and professional development events – all while strengthening a community of peers.

College of Engineering Student Organizations Website

Talk to a human: coe-studentorgsupport@umich.edu | (734) 615-5728

Semesters Offered/Recommended: Year Round

Financial: No Extra Fees

Wilson Student Team Project Center

The Wilson Student Team Project Center is a work space to exercise practical application of engineering knowledge through hands-on development, fabrication and testing. The Wilson Center facilitates idea sharing, collective learning and opportunities for students to develop leadership, management and presentation skills.

Wilson Student Team Project Center website

Talk to a human: WilsonCenter@umich.edu | (734) 615-6400

Semesters Offered/Recommended: Year Round

Financial: No Extra Fees

Women in Science and Engineering

WISE aims to increase the participation by women and gender minorities in academic programs and careers in science, technology, engineering and mathematics, and to foster their future success.

Women in Science and Engineering (WISE) Website

Talk to a human: umwise@umich.edu | (734) 615-4455

Semesters Offered/Recommended: Year Round

Financial: No Extra Fees

Research and Teaching

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 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. UROP Students will also have the opportunity to present their research at UROP's annual symposium.

Students may participate in UROP for academic credit, or they may use their Financial Aid Work-Study award, if available. Students who are enrolled in the College of Engineering and working on projects with Engineering faculty 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 wages 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.

Summer Undergraduate Research in Engineering – SURE (for U-M undergraduate students)

SURE offers summer research internships to outstanding undergraduate students who have completed their sophomore or junior year (preference will be given to those who have completed three years of study) by the time of their internship. Participants have the opportunity to conduct 10-12 weeks of full-time summer research with some of the country's leading faculty in a wide range of engineering disciplines. The program provides opportunities for students to assess their interests and potential in pursuing research at the Masters or Ph.D. level in graduate school. All participants must apply online through the SURE website. Accepted applicants from the University of Michigan receive guidance by a faculty advisor in a College of Engineering research facility, a stipend of $5,000 and attend regular meetings.

For more information, please visit the SURE website.

Work Experience

Center for Entrepreneurship

The CFE is an innovation hub where the ideas, people, resources, and technology meet and create the future. We provide active-learning experiences to all students via ENTR classes and immersive programs designed to translate high-potential projects and ideas into the world. CFE fosters an entrepreneurial mindset by preparing you to identify opportunities, innovate, experiment, build relationships, manage risk, and persevere. You'll learn to create and communicate via these constructs and become better prepared to lead teams that identify – then act to solve – impactful problems.

Center for Entrepreneurship (CFE) website

Talk to a human: entrepreneurship@umich.edu | (734) 763-1021

Semesters Offered/Recommended: Year Round

Financial: Aid Available

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. 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 become 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:
Engineering Career Resource Center

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. Co-op students are also required to complete assignments related to their co-op.

Getting Started

Students interested in the co-op programs should visit the **Engineering Career Resource Center website** or contact the Engineering Career Resource Center co-op coordinator at coe-intern-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

Multidisciplinary Design Program

The Multidisciplinary Design Program provides team-based, "learn by doing" opportunities for 950+ students from across the University every year. With MDP, you can: apply what you learn in class to engineering design challenges; gain the technical and professional skills necessary to thrive in engineering research or professional settings; experience how people from multiple disciplines collaborate within a team.

Multidisciplinary Design Program (MDP) website

Talk to a human: engin-mdp@umich.edu | (734) 763-0818

Semesters Offered/Recommended: Fall/Winter terms. Some projects have summer work opportunities.

Financial: No Extra Fees, some Paid Experience (summer)

Tauber Institute for Global Operations

The Tauber Institute for Global Operations is a program with the University of Michigan's Ross School of Business and College of Engineering, facilitating multidisciplinary education, leadership training and action based learning in cutting-edge operations and supply chain management. Intensive and immersive student-industry team projects are the capstone of the Tauber Institute experience, allowing students to apply their knowledge and teamwork to real-world settings.

Tauber Institute for Global Operations website

Talk to a human:

Bethany Williston, Student Experience Manager, bethanyw@umich.edu

Anne Partington, Managing Director, aparting@umich.edu

General Institute email: tauberinstitute@umich.edu

Semesters Offered/Recommended: 2-Year Capstone Fellowship Program

Financial: Scholarships available and required internship

Technical Communication Program

The Program in Technical Communication prepares engineering students to communicate, lead, and innovate in an increasingly global and digital environment, ensuring that every Michigan Engineer has the communication skills necessary to succeed in their professional lives - *because it's never just about the tech.* Engineers need to share their solutions, motivate their team, persuade stakeholders, and work across their organization, all with the goal of solving complex, messy, and wicked problems. Through its courses, instruction, and mentorship, the TC Program empowers students to succeed in the complex communication responsibilities they will face in their future engineering careers. Students start learning tech comm skills in ENGR-100, and continue throughout their four years in customized courses that integrate communication instruction within each engineering discipline.

Technical Communication Program website

Talk to a human: TC-PROGRAM-ADMIN@UMICH.EDU | (734) 764-1427

Semesters Offered/Recommended: Fall and Winter

Financial: Technical Communication courses are woven into students' Immersed academic experience, from ENGR-100 to the senior capstone course.

Military Officer Education Programs

The University of Michigan, in cooperation with the armed services of the United States, provides an opportunity for eligible 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 & Space 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 and United States Space Force.

Career Opportunities

Students 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 nuclear 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 field training course at Maxwell Air Force base between the sophomore and junior years. Students must compete nationally to attend field training; selection for field training and successful completion of field training is required for continuation in the program. 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 or visit afrotc.com.

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

Upon commissioning, graduates of the program will be called to active duty to serve in the Air Force or Space Force. 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 website and at the LSA Course Guide.

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 18 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. The option of room and board may be elected in place of tuition, if you should qualify. All students receive a monthly stipend to help cover additional expenses. The stipend is $420/month for all contracted Cadets for ten (10) months of each school year. This allowance is also available to all non-scholarship contracted cadets enrolled in Army ROTC (2nd, 3rd, & 4th years). 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 based on time remaining to complete your degree.

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 (6 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 website and at the LSA Course Guide.

Military Obligation

Newly commissioned Cadets into Active Duty incur a minimum of four years of active duty service obligation. Cadets commissioned into USAR or NG incur a eight year service obligation.

Chair: Lieutenant Colonel Thomas R Church

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-five-years of study. For a more detailed description of the available financial benefits and scholarships consult the Naval ROTC website and the Naval Education and Training Command website. 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 website and at the LSA Course Guide.

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.***

Military Officer Education Program (AERO, MILSCI, & NAVSCI)

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. ***(No credit granted to CoE Students)***
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. ***(No credit granted to CoE Students)***
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. ***(No credit granted to CoE Students)***
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.

Graduation

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 least one term prior to the student's expected graduation term (EGT), **but no later than the last day of classes for the EGT 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 (December) 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 required deadline.
- Plan to complete their graduation requirements in the upcoming Winter term and have applied to graduate in the Winter term by the required deadline.

For more information regarding the University Commencement event, please go to the University of Michigan Commencement website.

The Spring (April/May) 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 required deadline.
- 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 required deadline.

For more information, please go to the University of Michigan Commencement website.

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 required deadline.
- 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 required deadline.

For more information regarding the CoE Graduation Program, please go to the College of Engineering Graduation website.

Graduate Education

Graduate 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.

Degrees by Discipline

	MS/MSE	M. Eng.	Ph. D.	D.Eng.
Aerospace Engineering	•		•	
Applied Climate		•		
Applied Physics	•		•	
Automotive Engineering		•		
Biomedical Engineering	•	•	•	
Chemical Engineering	•		•	

Civil Engineering	•		•	
Climate & Space Sciences & Engineering	•		•	
Computer Science & Engineering	•		•	
Construction Engineering and Management	•	•		
Data Science	•			
Design Science	•		•	
Electrical & Computer Engineering	•	•	•	
Energy Systems Engineering		•		

Engineering Education Research	•		•	
Environmental Engineering	•		•	
Global Automotive & Manufacturing Engineering		•		
Industrial & Operations Engineering	•		•	
Macromolecular Science & Engineering	•		•	
Manufacturing		•		•
Materials Science & Engineering	•		•	
Mechanical Engineering	•		•	

Naval Architecture & Marine Engineering	•		•	
Nuclear Engineering & Radiological Sciences	•		•	
Robotics	•		•	
Scientific Computing			•	
Smart Infrastructure in Finance		•		
Space Engineering		•		
Structural Engineering		•		
Systems Engineering & Design		•		

Master's Degree Programs

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.

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.

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 Masters 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.

Rackham Graduate School Academic Policies

To learn more about the Rackham Graduate School's academic policies, please visit here.

Teaching & Learning Resources

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

- CRLT-E for Student Instructors
- Faculty Resources for Online & Hybrid Teaching
- Nexus Faculty Resources Blog

Were you looking for deadlines?

Funding and Fellowships

Funding for Master's Students

Find funding opportunities for master's students administered by the Rackham Graduate School. 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. Please reach out to your Graduate Coordinator for more information. Current master's students who have an 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, students who are U.S. citizens or permanent residents are nominated by departments 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 a monthly stipend. More information can be found at **Scholarships & Funding – Michigan Engineering**.

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 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 at **Doctoral Program Funding and Tuition Support Guidelines**.

Further Resources for Funding include:

- CoE Funding and Fellowship Application Resources

- Rackham Graduate School Fellowship Office
- Emergency Funding for Graduate Students
- Graduate Student Community Grants
- Other Funding for Engineering Graduate Students
- Careers.umich.edu

Online Programs

The College of Engineering currently offers 5 top-ranked online master's degree programs:

- **Automotive Engineering MEng**
- **Energy Systems Engineering MEng**
- **Global Automotive and Manufacturing Engineering MEng**
- **Manufacturing MEng**
- **Systems Engineering & Design MEng**

Nexus

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.

Sample Schedules

Sample Schedule 2022-2023

Aerospace Engineering

	Total Credit Hours	Term: 1	2	3	4	5	6	7	8
Subjects Required by all Programs (55 hours)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
ENGR 100, Introduction to Engineering	4	4	-	-	-	-	-	-	-
ENGR 101, Introduction to Computers	4	-	4	-	-	-	-	-	-
CHEM 125/126, 130 or 210, 211[1]	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141[2]	5	-	5	-	-	-	-	-	-
Physics 240 with Lab 241[2]	5	-	-	5	-	-	-	-	-
Intelectual Breadth	16	3	3	2	-	-	-	4	4
Related Technical Core Subjects (12 hours)									
MECHENG 240, Intro to Dynamics and Vibrations	4	-	-	-	4	-	-	-	-
Engineering distribution 1[3]	4	-	-	-	-	4	-	-	-
Engineering distribution 2[3]	4	-	-	-	-	4	-	-	-
Aerospace Science Subjects (26 hours)									
AEROSP 201, Introduction to Aerospace Science	2	-	-	-	2	-	-	-	-
AEROSP 215, Introduction to Solid Mechanics and Aerospace Structures	3	-	-	-	3	-	-	-	-
AEROSP 225, Introduction to Gas Dynamics	3	-	-	-	3	-	-	-	-
AEROSP 315, Aircraft and Spacecraft Structures	3	-	-	-	-	3	-	-	-
AEROSP 325, Aerodynamics	3	-	-	-	-	-	3	-	-
AEROSP 335, Aircraft and Spacecraft Propulsion	3	-	-	-	-	3	-	-	-
AEROSP 341, Aircraft Dynamics (W) or AEROSP 343, Spacecraft Dynamics (F)	3	-	-	-	-	-	3	-	-
AEROSP 350, Introduction to Aerospace Computing	3	-	-	-	-	-	3	-	-
AEROSP 470, Control of Aerospace Vehicles	3	-	-	-	-	-	-	3	-
Aerospace Engineering Subjects (17 hours)									
AEROSP 200, Introduction to the Aerospace Enterprise	2	-	-	2	-	-	-	-	-
Design/Build/Test/Fly Course Requirement[5]	3	-	-	3	-	-	-	-	-
AEROSP 305, Aerospace Engineering Lab I	4	-	-	-	-	-	4	-	-
AEROSP 405, Aerospace Engineering Lab II	4	-	-	-	-	-	-	4	-
AEROSP 481, Aircraft Design (F) or AEROSP 483, Space System Design (W)	4	-	-	-	-	-	-	-	4
Electives (18 Hours)									
Technical Electives[4]	9	-	-	-	-	-	-	3	6
General Electives	9	-	-	-	-	2	3	2	2

Total	128	16	16	16	16	16	16	16	16
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									
3. Engineering distribution requirement. Select two courses from: MSE 220, MSE 350, EECS 215, EECS 216, EECS 280, EECS 281									
4. Technical electives must total at least 9 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.									
5. DBTF Requirement. Can be met by any DBTF course recommended by the Aero undergrad advising office. If the course is not in the Aero department, 3 extra credits of tech elective are required.									

Fall 2023-2024

Biomedical Engineering Sample Schedule

	Credit Hours	1	2	3	4	5	6	7	8
Subjects Required by all Programs (55 hours)									
Mathematics 115, 116, 215, 216	16	4	4	4	4	-	-	-	-
Engineering 100, Introduction to Engineering	4	4	-	-	-	-	-	-	-
Engineering 101, Introduction to Computers	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 211[1]	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 241[2]	10	-	5	5	-	-	-	-	-
Intellectual Breadth	16	4	-	-	4	4	4	-	-
Life and Materials Science and Engineering (8 hours)									
Biology 172 or 174, Introduction to Biology[3]	4	-	4	-	-	-	-	-	-
MATSCIE 220 or 250, Principles of Engineering Materials	4	-	-	-	-	4	-	-	-
Required Program Subjects (35 hours)									
BIOMEDE 211, Circuits & Systems for Biomedical Engineers	4	-	-	-	4	-	-	-	-
BIOMEDE 221, Biophysical Chemistry & Thermodynamics	4	-	-	4	-	-	-	-	-
BIOMEDE 231, Introduction to Biomechanics	4	-	-	-	4	-	-	-	-
BIOMEDE 241, Statistics, Computation, and Data Analysis	4	-	-	4	-	-	-	-	-
BIOMEDE 350, Introduction to Biomedical Design	4	-	-	-	-	4	-	-	-
BIOMEDE 418, Quantitative Cell Biology	3	-	-	-	-	3	-	-	-
BIOMEDE 419, Quantitative Physiology	4	-	-	-	-	-	-	4	-
BIOMEDE 450, Biomedical Design or	4	-	-	-	-	-	-	-	4
BIOMEDE 451, Biomedical Design,	3	-	-	-	-	-	-	3	-
Part I and BIOMEDE 452, Biomedical Design, Part II	3	-	-	-	-	-	-	-	3
BIOMEDE 458, Biomedical Instrumentation & Design	4	-	-	-	-	-	4	-	-
Depth Requirements[4] (21 hours)									
Engineering Expertise	12	-	-	-	-	-	-	8	4
Advanced Science, Technology, Engineering or Math	6	-	-	-	-	-	3	-	3
Experiential Elective	3	-	-	-	-	-	3	-	
General Electives (9 hours)	9	-	-	-	-	-	3	3	3
Total	***128***	***17***	***17***	***17***	***16***	***15***	***17***	***15-18***	***13-14***

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.

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.

3. If 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 Requirement for BME.

4. Depth requirements: A list of depth requirements and optional tracks is available on the department website and in 1111 Gerstacker.

Chemical Engineering Sample Schedule

	Total Credit Hours	Term: 1	2	3	4	5	6	7	8
Subjects Required by all Programs (53 Hours)									
Mathematics 115+, 116+, 215+, 216+	**16**	**4**	**4**	**4**	**4**	-	-	-	-
Engineering 100, Introduction to Engineering +	**4**	**4**	-	-	-	-	-	-	-
Engineering 101, Introduction to Computers +	**4**	-	**4**	-	-	-	-	-	-
Chemistry 130[1] +	**3**	**3**	-	-	-	-	-	-	-
Physics 140+ with Lab 141+; Physics 240+ with Lab 241[2]+	**10**	-	**5**	**5**	-	-	-	-	-
Intellectual Breadth (to include a course in micro or macro economics)	***16***	***4***	-	-	-	***4***	-	***4***	***4***
Advanced Chemistry (11 Hours)									
Chemistry 210/211, Structure and Reactivity I and Lab +	**5**	-	**5**	-	-	-	-	-	-
Chemistry 215/216, Structure and Reactivity II and Lab +	**5**	-	-	**5**	-	-	-	-	-
Chemistry 261 Introduction to Quantum Chemistry[3]	**1**	-	-	-	-	**1**	-	-	-
Related Technical Subjects (11 Hours)									
Biology/Life Science Elective (Typically Bio 172 or 174)[4]	**4**	-	-	-	-	-	**4**	-	-
Materials Elective (MSE 250 or MSE 220) +	**4**	-	-	-	-	-	-	**4**	-
Engineering Electives[5]	**3**	-	-	-	-	-	-	-	**3**
Program Subjects (41 Hours)									
CHE 230 Material and Energy Balances +	**4**	-	-	**4**	-	-	-	-	-
CHE 330 Chemical and Engineering Thermodynamics +	**4**	-	-	-	**4**	-	-	-	-
CHE 341 Fluid Mechanics +	**4**	-	-	-	**4**	-	-	-	-
CHE 342 Mass and Heat Transfer +	**4**	-	-	-	-	**4**	-	-	-
CHE 343 Separation Processes +	**4**	-	-	-	-	**4**	-	-	-
CHE 344 Reaction Engineering and Design +	**4**	-	-	-	-	-	**4**	-	-
CHE 360 Chemical Engineering Laboratory I +	**4**	-	-	-	-	-	**4**	-	-
CHE 460 Chemical Engineering Laboratory II	**4**	-	-	-	-	-	-	-	**4**
CHE 466 Process Dynamics and Control	**3**	-	-	-	-	-	-	**3**	-
CHE 485 Chemical Engineering Process Economics +	**1**	-	-	-	-	-	**1**	-	-
CHE 487 Chemical Process Simulation and Design, or CHE 488/489, Chemical Product Design I and II (2cr. F / 3cr. W)	**5**	-	-	-	-	-	-	-	**5**
General Electives (12 Hours)	**12**	-	-	-	**3**	**3**	**3**	**3**	-
Total	***128***	***15***	***18***	***18***	***15***	***16***	***16***	***14***	***16***

Revised 15-Sep-2023

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 (+).

revised: 3/18/2024

Civil Engineering Sample Schedule

Civil Engineering Sample Schedule	Credit Hours	Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8
Subjects Required by all Programs (55 hours)									
MATH 115, 116, 215, 216	**16**	**4**	**4**	**4**	**4**	-	-	-	-
ENGR 100, Intro to Engineering	**4**	**4**	-	-	-	-	-	-	-
ENGR 101, Intro to Computers	**4**	-	**4**	-	-	-	-	-	-
CHEM 130 & 125/126 or CHEM 210 and 211[1]	**5**	**5**	-	-	-	-	-	-	-
PHYSICS 140 with Lab 141[2]	**5**	-	**5**	-	-	-	-	-	-
PHYSICS 240 with Lab 241[2]	**5**	-	-	**5**	-	-	-	-	-
Intellectual Breadth (includes ECON 101 or 102)	**16**	**4**	**4**	-	**4**	-	-	-	**4**
Mathematical Methods (7 hours) +									
CEE 303, Computational Methods	**4**	-	-	-	-	-	**4**	-	-
CEE 373, Statistical Methods	**3**	-	-	-	-	**3**	-	-	-
Required Program Subjects (22 hours)[3] +									
CEE 200, Intro to Civil & Environmental Engineering	**1**	-	-	-	**1**	-	-	-	-
CEE 211, Statics and Dynamics	**4**	-	-	**4**	-	-	-	-	-
CEE 212, Solid and Structural Mechanics	**3**	-	-	-	**3**	-	-	-	-
CEE 230, Thermodynamics and the Environment or CEE 375, Sensors and Circuits	**3**	-	-	**3 or**	**3**	-	-	-	-
CEE 265, Sustainable Engineering Principles	**3**	-	-	**3 or**	**3**	-	-	-	-
CEE 325, Fluid Mechanics	**4**	-	-	-	-	**4**	-	-	-
CEE 402, Professional Issues & Design[6]	**4**	-	-	-	-	-	-	-	**4**
Science Elective (3 hours) +									
Biology 171 or 172	**3**	-	-	-	-	-	-	**3**	-
EARTH 119, 201, 222, 284, or 320									
CEE 482/582, Environmental Microbiology									
Program Electives (24 hours)[4] +									
CEE 312, Structural Engineering	**24**	-	-	-	-	**8**	**8**	**8**	-
CEE 331, Construction Management									
CEE 345, Geotechnical Engineering									
CEE 351, Civil Engineering Materials									
CEE 365, Environmental Engineering Principles									
CEE 421, Hydrology and Floodplain Hydraulics									
CEE 450, Transportation Engineering									
Technical Electives (6 hours)[5] +									
CEE 413, 415, 428, 435, 465, 480, 526, 534, 545, 546, 547, 551, 552, or 574	**6**	-	-	-	-	-	-	**3**	**3**
General Electives (11 hours)	**11**	-	-	-	-	-	**4**	**3**	**4**
Total	**128**	**17**	**17**	**16**	**15**	**15**	**16**	**17**	**15**

Notes: Courses offered only in the fall term are purple. Courses offered only in the winter term are green.

(+) Civil Engineering students must earn a C- or better in all courses whose categories are marked with a plus.

[1]- If you have a satisfactory score or grade in Chemistry AP, A-Level, IB Exams, or transfer credit from another institution for CHEM 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.

[3]- CEE may accept equivalent courses offered by other departments in the College of Engineering, with permission from the program advisor.

[4]- At least six of the seven program electives are required.

[5]- A seventh program elective may count as a technical elective.

[6] - CEE 402 must be taken in the last Winter semester.

Civil Engineering BSE			
Subject	**Prerequisite(s)**	**Must Be Taken Before**	**Term(s) Offered**
College Requirements			
MATH 115		MATH 116, PHYSICS 140	Fall, Winter, Spring, Summer
MATH 116	MATH 115	MATH 215, 216; PHYSICS 240; CEE 230, CEE 265	Fall, Winter, Spring, Summer
MATH 215	MATH 116	CEE 373, CEE 450	Fall, Winter, Spring, Summer
MATH 216	MATH 116	CEE 303, CEE 373	Fall, Winter, Spring, Summer
ENGR 100			Fall, Winter
ENGR 101	Prior or concurrent enrollment in MATH 115	CEE 303	Fall, Winter
CHEM 130		CEE 230, CEE 265	Fall, Winter, Spring
CHEM 125/126		CEE 230	Fall, Winter, Spring
PHYSICS 140/141	MATH 115	CEE 211, PHYSICS 240	Fall, Winter, Spring
PHYSICS 240/241	PHYSICS 140, MATH 116	CEE 375, CEE 450	Fall, Winter, Spring
Mathematical Methods			
CEE 303	MATH 215, 216; ENGR 101	CEE 421	Winter
CEE 373	MATH 215, MATH 216 C or better	CEE 552	Fall
Required Program Subjects			
CEE 200			Fall, Winter
CEE 211	PHYSICS 140	CEE 212, CEE 325	Fall, Winter
CEE 212	CEE 211	CEE 312, CEE 345, CEE 351, CEE 574	Fall, Winter
CEE 230	MATH 116, CHEM 130 & 125/126		Fall
CEE 265	MATH 116, CHEM 130	CEE 365	Fall, Winter
CEE 325	CEE 211	CEE 421, CEE 428, CEE 465, CEE 526	Fall, Winter
CEE 375	PHYSICS 240		Winter
CEE 402	Senior Standing		Winter
Program Electives			
CEE 312	CEE 212	CEE 413, CEE 415	Fall
CEE 331	Junior Standing	CEE 435, CEE 534	Winter
CEE 345	PHYSICS 140, CEE 212	CEE 545, CEE 546, CEE 547	Fall, Winter
CEE 351	CEE 212		Fall, Winter
CEE 365	CHEM 130, MATH 116, CEE 265	CEE 465	Fall
CEE 421	CEE 303, CEE 325		Fall
CEE 450	MATH 215, PHYSICS 240 C or better	CEE 551, CEE 552	Winter
Technical Electives			
CEE 435	CEE 331 C or better		Fall
CEE 534	CEE 331, Junior Standing		Winter
CEE 413	CEE 312		Fall
CEE 415	CEE 312		Winter
CEE 547	CEE 345		Fall
CEE 574	CEE 212		
CEE 545	CEE 345		Fall
CEE 546	CEE 345		Winter
CEE 428	CEE 325, (CEE 345 or CEE 366)		Fall
CEE 526	CEE 325		Winter
CEE 465	CEE 325, CEE 365	CEE 480	Fall
CEE 480	CEE 465		Fall
CEE 551	CEE 450 C or better		Fall
CEE 552	CEE 373, CEE 450 C or better		Fall

Unless otherwise noted, a grade of C- is required for prerequisites.

Environmental Engineering Sample Schedule Updated 3/18/2024									
Subjects Required by All Programs (55 Hours)	**Credit Hours**	**Sem 1**	**Sem 2**	**Sem 3**	**Sem 4**	**Sem 5**	**Sem 6**	**Sem 7**	**Sem 8**
MATH 115, 116, 215, 216	16	4	4	4	4	-	-	-	-
ENGR 100, Intro to Engineering	4	4	-	-	-	-	-	-	-
ENGR 101, Intro to Computers	4	-	4	-	-	-	-	-	-
CHEM 130 & 125/126	5	5	-	-	-	-	-	-	-
PHYSICS 140 with Lab 141²	5	-	5	-	-	-	-	-	-
PHYSICS 240 with Lab 241²	5	-	-	5	-	-	-	-	-
Intellectual Breadth (includes ECON 101 or 102)	16	4	4	-	-	4	4	-	-
Mathematical Methods (7 Hours)+									
CEE 303, Computational Methods	4	-	-	-	-	-	4	-	-
CEE 373, Statistical Methods	3	-	-	-	-	3	-	-	-
Technical Core Subjects (33 Hours)³+									
CHEM 210, Structure & Reactivity	3	-	-	-	3	-	-	-	-
CEE 200, Intro to Civil & Environmental Engineering	1	-	-	-	1	-	-	-	-
CEE 211, Statics & Dynamics	4	-	-	4	-	-	-	-	-
CEE 230, Thermodynamics and the Environment	3	-	-	3	-	-	-	-	-
CEE 265, Sustainable Engineering Principles	3	-	-	-	3	-	-	-	-
CEE 325, Fluid Mechanics	4	-	-	-	4	-	-	-	-
CEE 365, Environmental Engineering Principles	4	-	-	-	-	4	-	-	-
CEE 366, Environmental Engineering Laboratory	3	-	-	-	-	-	3	-	-
CEE 421, Hydrology and Floodplain Hydraulics	4	-	-	-	-	-	-	4	-
CEE 465, Environmental Process Engineering	3	-	-	-	-	-	3	-	-
Environmental Sciences (9 Hours)+									
Earth Science Elective (CLIMATE 320, 410, 463 or 475, or EARTH 305, 315, 321, 323, 442, 451 or 477)	3	-	-	-	-	-	-	3	-
CEE 481/581, Aquatic Chemistry	3	-	-	-	-	-	-	-	3
CEE 482/582, Environmental Microbiology	3	-	-	-	-	-	-	3	-
Environmental Engineering Design (4 hours)+									
CEE 402, Professional Issues and Design-6*	4	-	-	-	-	-	-	-	4
Technical Electives (9 Hours)⁴+									
Water Quality and Health:	9	-	-	-	-	-	3	3	3
CEE 428*, CEE 480*, CHE 342, PUBHLTH 305									
Atmospheric and Earth Systems:									
CEE 549, CEE 563*, CEE 564, CLIMATE 463, CLIMATE 467, EARTH 413									
Environmental Fluid Dynamics:									
CEE 428*, CEE 521, CEE 522, CEE 526*									
Energy and Sustainable Infrastructure:									
CEE 567, URP 423, EARTH 344									
Environmental Policy and Entrepreneurship:									
ENGR 520, EAS 475, CLIMATE 480, ME 589									
General Electives (12 Hours)	12	-	-	-	-	4	-	4	4
Total	128	17	17	16	15	15	17	17	14

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

Notes: CEE courses offfered only in Fall are in purple. CEE courses offered only in Winter are in green.

(+)Environmental Engineering students must earn a C- or better in all courses whoses categories are marked with a plus.

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 140/141and 240/241, you will have met the Physics Core Requirement for the College of Engineering.

³- CEE may accept equivalent courses offered by other departments in the College of Engineering, with permission of the program advisor.

⁴- At least two of the three technical electives must be CEE courses, including one design course: CEE 428, 480, 526 or 563.

5- CEE 402 must be taken in the last Winter semester.

The design courses are marked with an *

Environmental Engineering Major			
Subject	**Prerequisite(s)**	**Must Be Taken Before**	**Semesters Offered**
College Requirements			
MATH 115		MATH 116	Fall, Winter, Spring, Summer
MATH 116	MATH 115	MATH 215, CEE 230, CEE 265	Fall, Winter, Spring, Summer
MATH 215	MATH 116	MATH 216	Fall, Winter, Spring, Summer
MATH 216	MATH 116	CEE 303	Fall, Winter, Spring, Summer
ENGR 100			Fall, Winter
ENGR 101	MATH 115 (or concurrent)	CEE 303, CEE 373	Fall, Winter
CHEM 130		CEE 230, CEE 265	Fall, Winter Spring
CHEM 125/126		CEE 481/581	Fall, Winter Spring
PHYS 140/141	MATH 115	CEE 211	Fall, Winter Spring
PHYS 240/241	PHYS 140, MATH 116		Fall, Winter Spring
Mathematical Methods			
CEE 303	MATH 216, ENGR 101	CEE 421	Winter
CEE 373	MATH 215, MATH 216		Fall
Technical Core Subjects			
CHEM 210	CHEM 130		Fall, Winter, Spring, Summer
CEE 200			Fall, Winter
CEE 211	PHYS 140	CEE 212, CEE 325	Fall, Winter
CEE 230	MATH 116, CHEM 130 & 125/126		Fall
CEE 265	MATH 116, Chem 130	CEE 365	Fall, Winter
CEE 325	CEE 211	CEE 421	Fall, Winter
CEE 365	CHEM 130, MATH 116	CEE 465	Fall
CEE 366	CEE 365		Winter
CEE 421	CEE 303, CEE 325	CEE 521	Fall
CEE 465	CEE 325, CEE 365	CEE 480	Fall
Environmental Sciences			
CLIMATE 320	MATH 116		
CLIMATE 410	CLIMATE 320, 321 (advised)		
CLIMATE 475	Senior Standing		
EARTH 305	Introductory geology lab		Fall
EARTH 315	CHEM 130		Fall
EARTH 321	MATH 215, MATH 216		Winter
EARTH 323			Winter
EARTH 442	MATH 115, CHEM 130		Fall
EARTH 451			Winter
EARTH 477	MATH 115		Fall
CEE 481/581	CHEM 130		Winter
CEE 482/582	CHEM 130		Fall
Environmental Engineering Design			
CEE 402	Senior Standing		Winter
Techncal Electives			
Water Quality & Health			
CEE 428	CEE 325, CEE 345 or 366		Fall
CEE 480	CEE 465		Fall
CHE 342	CHE 230, CHE 341, MATH 216		Fall
PUBHLTH 305			
Atmospheric & Earth Systems			
CEE 549	CEE 345		Winter
CEE 563	CEE 230, CEE 325 or equivalent		Winter
CEE 564	CEE 230 or Equivalent Advised		Fall
CLIMATE 463	MATH 215		
CLIMATE 467	MATH 116, CHEM 210, PHYSICS 240		
EARTH 413			
Environmental Fluid Dynamics			
CEE 428	CEE 325, CEE 345 or 366		Fall
CEE 521	CEE 325		Fall
CEE 522	CEE 325		Fall
CEE 526	CEE 325		Winter
Energy & Sustainable Infrastructure			
CEE 567	CEE 230 recommended		Fall
URP 423			
EARTH 344			
Environmental Policy & Enterpreneurship			
ENGR 520	Senior Standing		
EAS 475			
CLIMATE 480	Senior Standing, MATH 216		
ME 589	CEE 265 Advised		Fall

	Total	Term:							
Climate and Meteorology Sample Schedule	**Credit Hours**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Subjects Required by all Programs (55 hours)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engineering 100, Introduction to Engineering	4	4	-	-	-	-	-	-	-
Engineering 101, Introduction to Computers	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 2111	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 2412	10	-	5	5	-	-	-	-	-
Intellectual Breadth	16	4	4	4	4	-	-	-	-
Required Core Subjects (38 hours)									
CLIMATE 320, Earth and Space System Evolution	3	-	-	3	-	-	-	-	-
CLIMATE 321, Earth and Space System Dynamics	3	-	-	-	3	-	-	-	-
CLIMATE 323, Earth System Analysis	4	-	-	-	4	-	-	-	-
CLIMATE 350, Atmospheric Thermodynamics	3	-	-	-	-	-	3	-	-
CLIMATE 380, Introduction to Radiative Transfer	3	-	-	-	-	3	-	-	-
CLIMATE 401, Geophysical Fluid Dynamics	3	-	-	-	-	3	-	-	-
CLIMATE 410, Earth System Modeling	4	-	-	-	-	-	-	4	-
CLIMATE 414, Weather Systems	3	-	-	-	-	-	3	-	-
CLIMATE 324, Instrumentation for Atmos & Space Sciences	4	-	-	-	-	-	4	-	-
CLIMATE 423, Data Analysis and Visualization	4	-	-	-	-	-	4	-	-
CLIMATE 455, Capstone Design4	4	-	-	-	-	-	-	-	4
Concentrations: (select one)									
Meteorology (35 hours total)									
CLIMATE 411, Cloud and Precipitation Process	3	-	-	-	-	-	-	-	3
CLIMATE 485, Remote Sensing	3	-	-	-	-	-	-	-	3
CLIMATE 463, Boundary Layer Meteorology	3	-	-	-	-	3	-	-	-
CLIMATE 440, Meteorological Analysis Laboratory	4	-	-	-	-	-	-	4	-
Technical Electives	13	-	-	-	-	4	-	4	5
General Electives	9	-	-	-	-	3	3	3	-
Total	***128***	***17***	***17***	***16***	***15***	***16***	***17***	***15***	***15***
Climate Sciences and Impacts Engineering (35 hours total) 6									
CLIMATE 473, Climate Physics	3	-	-	-	-	-	-	-	3
Statistics/GIS Elective	3	-	-	-	-	3	-	-	-
Climate/Climate Change Elective5	3	-	-	-	-	-	-	-	3
Energy/Sustainability Elective5	3	-	-	-	-	-	-	3	-
Interactions Elective5	4	-	-	-	-	-	-	-	4
Technical Electives	10	-	-	-	-	3	-	4	3
General Electives	9	-	-	-	-	3	3	3	-
Total	***128***	***17***	***17***	***16***	***15***	***15***	***17***	***14***	***17***

Revised: 23-Feb

Candidates for the Bachelor of Science in Engineering in Climate and Meteorology 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

	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
	4.New Course. Students may take year-long (2 hours each term) CLIMATE 499 Directed Study as a Senior Thesis option.
	5.See department undergradaute program office for list of approved courses.

Space Sciences and Engineering Sample Schedule

	Total Credit Hours	Term: 1	2	3	4	5	6	7	8
Subjects Required by all Programs (55 hours)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engineering 100, Introduction to Engineering	4	4	-	-	-	-	-	-	-
Engineering 101, Introduction to Computers	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 211	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 241	10	-	5	5	-	-	-	-	-
Intellectual Breadth	16	4	4	4	4	-	-	-	-
Required Core Subjects (30 hrs.)									
SPACE 320, Earth and Space System Evolution	3	-	-	3	-	-	-	-	-
SPACE 321, Earth and Space System Dynamics	3	-	-	-	3	-	-	-	-
SPACE 323, Earth System Analysis	4	-	-	-	4	-	-	-	-
SPACE 370, Solar-Terrestrial Relations	4	-	-	-	-	4	-	-	-
SPACE 324, Instrumentation for Atmos & Space Sciences	4	-	-	-	-	-	4	-	-
SPACE 478, Space Environment	4	-	-	-	-	-	-	4	-
SPACE 423, Data Analysis and Visualization	4	-	-	-	-	-	-	-	4
SPACE 495/595 (Note 1)	495 (4) / 595 (3)	-	-	-	-	-	-	-	4
Total	**85**								
Concentrations: (select one)									
Space Science (43 hrs. total)									
PHYSICS 340, Waves Heat and Light	3	-	-	-	-	3	-	-	-
SPACE 380, Introduction to Radiative Transfer	3	-	-	-	-	3	-	-	-
PHYSICS 405, Intermediate Electricity and Magnetism (Note 4)	4	-	-	-	-	-	4	-	-
PHYSICS 390, Modern Physics	3	-	-	-	-	-	3	-	-
PHYSICS 391, Lab	2	-	-	-	-	-	2	-	-
NERS 471, Introduction to Plasmas	3	-	-	-	-	-	-	3	-
SPACE 499/455 Capstone Research (Note 2)	4	-	-	-	-	-	-	-	4
Technical Electives (11/12 hours)	11	-	-	-	-	3	-	4	4
General Electives (10 Hours)	10	-	-	-	-	3	3	4	-
Total	**128**								
Space Instrumentation (43 hr. total)									
Engineering Breadth (programming or EECS 215 Intro to Electronic Circuits) (Note 3)	4	-	-	-	-	4	-	-	-
SPACE 310 Small Satellite Design	**3**	-	-	-	-	-	3	-	-
SPACE 371 Astrophysics Engineering	3	-	-	-	-	-	-	3	-
Sensors/Data/Stats Course/AERO 305 (Note 5)	3	-	-	-	-	-	-	-	3
SPACE 471, Space Sciences Instrumentation, or SPACE 431 (Note 6)	471 (3)/431 (4)	-	-	-	-	-	3	-	-
SPACE 477, Space Weather Modeling	4	-	-	-	-	-	-	-	4
Technical Electives (10/11 hours)	10/11	-	-	-	-	4	3	3/4	-
General Electives (12 Hours)	12	-	-	-	-	4	3/4	4	-
Total	***128***	***17***	***17***	***16***	***15***	***16***	***16/17***	***15***	***15/16***

Revised: January-23

Candidates 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. SPACE 499 Directed Study as a Senior Thesis option or SPACE 455 Senior Capstone Design.
3. Recommend students minor in another Engineering Discipline. If not, an intro CS, ME, EECS, MATSCI course. CoE Bulletin describing minors: https://bulletin.engin.umich.edu/ug-ed/engin-minors/
4. Students need to request waiver to Physics 351 for 405 or take 351 as a Tech Elective.
5. CEE 575 Sensing for Civil Infrastructure Systems (3 cr) and Data; STATS 412 Introduction to Probability and Statistics (3 cr) or AERO 305 Aero Engineering Lab I (4 cr). If AERO 305 is taken reduce Unrestricted Elective from 12 to 11 credits. Have discu

	6. SPACE 471 and 431 are Every-other-year courses. If 431 is taken, reduce Tech Elective requirement from 11 to 10 credits							

Computer Engineering Sample Schedule

Below is an eight-semester (four-year) plan to help students envision how requirements may fit together over the course of their time at Michigan. This plan is only a sample; it is not necessary to follow the below plan exactly outside of following prerequisite chains.

	Total Credits	**Terms**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Subjects Required by all Programs									
MATH 115, 116, and 216	**12**	**4**	**4**			**4**			
MATH 214, 215, 217, 417 or 419	**4**				**4**				
ENGR 100, Introduction to Engineering	**4**		**4**						
ENGR 101, Introduction to Computers and Programming	**4**	**4**							
CHEM [125/126 and 130] or CHEM [210 and 211]	**5**	**5**							
PHYSICS 140 and 141	**5**		**5**						
PHYSICS 240 and 241	**5**			**5**					
Intellectual Breadth	**16**	**4**	**4**		**4**		**4**		
General Electives	**13**			**3**		**3**		**4**	**3**
Program Subjects									
EECS 203, Discrete Mathematics	**4**			**4**					
EECS 215, Introduction to Electronic Circuits	**4**				**4**				
EECS 216, Introduction to Signals and Systems	**4**					**4**			
EECS 270, Introduction to Logic Design	**4**			**4**					
EECS 280, Programming and Introductory Data Structures	**4**				**4**				
EECS 370, Introduction to Computer Organization	**4**					**4**			
EECS 301, MATH 425 or STATS 412	**3**						**3**		
EECS 496, Major Design Experience Professionalism	**2**								**2**
TCHNCLCM 300, Technical Communication for EECS	**1**					**1**			
TCHNCLCM 496, Advanced Technical Communication	**2**								**2**
Technical Electives									
Core Electives	**8**						**8**		
Upper Level CE Electives, including Major Design Experience	**10**							**4**	**6**
EECS Electives	**3**							**3**	
Flexible Technical Electives	**7**							**5**	**2**
Total	**128**	**17**	**17**	**16**	**16**	**16**	**15**	**16**	**15**

CS-Eng Sample Schedule

Below is an eight-semester (four-year) plan to help students envision how requirements may fit together over the course of their time at Michigan. This plan is only a sample; it is not necessary to follow the below plan exactly outside of following prerequisite chains.

	Total Credits	Terms							
		1	2	3	4	5	6	7	8
Subjects Required by all Programs (55 hours)									
Mathematics 115, 116, and 214[1]	**12**	**4**	**4**		**4**				
Mathematics 215 or 216[2]	**4**					**4**			
Engineering 100, Introduction to Engineering	**4**		**4**						
Engineering 101, Introduction to Computers[6]	**4**	**4**							
Chemistry [125/126 and 130] or Chemistry [210 and 211]	**5**	**5**							
Physics 140 and Lab 141	**5**		**5**						
Physics 240 and Lab 241	**5**			**5**					
Intellectual Breadth	**16**	**4**	**4**		**4**	**4**			
Program Subjects (26 hours)									
EECS 203, Discrete Mathematics (or MATH 465/565)	**4**			**4**					
EECS 280, Programming and Elementary Data Structures	**4**			**4**					
EECS 281, Data Structures and Algorithms	**4**				**4**				
EECS 370, Introduction to Computer Organization	**4**					**4**			
STATS 250 or STATS 206 or STATS 280 or STATS 412 or STATS 426 or EECS 301/401 or TO 301 or IOE 265	**3**						**3**		
EECS 376, Foundations of Computer Science	**4**					**4**			
TCHNCLCM 300	**1**						**1**		
EECS 496 (or ENGR 499-002, or COMPFOR 111, CSE 543, or approved Special Topics sections)	**2**							**2**	
Major Design Experience (6 hours)									

Approved CS MDE course[3]	**4**							**4**	
TCHNCLCM 497	**2**							**2**	
Technical Electives (25 hours)									
Upper Level CS Technical Electives[4]	**15**						**4**	**4**	**7**
Flexible Technical Electives[5]	**10**				**4**		**4**		**2**
General Electives (16 hours)	**16**			**3**			**4**	**4**	**5**
Total	**128**	**17**	**17**	**16**	**16**	**16**	**16**	**16**	**14**

Notes:

Credits from a course may only be used to fulfill a single requirement (no double-counting).

1. The requirements for MATH 214 can alternatively be satisfied by MATH 217, 417, 419, or Robotics 101.
2. If both MATH 215 and MATH 216 are taken, MATH 216 can count as a Flexible Technical Elective.
3. See page 5 for the current list. TCHNCLCM 497 must be taken in the same or later semester as the MDE (preferably the same semester).
4. This includes 12 credits of ULCS and 3 credits of Expanded ULCS. See page 3 of Program Guide for the current lists.
5. A maximum of 4 credits of EECS 499/399 (or other upper-level directed/independent study) may count in Flexible Technical Electives; additional credits will count as general electives. Check with an advisor to ensure you are not in violation of this policy.
6. The requirement for ENGR 101 can also be satisfied by Engineering 151, EECS 180 AP credit, EECS 183, or Robotics 102

DS-Eng Sample Schedule (for students who matriculate to the University of Michigan Fall 2024 or later)

The sample schedule below summarizes the program requirements. DS-Eng students need 128 total credits towards their program and at least 42 credits in the major, excluding prerequisites.

Course Planning: Students can reference the EECS course descriptions and Atlas for a basic introduction to our courses. CSE Peer Advisors have also developed an ULCS/Senior Design Info Sheet providing student narratives about their experiences in our courses. Several core course syllabi are also available at the link provided. For more planning assistance, students should schedule an appointment with an advisor on the EECS undergraduate website

Note that General Electives are intended to help students reach 128 total credits required for graduation and may vary from student to student, with 15 credits being the maximum needed. Please discuss with your advisor if you are unsure of the necessary number of General Elective credits for your degree.

Data Science in Engineering	Total	1	2	3	4	5	6	7	8
Subjects Required by all Programs (55 credits)									
Mathematics 115, 116, and (214 or 217)	**12**	**4**	**4**		**4**				
Mathematics 215	**4**			**4**					
Engineering 100, Introduction to Engineering	**4**		**4**						
Engineering 101, Introduction to Computers	**4**	**4**							
Chemistry 125/126 and 130, or Chemistry 210 and 211	**5**			**5**					
Physics 140 and Lab 141	**5**			**5**					
Physics 240 and Lab 241	**5**				**5**				
Intellectual Breadth	**16**	**4**			**4**	**4**	**4**		
Program Core (30 credits)									
Introductory Data Science: DATASCI 101 (strongly recommended), STATS 250, STATS 280, IOE 265, or ECON 451	**3-4**	**3-4**							
Discrete Mathematics: EECS 203 or MATH 465	**4**		**4**						
EECS 280, Programming and Elementary Data Structures	**4**		**4**						
EECS 281, Data Structures and Algorithms	**4**			**4**					
STATS 412, Introduction to Probability & Statistics	**3**				**3**				
STATS/DATASCI 413, Applied Regression Analysis	**4**					**4**			
Databases and Applications: EECS 484 or EECS 485	**4**						**4**		
Machine Learning/Data Mining: EECS 445 or STATS/DATASCI 415	**4**					**4**			
Data Science Applications elective (see online list)	**3**								**3**
Advanced Electives and Capstone (12 credits)									
Advanced Technical Elective (see online list)	**4**						**4**		
Advanced Statistical Analysis Elective (see online list)									**4**

Capstone Experience Course	**4**							**4**	
Other Requirements									
Flexible Technical Electives. 200-level or higher from a pre-approved list of courses, or with advisor approval prior to taking the courses.	**11**					**4**		**4**	**3**
TCHNCLCM 300	**1**						**1**		
EECS 496 (or ENGR 499-002, or COMPFOR 111 through WN25, or CSE 543, or [approved Special Topics sections])	**2**							**2**	
TCHNCLCM 497, TCHNCLCM 499, STATS 404, or STATS 485	**2**								**2**
General Electives (15 credits) – See note above	**15**						**3**	**6**	**6**
Total	**128**	**16**	**16**	**18**	**16**	**16**	**16**	**16**	**18**

Notes:

- Students must complete additional application electives, advanced technical electives, or advanced statistical analysis electives, as needed to satisfy the required 46 credits for the major.
- A course taken for capstone credit cannot also count for an advanced technical elective or advanced statistical analysis elective.

Electrical Engineering Sample Schedule

Below is an eight-semester (four-year) plan to help students envision how requirements may fit together over the course of their time at Michigan. This plan is only a sample; it is not necessary to follow the below plan exactly outside of following prerequisite chains.

	Total Credits	Terms							
		1	2	3	4	5	6	7	8
Subjects Required by all Programs									
MATH 115, 116, 215 and 216	**16**	**4**	**4**	**4**	**4**				
ENGR 100, Introduction to Engineering	**4**		**4**						
ENGR 101, Introduction to Computers and Programming	**4**	**4**							
CHEM [125/126 and 130] or CHEM [210 and 211]	**5**	**5**							
PHYSICS 140 and 141	**5**		**5**						
PHYSICS 240 and 241	**5**			**5**					
Intellectual Breadth	**16**	**4**	**4**			**4**	**4**		
General Electives	**11**				**3**			**4**	**4**
Program Subjects									
EECS 200, Electrical Engineering Systems Design I	**2**				**2**				
EECS 215, Introduction to Electronic Circuits	**4**			**4**					
EECS 216, Introduction to Signals and Systems	**4**				**4**				
EECS 230, Electromagnetics I	**4**				**4**				
EECS 280, Programming and Introductory Data Structures	**4**			**4**					
EECS 300, Electrical Engineering Systems Design II	**3**						**3**		
EECS 301, Probabilistic Methods in Engineering	**4**					**4**			
EECS 496, Major Design Experience Professionalism	**2**								**2**
TCHNCLCM 300, Technical Communication for EECS	**1**					**1**			
TCHNCLCM 496, Advanced Technical Communication	**2**								**2**
Technical Electives (including PES course)									
Upper Level EE Electives	**19**					**4**	**8**	**7**	
Major Design Experience	**4**								**4**
Flexible Technical Electives	**9**					**3**		**4**	**4**
Total	**128**	**17**	**17**	**17**	**17**	**16**	**15**	**15**	**16**

Engineering Physics Sample Schedule

	Total Credit Hours	Term: 1	2	3	4	5	6	7	8
Subjects required by all programs (55 hours)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engr 100, Intro to Engr	4	4	-	-	-	-	-	-	-
Engr 101, Intro to Computers[1]	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 211[2]	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 241[3]	10	-	5	5	-	-	-	-	-
Intellectual Breadth	16	4	4	4	4	-	-	-	-
Advanced Mathematics (3 hours)									
Mathematics Electives (3 hours)[4]	3	-	-	-	-	-	-	3	-
Related Technical Subjects (8 hours)									
MATSCIE 250, Princ of Eng Materials or MATSCIE 220, Intr	4	-	-	4	-	-	-	-	-
EECS 314, Elect Cir, Sys, and Appl or EECS 215, Intro to Cir	4	-	-	-	4	-	-	-	-
Physics Technical Subjects (23 hours)									
Physics 340, Waves, Heat and Light	3	-	-	-	3	-	-	-	-
Physics 351, Methods of Theoretical Physics I[5]	3	-	-	-	-	3	-	-	-
Physics 390, Intro to Modern Physics or NERS 311, Ele of N	3	-	-	-	-	3	-	-	-
Physics 401, Int Mech[6]	3	-	-	-	-	-	3	-	-
Physics 405, Int Elect and Mag	3	-	-	-	-	-	-	3	-
Physics 406, Stat/thermal Physics	3	-	-	-	-	-	-	-	3
Physics Lab Elective or Directed Study with Research Lab	2	-	-	-	-	2	-	-	-
Physics Elective (300-level or higher)	3						3		
Engineering Concentration (20 hours)[7]									
Engineering Electives	16	-	-	-	-	4	4	4	4
Engineering Laboratory Elective (400-level or higher)	4	-	-	-	-	-	-	-	4
Technical Electives (7 hours)[8]									
Mathematics, Physics or Engr Courses (300-level or higher	7	-	-	-	-	-	4	3	-
General Electives (12 hours)	12	-	-	-	-	3	3	3	3
Total	128	17	17	17	15	15	17	16	14

Revised 2-2024

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. EECS 180 credit (Exam/Transfer Introductory Computer Programming) will not meet the programming requirement on its own. Students must also select from Engr 190-002, Engr 101, Engr 151, or EECS 280.
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 CoE.
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 CoE.
4. Math Electives must be 300-level or higher.
5. NERS 320 can be used as a subsitute, as well as possibly other similar courses, subject to Undergraduate Chair approval.
6. For students pursuing ME in Engr Technical Elecives, 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.
7. Engineering Electives are to be chosen in consultation with the Undergraduate Chair to form a coherent sequence that clearly defines professional goals for the student. Sample elective sequences for a number of different subject areas are available from the academic or faculty advisors.

8 .Students contemplating graduate studies in Physics should elect Physics 453, Quantum Mech and Physics 463, Solid State for a complete background.

Industrial Operations Engineering Sample Schedule

	Total Credit Hours	Term: 1	2	3	4	5	6	7	8
Subjects required by all programs (55 hours)									
Mathematics 115, 116, 215, and 214	16	4	4	4	4	-	-	-	-
Engr 100, Intro to Engr	4	4	-	-	-	-	-	-	-
Engr 101, Intro to Computers	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 211[1]	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 241[2]	10	-	5	5	-	-	-	-	-
Intellectual Breadth	16	4	4	4	-	-	4	-	-
Related Engineering Subjects (11-12 hours)									
Non-IOE Engineering Courses (11-12 hours)[3]	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 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	-	-	-	-	-			4
TC 380, Technical Communication in IOE	2	-	-	-	-	-	2	-	-
Technical Electives (19)[5]	19	-	-	-	-	3	6	6	4
General Electives (9-12 hours)	9-12	-	-	-		-	-	6	3
Total	***128***	***17***	***17***	***17***	***14***	***16***	***16***	***16***	***15***

Revised: January 2022

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
EECS 280

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 7 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 7 hours allowed from IOE 461, 465, 466.

**Consult IOE academic advisor for requirements based on term of admission.

Materials Science and Engineering Sample Schedule	Credit Hou	1	2	3	4	5	6	7	8
subjects Required by all programs									
Mathematics 115, 116, 215, and 216	16	4	4	4	4				
Engineering 100, Introduction to Engineering	4	4							
Engineering 101, Introduction to Computers	4		4						
Chemistry 125/126 and 130 or Chemistry 210 and 211	5	5							
Physics 140 with Lab 141; Physics 240 with Lab 241	10		5	5					
Intellectual Breadth	16	4	4		4		4		
Science and Technical Subjects (14 hours)									
ME 211, Introduction to Solid Mechanics	4				4				
Science and Technical Electives (must include math course from MSE list)	10						3	4	3
Program Subjects (47 hours)									
MSE 250, Principles of Engineering Materials or MSE 220, Introduction to Materials and Manufacturing	4			4					
MSE 242, Physics of Materials	4				4				
MSE 330, Thermodynamics of Materials	4					4			
MSE 335, Kinetics and Transport in Materials Engineering	4						4		
MSE 350, Structure of Materials	4					4			
MSE 360, Materials Lab I	3					3			
MSE 365, Materials Lab II	3						3		
MSE 420, Mechanical Behavior of Materials	3							3	
MSE 481, Designing Sustainable Products and Processes	3								3
MSE 482, Product Deign and Manufacturing	3							3	
Choose four MSE courses 400 level or above	12					3		3	6
Electives									
General Electives	12			3			3	3	3
Total	128	17	17	16	16	14	17	16	15

Mechanical Engineering Sample Schedule

	Total Credit Hours	Term: 1	2	3	4	5	6	7	8
Subjects Required by all Programs (52-55 hours)									
Mathematics 115+, 116+, 215+, 216+	16	4	4	4	4	-	-	-	-
Engineering 100, Introduction to Engineering+	4	4	-	-	-	-	-	-	-
Engineering 101, Introduction to Computers+	4	-	4	-	-	-	-	-	-
Chemistry 125+/126+ and 130+ or Chemistry 210+ and 211[1]+	5	5	-	-	-	-	-	-	-
Physics 140+ with Lab 141+; Physics 240+ with Lab 241+[2]	10	-	5	5	-	-	-	-	-
Intellectual Breadth (including one course in economics or financials[4])	16	3	4	-	-	-	3	-	6
Related Program Subjects (7 hours)									
Advanced Mathematics[3]	3	-	-	-	-	-	3	-	-
EECS 314, Elect Cir, Sys, and Appl or EECS 215, Intro to Circuits	4	-	-	-	-	4	-	-	-
Program Subjects (45 hours)									
ME 211, Introduction to Solid Mechanics +	4	-	-	4	-	-	-	-	-
ME 235, Thermodynamics I+	3	-	-	-	3	-	-	-	-
ME 240, Introduction to Dynamics and Vibrations+	4	-	-	-	4	-	-	-	-
ME 250, Design and Manufacturing I *	4	-	-	-	4	-	-	-	-
ME 320, Fluids I+	3	-	-	-	-	3	-	-	-
ME 335, Heat Transfer #	3	-	-	-	-	-	3	-	-
ME 350, Design and Manufacturing II *	4	-	-	-	-	4	-	-	-
ME 360, Systems and Controls *	4	-	-	-	-	-	4	-	-
ME 382, Engineering Materials *	4	-	-	-	-	4	-	-	-
ME 395, Laboratory I *	4	-	-	-	-	-	4	-	-
ME 450, Design and Manufacturing III #	4	-	-	-	-	-	-	-	4
ME 495, Laboratory II #	4	-	-	-	-	-	-	4	-
Electives (21 to 24 hours)									
Technical Electives #[3]	9	-	-	-	-	-	-	6	3
Specialization Elective #[5]	3								3
General Electives #	9	-	-	3	-	-		6	
Total	***128***	***16***	***17***	***16***	***15***	***15***	***17***	***16***	***16***

Revised: April-18

Candidates for the Bachelor of Science Degree in Engineering in Mechanical Engineering - B.S.E. in Mech. 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 or Chemistry 210/211, you will have met the Chemistry Core Requirement for the College of Engi

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/or Physics 240/241 you will have met the Physics Core Requirement for the College of Engineering.

3. Advanced Mathematics, and Technical Electives: A list of approved courses is available on the ME Dept website & in the Academic Services Office (ASO), 2380 G.G. Brown.

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 c

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 "C-" or better in pre-requisite design/manufacturing or lab course indicated by (*) symbol;
(#) Students must earn a "D" or better in advanced courses indicated by the (#) 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.

NAME Sample Schedule - Fall 2023

	Total Credit Hours	Term: 1	2	3	4	5	6	7	8
Subjects Required by All Programs (55 hours)									
Mathematics 115, 116, 215, and 216	**16**	**4**	**4**	**4**	**4**	-	-	-	-
Engineering 100, Introduction to Engineering	**4**	**4**	-	-	-	-	-	-	-
Engineering 101, Introduction to Computers	**4**	-	**4**	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 211	**5**	**5**	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 241[2]	**10**	-	**5**	**5**	-	-	-	-	-
Intellectual Breadth	**16**	**4**	**4**	-	-	-	-	**4**	**4**
Related Technical Core Subjects (11 hours)									
ME 211, Solid Mechanics	**4**	-	-	-	**4**	-	-	-	-
ME 240, Introduction to Dynamics	**4**	-	-	-	**4**	-	-	-	-
ME 235, Thermodynamics	**3**	-	-	**3**	-	-	-	-	-
Program Subjects (47 hours)									
NA 270, Vessel/Platform Design	**4**	-	-	**4**	-	-	-	-	-
NA 280, Probability for Marine Engineers	**3**	-	-	-	**3**	-	-	-	
NA 310, Marine Structures I	**4**	-	-	-	-	-	**4**	-	-
ME/NA 320, Intro to Fluid Mechanics	**3**	-	-	-	-	**3**	-	-	-
NA 321, Marine Hydrodynamics	**4**	-	-	-	-	-	**4**	-	-
EECS 314, Elec Circuits, Systems and Apps	**4**	-	-	-	-	**4**	-	-	-
NA 332, Marine Power and Energy	**4**	-	-	-	-	-	**4**	-	-
NA 340, Marine Dynamics I	**4**	-	-	-	-	**4**	-	-	-
NA 370 Conceptual Vessel/Platform Design	**3**	-	-	-	-	-	**3**	-	-
NA 461, Marine Structures Construction	**3**	-	-	-	-	-	-	-	**3**
NA 470, Foundations of Ship Design	**4**	-	-	-	-	-	-	**4**	-
NA 475, Marine Design Team Project	**4**	-	-	-	-	-	-	-	**4**
NA 492, Marine Engineering Laboratory	**3**	-	-	-	-	-	-	**3**	-
Electives (~ 15 hours)									
Technical Electives[3]	**6-8**	-	-	-	-	-	-	**3**	**4**
General Electives	**8-9**	-	-	-	**2**	**4**	**2**		
Total	**128**	**17**	**17**	**16**	**17**	**15**	**17**	**14**	**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 (4)
NA 423, Introduction to Numerical Hydrodynamics (4)
NA 431, Marine Engineering II (3)
NA 440, Marine Dynamics II (4)

Group 2

NA 401, Small Craft Design (4)
NA 403, Sailing Craft Design Principles (3)
NA 416, Theory of Plates and Shells (3)
NA 483 Marine Control Systems (3)
NA 525 Drag Reduction Techniques (3)
NA 562, Marine Systems Production Strategy Operations Management (3)
Advanced Mathematics: Math 450, Math 454, or Math 471
Other courses as approved by the department.

Nuclear Engineering and Radiological Sciences Sample Schedule

	Total	Term:							
	Credit Hours	1	2	3	4	5	6	7	8
Subjects required by all programs (55 hours)									
Mathematics 115, 116, 215, and 216	16	4	4	4	4	-	-	-	-
Engr 100, Intro to Engr[1]	4	4	-	-	-	-	-	-	-
Engr 101, Intro to Computers	4	-	4	-	-	-	-	-	-
Chemistry 125/126 and 130 or Chemistry 210 and 211[2]	5	5	-	-	-	-	-	-	-
Physics 140 with Lab 141; Physics 240 with Lab 241[3]	10	-	5	5	-	-	-	-	-
Intellectual Breadth	16	4	4	4	-	-	4	-	-
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, Applied Mathematics for Engineering Physics	4	-	-	-	-	4	-	-	-
NERS 344, Fluid Mech Nucl Eng	3	-	-	-	-	-	3	-	-
NERS 441, Nuclear Reactor Theory I	4	-	-	-	-	-	-	4	-
NERS 444, Fundamentals of Heat and Mass Transfer								3	
Laboratory Course (above NERS 315)[4]	4	-	-	-	-	-	-	-	4
NERS 491, Nuclear Engineering and Radiological Sciences Design I	1	-	-	-	-	-	-	1	-
NERS 492, Nuclear Engineering and Radiological Sciences Design II	3	-	-	-	-	-	-	-	3
NERS Electives[5]	12	-	-	-	-	-	-	3	6
Technical Electives (5 hours)[6]	5	-	-	-	-	2	-	-	3
General Electives (12 hours)	12	-	-	3	3	-	3	3	-
Total	***128***	***17***	***17***	***16***	***15***	***16***	***17***	***14***	***16***

Revised: 2/2024

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] EECS 180 credit (Exam/Transfer Introductory Computer Programming) will not meet the programming requirement on its own. Students must also select from: Engr 190-002, Engr 101, Engr 151, or EECS 280.

[2] 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.

[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 Physics 240/241 you will have met the Physics Core Requirement for the College of Engineering.

[4] Laboratory course, (above NERS 315) select one of the following: NERS 425, 535, 575, 586.

[5] One course must be selected from the following: NERS 421, 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 credits can only be counted as a general elective.

[6] Technical electives are defined as: 300-level and above Mathematics, Physics, or non-NERS engineering courses. Content must be technical. All subsitutions must be approved by the faculty advisor.

Robotics Sample Schedule[1]

			Term							
Requirement Group	**Course Name**	**Credit hours**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Required for all CoE	Robotics 101 or Math 214	4	4							
	Engineering 100	4		4						
	Engineering 101 or Robotics 102	4	4							
	Mathematics 115 and 116	8	4	4						
	Mathematics 216	4			4					
	Physics 140 and Lab 141	5		5						
	Physics 240 and Lab 241	5			5					
	Chemistry 125/126/130 or 210/211	5				5				
	Intellectual Breadth	16	4		4		4			4
Robotics Program Core	Robotics 204	4				4				
Robotics Intermediate	Robotics 310*	4						4		
	Robotics 311*	4					4			
	Robotics 320	4								4
	Robotics 330	4							4	
	Robotics 340	4					4			
Disciplinary Breadth	EECS 280 - Data Structures	4			4					
	IOE 265 - Probability and Stat	3				3				
	EECS 215 or 270 or BME 211	4				4				
	ME 240 or BME 231	4						4		
Disciplinary Depth	NAVARCH 270	4					4			
Capstone	TCHNCLCM 350	3							3	
	Robotics 450 or EECS 467	4								4
Technical Electives	Upper Level Robotics Electives	12						4	4	4
	Flexible Technical Electives	0								
General Electives	General Electives	11		3				4	4	
* counted as Upper Level Robotics Elective credit	**Total**	128	16	16	17	16	16	16	15	16

[1] Please note: This schedule selects 300-level courses and electives which allow the student to emphasize breadth-focused, well rounded robotics. There is a high degree of flexibility within the requirements of the Robotics BSE and it is possible to select 300-level courses and electives to emphasize many other areas. Please see the Robotics Undergraduate Program Guide for more information and sample schedules.

Aerospace Engineering

Aerospace Engineering (AEROSP)

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.

Course Guide

Aerospace Engineering Courses

Contact

Departmental Website: https://aero.engin.umich.edu

Aerospace Engineering Dept.
3000 Francois-Xavier Bagnoud Building (FXB)
1320 Beal Ave
Ann Arbor, MI 48109-2140
Phone: (734) 764-3310

Department Administration

Department Chair
Carlos Cesnik, Richard A. Auhll Department Chair, Clarence L. (Kelly) Johnson 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 use their outstanding preparation to take 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 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

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally you can see recent degrees granted below.

Level	**2021**	**2022**	**2023**
Bachelors Degrees	126	165	103
Masters Degrees	80	77	119
Doctoral Degrees	28	16	23

Accreditation

The Aerospace Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Aerospace and Similarly Named Engineering Programs.

Program Outcomes

The matrix maps how each course in our curriculum addresses our program outcomes. Only the outcomes tracked are noted below.

Course	Student Outcomes (Black – High)						
	Apply math and science	Design	Communicate	Ethics	Teams	Experiments, Analyze, and Interpret Data	Lifelong Learning
AEROS P200			■	■			
AEROS P201				■			
AEROS P215	■						

AEROS P225							
AEROS P305							
AEROS P315							
AEROS P325							
AEROS P335							
AEROS P341							
AEROS P343							
AEROS P350							
AEROS P405							
AEROS P470							

AEROS P481							
AEROS P483							

Undergraduate Degree Program

The degree program gives the student a broad education in engineering by requiring basic courses in aerodynamics and propulsion, 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 aerodynamics and propulsion 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 dynamic 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

Please see the PDF version of the **sample schedule**. Additional information can be found on the department advising website.

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.

Available programs include:

- B.S.E. in Aerospace Engineering/M.S.E. in Aerospace Engineering
- B.S.E. in Aerospace Engineering

Check the SUGS website for more details.

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: five, 500-level or higher classes in aerospace engineering – which includes graduate-level engineering courses that have been cross-listed with aerospace engineering courses, and two 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 although it is not required to graduate. The M.S.E. program does not include an option for a thesis per se; however, through AEROSP 590, students can perform research work under the 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 Master of Science in Engineering

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 the 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: The Master of Engineering Degree in Space Engineering

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
3. Research & Dissertation

Doctoral Degree Requirements

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 at least one graduate-level course outside the student's field of study but still be 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 that engage students to be able to recognize, address, and resolve ethical issues in classroom, professional, and research settings.

2. **Preliminary Examination**

There are two mandatory preliminary examinations. The first is an oral coursework examination covering material taught in the five selected core courses administered by the preliminary examination committee. This examination is offered twice a year. The second is an oral research examination, which takes place some months after the coursework examination. A student must pass both preliminary examinations to earn their degree.

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 Doctor of Philosophy

Aerospace Engineering Courses (AEROSP)

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 288. Fundamentals of Product Development
Prerequisite: None. (3 credits)

Focuses on the development of complex products (aircraft, spacecraft, automobiles, etc.). Model-Based Systems Engineering tools and methods will be taught on a known system, so students can learn fundamentals and apply them to their own student projects. Other product development leadership tools and processes are also included. ***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. ***CourseProfile (ATLAS)***

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. **CourseProfile (ATLAS)**

AEROSP 341. Aircraft Dynamics
Prerequisite: MECHENG 240, MATH 216 and AEROSP 201. Minimum grade of a “C-” for enforced prerequisites. (3 credits)

Introduction to the dynamics and control of atmospheric flight vehicles. Nonlinear equations of motion. Stability derivatives and linearized equations for longitudinal and lateral flight dynamics. Concepts from linear systems: state equations, transfer functions, stability, time response, frequency response. Flight simulation using relevant software. **CourseProfile (ATLAS)**

AEROSP 343. Spacecraft Dynamics
Prerequisite: MECHENG 240, MATH 216 and AEROSP 201. Minimum grade of a "C-" for enforced prerequisites. (3 credits)
Introduction to space flight mechanics. The two-body problem. Orbital transfers, maneuvers and orbital analysis. Ground tracks and relative motion in orbit. Gravity-assist trajectories. Spacecraft attitude and rotational dynamics. Euler and Poisson equations and their linearization. Stability analysis. Momentum management using thrusters and reaction wheels. Orbital simulation using relevant software. ***CourseProfile (ATLAS)***

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

AEROSP 388. Aerospace Tools & Methods (MBSE)
Prerequisite: AEROSP 288. Minimum grade of "B" or instructor permission for enforced prerequisite. (4 credits)
Comprehensive teachings in Aerospace tools and methods, and statistical modeling, featuring Model-Based Systems Engineering (MBSE). Physical and virtual verification and validation (V&V) methods will be taught, emphasizing correlation of virtual modeling to physical testing. Root cause analysis and Six Sigma tools and process are included to put V&V into context. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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 two-semester sequence covering instrumentation and measurement and their application in engineering testing and experimentation. Application of the principles learned in Aero 305 to more advanced test and measurement applications. Experiments and Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

AEROSP 416 (NAVARCH 416). Theory of Plates and Shells
Prerequisite: AEROSP 315. (3 credits)
Linear elastic plates. Membrane and bending theory of axisymmetric and non-axisymmetric shells. Variational formulation of governing equations boundary conditions. Finite element techniques for plate and shell problems. **CourseProfile (ATLAS)**

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 system approach aimed at designing an aircraft for a set of specifications. Team based projects are overseen and graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

AEROSP 483. Space System Design
Prerequisite: preceded by AEROSP 343. Preceded or accompanied by AEROSP 315, 325, and 335 (Advisory). (4 credits)
Engineering design process for space systems. Mission planning, launch vehicle integration, propulsion, power systems, communications, budgeting, and reliability. Space-systems engineering by including components, subsystems and mission design. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **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 488. Product Development Leadership
Prerequisite: AEROSP 388. Minimum grade of "B" or instructor permission for enforced prerequisite. (4 credits)
Students lead and manage comprehensive product design and development project. Senior team leader training, including both coaching and facilitation. Students are involved with coaching and mentorship of undergraduate students in AEROSP 288 and 388. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **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 501. Aerospace Economics
Prerequisite: None. (3 credits)
Graduate course in informing optimal engineering decisions based upon product lifecycles and customer usage profiles. Students will learn about customer needs and how they're fulfilled by aerospace products, ultimate lifecycles of those products, how they inform the best product decisions, and future considerations around technology, sustainability, and industry trends. **CourseProfile (ATLAS)**

AEROSP 502. Aerospace Leadership Capstone
Prerequisite: None. (3 credits)
Graduate Capstone course/project where students work in teams of 4-5 to develop a comprehensive technology, product development, and business proposal, and apply all program learnings to the project. Students present to a panel of industry judges who grade the quality of the project, presentation, and use of the tools/methods. **CourseProfile (ATLAS)**

AEROSP 505. Engineering Tools & Methods
Prerequisite: None. (2 credits)
A Model-Based Systems Engineering (MBSE) course covering physical and virtual engineering, emphasizing move from physical to virtual. Correlations between physical and virtual evaluations for different technologies and systems will be discussed. Formal requirements delivery through MBSE, and Six Sigma (6σ) tools/processes will drive understanding of MBSE model use and limitations. **CourseProfile (ATLAS)**

AEROSP 510. Finite Elements in Mechanical and Structural Analysis I
Prerequisite: AEROSP 315. (3 credits)
Introductory level. Finite element solutions for structural dynamics and nonlinear problems. Normal modes, forced vibrations, Euler buckling (bifurcations), large deflections, nonlinear elasticity, transient heat conduction. Computer laboratory based on a general purpose finite element code. **CourseProfile (ATLAS)**

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)
Effective stiffness properties of composites. Constitutive description of laminated plates. Laminated plate theory. Edge effects in laminates. Nonlinear theory of generally laminated plates. Governing equations in the Von Karman sense. Laminated plates with moderately large deflections. Post-buckling and nonlinear vibration of laminated plates. Failure theories and experimental results for laminates. **CourseProfile (ATLAS)**

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)
A Natural frequencies and mode shapes of elastic bodies. Non-conservative elastic systems. Structural and viscous damping. Influence coefficient methods for typical flight structures. Response of structures to random and shock loads. **CourseProfile (ATLAS)**

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)
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability. **CourseProfile (ATLAS)**

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.
Information systems for Aerospace applications. Data abstraction, elementary data structures. Graphs, automata theory. Life cycle models, validation & verification. Deterministic search

algorithms. Decision making under uncertainty; review of probability theory, introduction to information theory, Bayesian Networks, Markov chains, Markov Decision Processes. Substantial code development in a traditional programming language. **CourseProfile (ATLAS)**

AEROSP 566. Data Analysis and System Identification
Prerequisite: Graduate standing (3 credits)
Methods of data analysis and empirical modeling. Sensors and measurement concepts. Time and frequency data analysis; statistical and spectral concepts. Linear regression and identification of time-series models. Parameter estimation using optimization. Basis-function expansions and nonlinear time series identification. Eigensystem realization and subspace identification. Nonlinear state space identification. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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
Advisory Prerequisite: AEROSP 550. (3 credits) (Credit for both AEROSP 580 and EECS 565 not allowed.)
Standard problem for state space and transfer function models. Specialization to the basic servo loop with feedback and feedforward control. Pole placement. Internal model principle for commands and disturbances. Stability, norms, and solution of the Lyapunov equation. Treatment of the linear-quadratic regulator and linear-quadratic-Gaussian controllers. Analysis of the Riccati equation. **CourseProfile (ATLAS)**

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. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. ***CourseProfile (ATLAS)***

AEROSP 583 (SPACE 583). Management of Space Systems Design
Prerequisite: None. (4 credits)
Students lead teams in high level project design of a space system. Modern methods of concurrent engineering manufacturing, marketing and finance, etc., are incorporated. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

AEROSP 584. Avionics, Navigation and Guidance of Aerospace Vehicles
Prerequisite: AEROSP 470 or graduate standing (Advisory). (3 credits)
Principles of aerospace navigation and guidance. Deterministic and stochastic linear perturbation theory. Position fixing and celestial navigation with redundant measurements. Recursive navigation and Kalman filtering. Pursuit guidance, proportional navigation, ballistic guidance and velocity-to-be-gained guidance. **CourseProfile (ATLAS)**

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)**

AEROSP 650. Aerospace Enterprise Leadership
Prerequisite: Declaration in MEng program in Global Aerospace Leadership. (1.5 credits)
Leadership, strategic technology, and critical business skills essential to leading and managing large technical teams and operations, with a focus on the Aerospace Enterprise. Provides teachings and coaching on role-model leadership behaviors through instructor lectures, case study analyses, and thoughts and perspectives from senior leaders in industry, government, and academia. **CourseProfile (ATLAS)**

AEROSP 656. Technical Project Management & Leadership Skills for Engineers
Prerequisite: Declaration in MEng program in Global Aerospace Leadership. (1.5 credits)
Provides essential project management skills and tools. Topics range from initiating projects and project planning through project execution, control, and close-out. Emphasizes commonly used tools and their practical application along with the interpersonal skills to successfully manage complex technical projects. **CourseProfile (ATLAS)**

AEROSP 690. Financial Analysis for Non-Finance Managers
Prerequisite: Declaration in MEng program in Global Aerospace Leadership. (1 credit)
Explores decision-making frameworks using evaluation tools to evaluate the impact and efficacy of different projects. Takes a deep dive into valuation at the firm level, getting to grips with new techniques and mechanisms to estimate the value of an enterprise. **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)

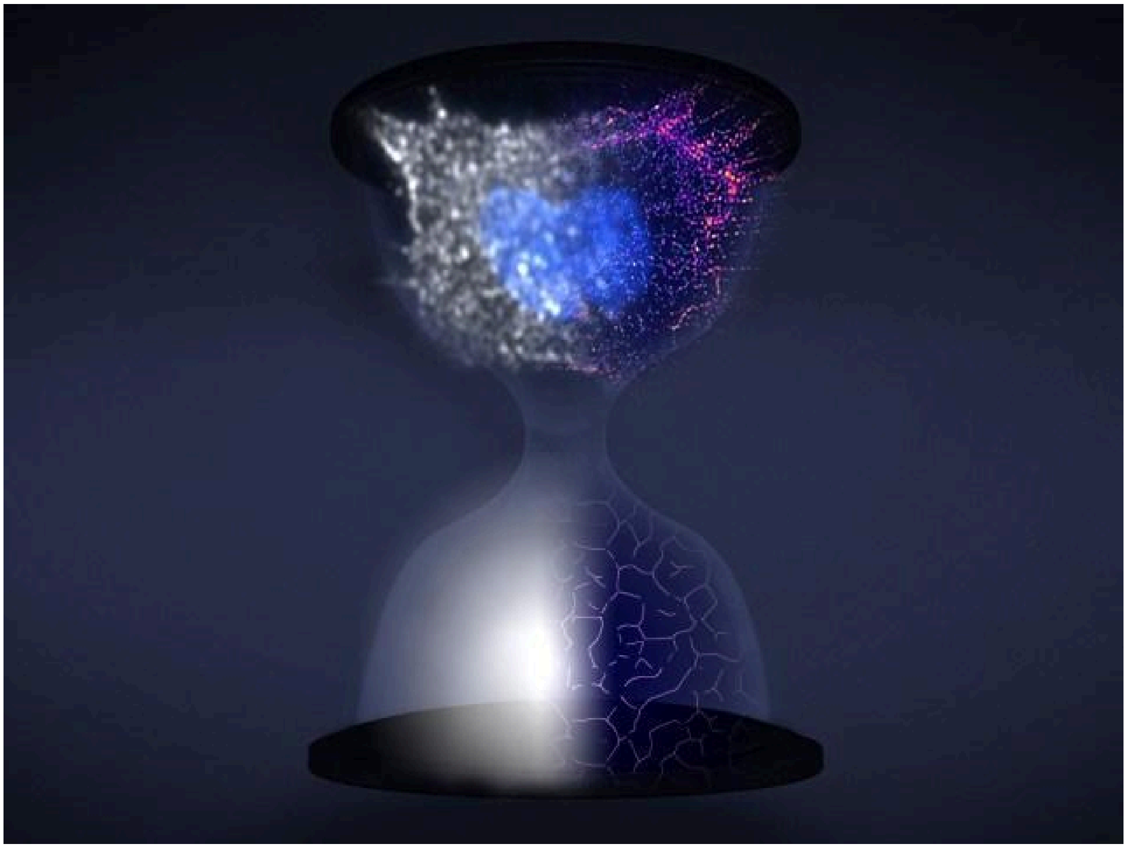
900 Level Courses

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

Applied Physics (APPPHYS)



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 students enrolled annually in this program, and the number of degrees granted each term by this program.

Course Guide

Applied Physics Courses

Contact

Departmental Website: https://lsa.umich.edu/appliedphysics/about.html

Applied Physics Dept.
450 Church St., 1425 Randall Lab.
Ann Arbor, MI 48109-2140

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 Master's 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. 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 January 5.

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, five prescribed 500 level courses must be passed with a grade B or better. 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 (APPPHYS 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 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. After 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 fourth term in graduate school. Approval of the Dissertation Prospectus is a program requirement prior to Candidacy.

Applied Physics Courses (APPPHYS)

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)
Theory of electromagnetic, physical and geometrical optics. Classical theory of dispersion. Linear response, Kramers-Kronig relations and pulse propagation. Light scattering. Geometrical optics and propagation in inhomogeneous media. Dielectric waveguides. Interferometry and theory of coherence. Diffraction, Fresnel and Fraunhofer. Gaussian beams and ABCD law. **CourseProfile (ATLAS)**

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)

Propagation of ultrashort optical pulses in linear and nonlinear media and through dispersive optical elements. Laser mode-locking and ultrashort pulse generation. Chirped-pulse amplification. Experimental techniques for high time resolution. Ultrafast Optoelectronics. Survey of ultrafast high field interactions. **CourseProfile (ATLAS)**

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)**

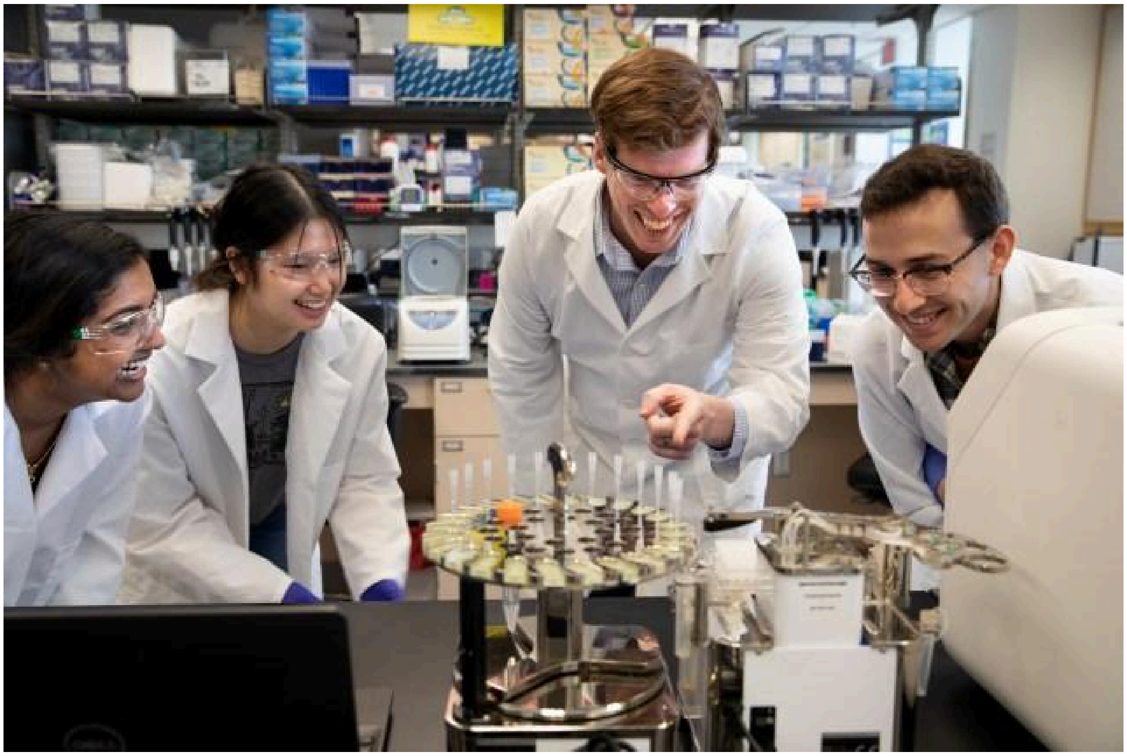
APPPHYS 669 (Chem 669). Physics of Extended Surfaces
Prerequisite: quantum mechanics or solid state physics, or permission of instructor. (3 credits)
Chemical physics of extended surfaces: basic surface phenomena which control the physical and chemical properties of extended surfaces. A wide range of 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)**

Biomedical Engineering

Biomedical Engineering (BIOMEDE)



Students who enjoy math, physics and chemistry, but who also have a keen interest in biology and medicine, should consider a career in Biomedical Engineering (BME). Synthetic heart valves, the fMRI scanner, and automatic bio-sensors for rapid gene sequencing are each examples of BME.

With the rapid advances in biomedical research, and the severe economic pressures to reduce the cost of healthcare, BME plays an important role in the medical environment of the 21st century. BME brings the quantitative concepts of design and optimization to problems in biomedicine. In BME, we seek to tackle these problems for the benefit of humanity.

The opportunities for biomedical engineers are wide-ranging. The medical device and pharmaceutical industries are increasingly investing in biomedical engineers. As gene therapies become more sophisticated, biomedical engineers will have a key role in bringing these ideas into real clinical practice. Finally, as technology plays an ever-increasing role in medicine, there will be a larger need for physicians with a solid engineering background. From biotechnology to tissue engineering, from medical imaging to microelectronic prostheses, from biopolymers to rehabilitation engineering, biomedical engineers are in demand.

Course Guide

Biomedical Engineering Courses

Contact

Departmental Website: https://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

Department Administration

Department Chair

Mary-Ann Mycek, Professor Biomedical Engineering, College of Engineering & the Medical School.

1107 Carl A. Gerstacker Building

For more specific information on contacting people – go to our **Contacts page**.

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 BME graduates may pursue a broad range of careers, the BME Program Objectives are phrased to reflect the preparation provided by the program for these career options. The Program Educational Objectives for the Department of Biomedical Engineering are as follows:

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.

Program Criteria

In addition to providing both breadth and depth across the range of engineering and science topics consistent with the program educational objectives and student outcomes, our curriculum also provides experience in the following Biomedical Engineering program-specific criteria:

1. An ability to apply principles of engineering, biology, human physiology, chemistry, calculus-based physics, mathematics (through differential equations) and statistics.
2. An ability to solve bio/biomedical engineering problems, including those associated with the interaction between living and non-living systems.
3. An ability to analyze, model, design, and realize bio/biomedical engineering devices, systems, components, or processes.
4. An ability to make measurements on and interpreting data from living systems.

Enrollment and Graduation Data

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally you can see recent degrees granted below:

Level	**2021**	**2022**	**2023**
Bachelors Degrees	124	103	138
Masters Degrees	108	90	80
Doctoral Degrees	15	24	25

Accreditation

The Biomedical Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Bioengineering and Biomedical and Similarly Named Engineering Programs.

Undergraduate Degree Program

BME offers a four-year undergraduate degree along with an optional one-year master's degree in a Sequential Undergraduate/Graduate Studies (SUGS) program. Students will complete 53 credits of Core Biomedical Engineering courses and 21 credits of depth requirements leading to a Bachelor of Science in Engineering degree (B.S.E. in Biomedical Engineering). Students may then pursue a graduate degree within one of the five graduate concentrations: bioelectrics and neural engineering, biomaterials and regenerative medicine, biomechanics and biotransport, biomedical imaging and ultrasonics, and biotechnology and systems biology, leading to a Master of Science in Engineering degree (M.S.E. in Biomedical Engineering). Students may also pursue the Master of Engineering degree (M.Eng. in Biomedical Engineering) through the Advanced Medical Product Engineering and Development (AMPED) program.

Sample Schedule

B.S.E. in Biomedical Engineering

Please see the PDF version of the **sample schedule here**. Additional information can be found on the Biomedical Engineering Department Advising website.

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 either a M.S.E. or an M.Eng. degree upon completion of a minimum of 149 credit hours (146 credits minimum for the M.Eng.). Students should speak with the department advising staff to learn more about the SUGS application process and procedures. SUGS admissions requirements will vary. Please review the CoE Bulletin page for Combined Bachelor's/Master's Programs for further information.

Available programs include:

- B.S.E. in Biomedical Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Biomedical Engineering/M.Eng. in Advanced Medical Product Engineering & Development
- B.S. in Cellular Molecular Biology Studies (CMBS)/M.S.E. in Biomedical Engineering
- B.S. in Cellular Molecular Biology Studies (CMBS)/M.Eng. in Advanced Medical Product Engineering & Development
- B.S.E. in Chemical Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Chemical Engineering/M.Eng. in Advanced Medical Product Engineering & Development
- B.S.E. in Electrical Engineering and Computer Science/M.S.E. in Biomedical Engineering
- B.S.E. in Electrical Engineering and Computer Science/M.Eng. in Advanced Medical Product Engineering & Development
- B.S.E. in Industrial and Operations Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Industrial and Operations Engineering/M.Eng. in Advanced Medical Product Engineering & Development
- B.S.E. in Material Science Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Material Science Engineering/M.Eng. in Advanced Medical Product Engineering & Development
- B.S.E. in Mechanical Engineering/M.S.E. in Biomedical Engineering
- B.S.E. in Mechanical Engineering/M.Eng. in Advanced Medical Product Engineering & Development
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.S.E. in Biomedical Engineering
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.Eng. in Advanced Medical Product Engineering & Development
- B.S.E. in Robotics/M.S.E. in Biomedical Engineering
- B.S.E. in Robotics/M.Eng. in Advanced Medical Product Engineering & Development

Students who have not completed a B.S./B.S.E. in Biomedical Engineering or Cellular Molecular Biology Studies 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 Degrees

- Master of Science (M.S. or M.S.E.) in Biomedical Engineering
- Master of Engineering (M.Eng.) in Advanced Medical Product Engineering & Development
- 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. (or M.S.E.) and Ph.D. degrees in Biomedical Engineering. The M.Eng. AMPED program is in the College of 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./M.S.E. 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) or a directed research experience, to familiarize them 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 five (5) concentration options available:

- Bioelectrics and Neural Engineering
- Biomaterials and Regenerative Medicine
- Biomechanics and Biotransport
- Biomedical Imaging and Ultrasonics
- Biotechnology and Systems Biology

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.

M.Eng. in Biomedical Engineering

Degree Requirements

The Master of Engineering degree in Biomedical Engineering is a professional master's degree in Advanced Medical Product Engineering and Development (AMPED). Students must satisfactorily complete (B or better) a minimum of 27 credit hours of graduate study beyond the bachelor's degree. The curriculum consists of a defined set of advanced core courses in the AMPED program, as well as graduate-level requirements in statistics, and ethical and professional conduct. Within the curriculum, each student will also complete 2-5 graduate technical electives. The core AMPED curriculum includes courses in:

- Biomedical Product Realization Practicum
- Quality Systems, Risk Management, and Regulatory Systems
- Professional and Leadership Development
- Advanced Topics in Medical Product Development

Please see the department web site and the AMPED 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 student's research advisor. 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 their 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 identified for each applicant to supervise the work of the student 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.

The most up to date information on the Biomedical Engineering graduate programs is available online on the Graduate Studies page.

Biomedical Engineering Courses (BIOMEDE)

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

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
Advisory Prerequisite: BIOL 172 or AP Biology Credit.
Prerequisite: (CHEM 130 or 210) and (MATH 116 or 121 or156 or 186). Minimum grade of a "C-" for enforced prerequisites. (4 credits)
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 121 or 156 or 186) and (PHYSICS 140 or 160). Minimum grade of a "C-" for enforced prerequisites. (4 credits)
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 or EECS 183 or EECS 180 or ROB 102. Minimum grade of a "C-" for enforced prerequisites. (4 credits)
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 & 216); OR (Math 285 & 286). Minimum grade of a "C-" required for enforced prerequisites. (4 credits)
Introduces the fundamentals of biofluid dynamics and continuum mechanics, and covers the application of these principles to 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
Prerequisite: ENGR 100, and [MATH 216 or 256 or 286] and BIOMEDE 231, and BIOMEDE 241. Minimum grade of a "C-" for enforced prerequisites. Advisory Prerequisite: BIOMEDE 211 and 221 (4 credits)
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
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
Prerequisite: (ENGR 101 or 151) or (EECS 180 or 183 or 280). Minimum grade requirement of "C- or better". (3 credits)
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. Students are exposed to design process: problem definition, generation of specifications, documentation, review process,

prototype fabrication, & testing. Students may receive credit for either 450 or 451. Projects are overseen and graded by faculty and may also involve mentoring by representatives from external organizations. **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 overseen/graded by faculty and may also involve mentoring by representatives from external organizations. 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 overseen/graded by faculty and may also involve mentoring by representatives from external organizations. 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 231 or MECHENG 211], and [BIOMEDE 332 or MECHENG 382] (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
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 radioisotope 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 487. Artificial Intelligence in Biomedical Engineering
Advisory Prerequisite: *Linear Algebra and BIOMEDE 241*.
Prerequisite: (Biology 172, or 174, or 195); AND (Math 116 or 121); AND (Engr 101 or 151 or EECS 183, or 180); (C- or better); or Graduate Standing. Minimum grade of a “C-” for enforced prerequisites. (3 credits)
Introduces AI tools and applies them to real-world biomedical problems. Will cover a wide range of AI and machine-learning tools, biomedical data sets and disease applications. The focus will be on practical applications of AI in BME with hands-on tutorials and a design project. **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 502. Professional Skills for Graduate Success
Prerequisite: Graduate standing. (1 credit)
Give an orientation to the BME PhD program, help students understand expectations of BME PhD students, and provide introductions to key concepts and skills (e.g., citation manager usage, communication etiquette) that will be helpful as BME PhD students. **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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

BIOMEDE 509 (CHE 509) (MACROMOL 509) (MATSCIE 509). Advanced Biomaterials
Advisory Prerequisite: MATSCIE 220 or MATSCIE 250. Enforced Prerequisite: None. (3 credits)
Applications of biomaterials in implants, regenerative medicine, tissue engineering, and drug delivery systems will be covered. Principles of biomaterials incorporating contemporary research related to rational design strategies for biomaterials, their processing and fabrication, biomimetics, immunomodulation, degradation, and in vivo responses will be included. **CourseProfile (ATLAS)**

BIOMEDE 510. Medical Imaging Laboratory
Prerequisite: BIOMEDE 516 or permission of instructor. Minimum grade requirement: B. (3 credits)
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. **CourseProfile (ATLAS)**

BIOMEDE 516 (EECS 516). Medical Imaging Systems
Advisory 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. **CourseProfile (ATLAS)**

BIOMEDE 517. Sensing & Machine Learning for Neural Interfaces
Prerequisite: (BIOMEDE 211 or EECS 215 or EECS 314); and (EECS 216); and (Math 216); and (ENGR 101 or EECS 183 or EECS 180 or EECS 208) or Graduate Standing (B or better, NO OP/F). Minimum

grade requirement: B. (3 credits)
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. Then students apply machine learning techniques to extract information from large neural datasets. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

BIOMEDE 523. Business of Biology: The New Frontiers of Genomic Medicine
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 527. Current Topics in Neuromodulation
Prerequisite: BIOMEDE 417 or Graduate status. Minimum grade requirement: C-. (3 credits)
We will review current findings in neuromodulation, focusing on important recent work and seminal results. Engineering considerations common to electrical implants will be discussed, such as electrode measurement and design, packaging and circuits, and modeling of electrical fields and neurons. **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 533). Neuromechanics
Prerequisite: Graduate standing. (3 credits)
This graduate course examines the structural and physiologic properties of muscle, as well as its force production, and overall biomechanical function. Muscle structure and neuromuscular function will be explored at the neural, protein, single fiber, and whole tissue levels. **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 537. Computational Tools for Genomic Technologies
Prerequisite: [BIOL 172 OR 195] AND [ENGR 101 OR 151, OR EECS 183 OR180, OR ROB 102]. Minimum grade requirement: C-. (3 credits)
The dramatic reductions in cost and accessibility of next-generation sequencing technologies has facilitated new approaches to understand disease and cellular biology . Understanding how to read sequencing datasets is not only incredibly useful for researchers seeking to glean insights into their own experiments but also the capacity to generate data-driven hypotheses. Develop an understanding of foundational methods in bioinformatics. **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 a 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
Prerequisite: Permission of Instructor; Advisory 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
Advisory 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 Sytems 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 646 (MECHENG 646). Mechanics of Human Movement
Prerequisite: MECHENG 540 (AEROSP 540) or MECHENG 543 or equivalent. (3 credits)
Dynamics of muscle and tendon, models of muscle contraction. Kinematics and dynamics of the human body, methods for generating equations of motion. Mechanics of proprioceptors and other sensors. Analysis of human movement, including gait, running and balance. Computer simulations and discussion of experimental measurement techniques. **CourseProfile (ATLAS)**

BIOMEDE 651. Biomedical Engineering Product Realization Practicum I
Prerequisite: Graduate Standing. Advised Prerequisite: Background in engineering or a physical science, including familiarity with engineering design processes. (2 credits)
Graduate Design-Build-Test practicum for students in the medical product development program. Focus is on identification and solution of an existing clinical problem, using engineering design and product development concepts. Continues in Winter term with BME-PRP II. **CourseProfile (ATLAS)**

BIOMEDE 652. Biomedical Engineering Product Realization Practicum II
Prerequisite: BIOMEDE 651 (B or better, NO OP/F) & Graduate Standing. Advised Prerequisite: Background in engineering or a physical science, including familiarity with engineering design processes. (2 credits)
Graduate Design-Build-Test practicum course for students in the medical product development program. Focus is on identification and solution of an existing clinical problem, using engineering design and product development concepts. Continuation of BME-PRP I from Fall term. **CourseProfile (ATLAS)**

BIOMEDE 653. Quality Systems, Risk Management, & Regulatory Structures I
Prerequisite: Graduate Standing. Advised Prerequisite: Background in engineering or a physical science, including familiarity with engineering design processes. (2 credits)
Current concepts and regulations in quality management systems, risk management, and regulatory structures impacting medical product development. Continues in Winter term with Qual Risk Reg II. **CourseProfile (ATLAS)**

BIOMEDE 654. Quality Systems, Risk Management, & Regulatory Structures II
Prerequisite: BIOMEDE 653 (B or better, No OP/F), and Graduate Standing. Advised Prerequisite: Background in engineering or a physical science, including familiarity with engineering design processes. (2 credits)
Current concepts and regulations in quality management systems, risk management, and regulatory structures impacting medical product development. Continuation of Qual Risk Reg I from the Fall term. **CourseProfile (ATLAS)**

BIOMEDE 655. Professional & Leadership Development I
Prerequisite: Graduate Standing. Advised Prerequisite: Background in engineering or a physical science, including familiarity with engineering design processes. (2 credits)
Topics in career preparation and progression, professional development, and leadership, with a focus on areas of importance for engineers in the medical technology industries. Continues with Prof Lead Dev II in the Winter term. **CourseProfile (ATLAS)**

BIOMEDE 656. Professional & Leadership Development II
Prerequisite: BIOMEDE 655 (B or better, NO OP/F), Graduate Standing. Advised Prerequisite: Background in engineering or a physical science, including familiarity with engineering design processes. This course is part of the AMPED curriculum. (2 credits)
Topics in career preparation and progression, professional development, and leadership, with a focus on areas of importance for engineers in the medical technology industries. Continuation of Prof Lead Dev I in the Fall term. **CourseProfile (ATLAS)**

BIOMEDE 657. Advanced Topics in Medical Product Development I
Prerequisite: Graduate Standing. Advised Prerequisite: Background in engineering or a physical science, including familiarity with engineering design processes. (2 credits)
Current and advanced topics in the area of medical product development, realization, and commercialization. Content tracks trends and needs in the medical technology industries. Continues in Winter term with Advanced MPD II. **CourseProfile (ATLAS)**

BIOMEDE 658. Advanced Topics in Medical Product Development II
Prerequisite: BIOMEDE 657 (B or better, No OP/F), Graduate Standing. Advised Prerequisite: Background in engineering or a physical science, including familiarity with engineering design processes. (2 credits)
Current and advanced topics in the area of medical product development, realization, and commercialization. Content tracks trends and needs in the medical technology industries. Continuation of Advanced MPD I from the Fall term. **CourseProfile (ATLAS)**

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

Chemical Engineering (CHE)

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 reaction kinetics, thermodynamics, fluid mechanics, heat transfer, mass transfer, 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, data science, education, law, medicine, public health, and government work. More information on careers for chemical engineers is available on 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.

Course Guide

Chemical Engineering Courses

Contact

Departmental Website: http://che.engin.umich.edu/

Chemical Engineering Department
3074 H. H. Dow
2300 Hayward St.
Ann Arbor, MI 48109-2136

Undergraduate Email:
cheugadvising@umich.edu
Graduate Email:
che-gradquestions@umich.edu

Phone: (734) 764-2383
Fax: (734) 763-0459

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

Michigan Chemical Engineering seeks to drive human excellence by shaping the future of chemical engineering through groundbreaking research and by producing engineers whose empathy, insight, and knowledge enable them to translate ideas and discoveries into equitable engineering solutions.

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, graduates of the University of Michigan Chemical Engineering Program 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 collaborating 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

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally you can see recent degrees granted below:

Level	**2021**	**2022**	**2023**

Bachelors Degrees	118	73	97
Masters Degrees	39	32	26
Doctoral Degrees	21	26	28

Accreditation

The Chemical Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Chemical, Biochemical, Biomolecular and Similarly Named Engineering Programs

Program Outcomes

The matrix maps how each course in our curriculum addresses our program outcomes. Only the outcomes tracked are noted below.

	Student Outcomes (Black; assessed)						
Course	1	2	3	4	5	6	7
ChE 230				■	■		■
ChE 330	■	■					
ChE 341	■	■					■
ChE 342	■		■	■			

ChE 343		■		■			■
ChE 344		■			■	■	
ChE 360			■		■	■	
ChE 460			■		■	■	
ChE 466	■	■		■			
ChE 485		■		■			
ChE 487		■	■	■	■		■
ChE 488/489		■	■	■	■		■

Undergraduate Degree Program

Sample Schedule

B.S.E. in Chemical Engineering

The Chemical Engineering program is accredited by the Engineering Accreditation Commission of ABET. Please see the PDF version of the sample schedule. Additional information can be found on the Chemical Engineering Department Advising website.

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. Please review the Minors, Concentrations, and Specialized Studies page for more information on concentration requirements.

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 the Master's and SUGS Programs page.

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 or 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 within 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 experience 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 coursework from various engineering disciplines (80%) and business (20%). Applicants to this program must have completed 80 or more credits of coursework 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.

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 three 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 their 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 within some relatively broad fields 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 their 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 as to the election of courses, conduct of new research, and preparation of the dissertation.

Information on the general procedure leading to the doctorate is available at the Rackham Graduate School website.

Chemical Engineering Courses (CHE)

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 or 119 or 156 or 176 or 186 or 296 or 121); (C- or better). (4 credits)
An introduction to material and energy balances in chemical engineering applications, including environmental and biological systems. Systematic Engineering problem solving, the equilibrium concept in single phase or multiple phase systems, first law of thermodynamics, heats of reaction. 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. (1-4 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. **CourseProfile (ATLAS)**

CHE 296. Special Topics in Chemical Engineering
Prerequisite: None. (1-4 credits)
Selected topics pertinent to lower-level chemical engineering students. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

CHE 341. Fluid Mechanics
Prerequisite: *(PHYSICS 140 or 160) and (MATH 215 or 285), preceded or accompanied by CHE 230 and (MATH 216 or 286). Minimum grade requirement: C-. (4 credits)*
Fluid mechanics for chemical engineering. Mass, momentum, and energy balance on static and flowing
systems. Laminar and turbulent flow in pipes, equipment, and porous media. Advanced topics including boundary layers, potential and irrotational flows, non-Newtonian fluids, and microfluidic systems. **CourseProfile (ATLAS)**

CHE 342. Mass and Heat Transfer
Prerequisite: ChE 230 and ChE 341 and (Math 216 or 256 or 286 or 316); (C- or better). Minimum grade requirement: C-. (4 credits)
Theories and applications of mass and heat transport phenomena. Fick's law and Fourier's Law. Steady and unsteady diffusion and conduction. Mass and heat transfer coefficients. Simultaneous momentum and mass/heat transfer. Heat exchangers. Condensation and boiling. Radiation, Kirchoff's law and view factors. Ion diffusion in solution. Mass transfer in polymer membranes. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

CHE 344. Reaction Engineering and Design
Prerequisite: CHE 330, CHE 342. (4 credits)
Fundamentals of chemical reaction engineering. Rate laws, kinetics and mechanisms of homogeneous and heterogeneous reactions. Analysis of rate data, multiple reactions, heat effects, bioreactors, Safety (Runaway reactions). Design of industrial reactors. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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 (MACROMOL 412) (MATSCIE 412). Polymeric Materials
Prerequisite: MATSCIE 220 or 250 or Graduate Standing. Minimum grade of "C-" for enforced prerequisites. (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. **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
Prerequisite: CHE 343 and CHE 344. Minimum grade requirement: C-. (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.
Optimization and model predictive control. **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)**

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)**

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)**

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. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

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)**

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)**

CHE 490. Advanced Directed Study, Research and Special Problems
Prerequisite: CHE 230 & CHE 341 or CHE 290 or equivalent and permission of instructor. (1-4 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. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **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 506 (MACROMOL 506) (MATSCIE 506). Soft Robotic Matter
Advisory Prerequisite: None. Enforced Prerequisite: Senior Standing or Graduate Standing. (3 credits)
Soft robotic matter consists of active materials that can sense, move within, and alter their working environment. Fundamentals and emerging approaches will be explored in soft active matter design, actuation, power, and fabrication across length scales, with focus on engineering their properties and structures for programmable robotic functions. **CourseProfile (ATLAS)**

CHE 509 (BIOMEDE 509) (MACROMOL 509) (MATSCIE 509). Advanced Biomaterials
Advisory Prerequisite: MATSCIE 220 or MATSCIE 250. Enforced Prerequisite: None. (3 credits)
Applications of biomaterials in implants, regenerative medicine, tissue engineering, and drug delivery systems will be covered. Principles of biomaterials incorporating contemporary research related to rational design strategies for biomaterials, their processing and fabrication, biomimetics, immunomodulation, degradation, and in vivo responses will be included. **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). 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)

Foundations of transport phenomena. Heat and mass transfer with chemical reaction in three dimensions, selective motion. Unsteady energy and mass balances in three dimensions. Distributions in more than one variable. Boundary layer theory. Estimation of interfacial transport coefficients. Dispersive flows: Taylor Dispersion. Application to equipment design. **CourseProfile (ATLAS)**

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 SUGS 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)**

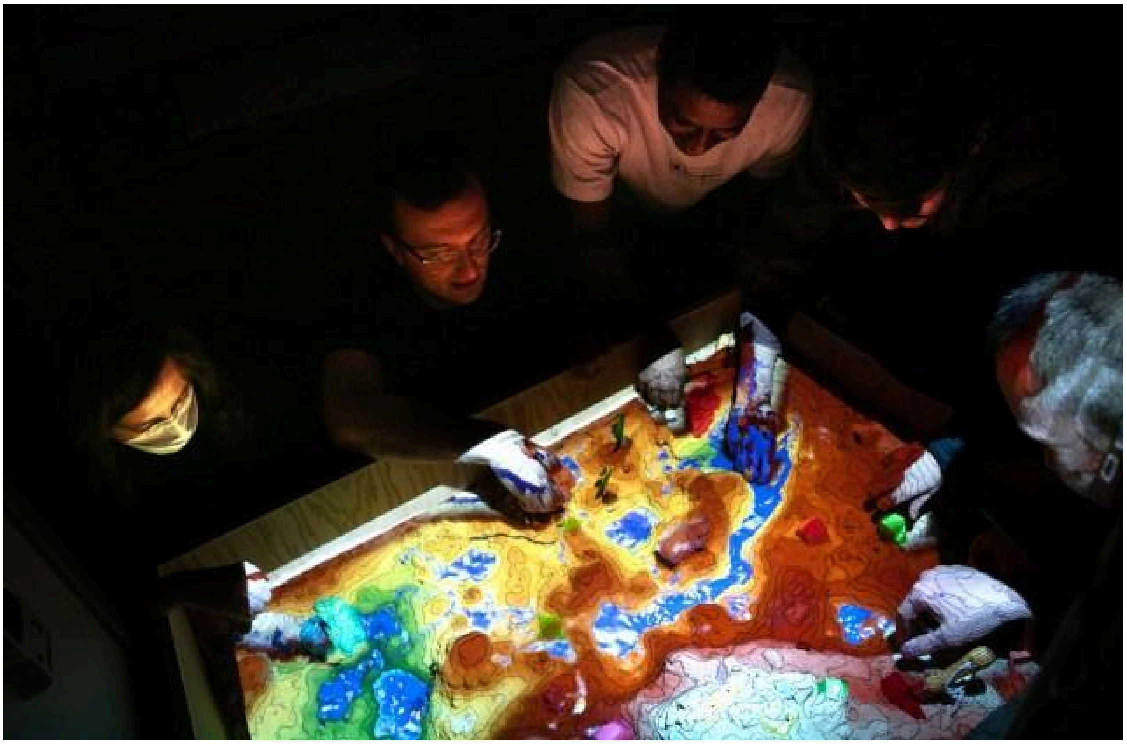
900 Level Courses

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)
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)**

Civil and Environmental Engineering

Civil and Environmental Engineering (CEE)



Civil and environmental engineers design, plan and construct infrastructure systems including buildings, bridges, highways, airports, tunnels, pipelines, channels, waste-water systems, waste sites, 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 program and technical elective courses in several areas: 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 the Civil & Environmental Engineering website.

Two minors, one in Civil Engineering and one in Environmental Engineering, are also offered through the Department. Eligibility information and requirements of the minors are described at: Minor in Civil Engineering, and Minor in 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 at: Sequential Undergraduate/Graduate Studies (SUGS) Applicants.

Information and assistance regarding fellowships and assistantships for graduate studies may be obtained from the Graduate Student Services of the Department of Civil and Environmental Engineering.

Course Guide

Civil and Environmental Engineering Courses

Contact

Departmental Website: http://cee.engin.umich.edu/

Civil and Environmental Engineering Department
2105 G. G. Brown Building
2350 Hayward St.
Ann Arbor, MI 48109-2125

Phone: (734) 764-8495
Fax: (734) 764-4292

Department Administration

Department Chair

Professor Yafeng Yin, Department Chair of Civil and Environmental Engineering

2120 G G Brown Building

For more specific information on contacting people, go to: CEE People.

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 committed to solving major societal problems by providing forward-looking education, enhancing multidisciplinary research and performing broad-based service. 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.

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.
- Foster and support the spirit of entrepreneurship among our students, faculty, and staff.

Objectives

The following set of objectives is consistent with ABET accreditation criteria and 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 leaders of interdisciplinary and culturally diverse teams, and will successfully address open-ended problems applying creativity and 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

Student outcomes describe what students are expected to know and be able to do by the time of graduation. Graduates of the Civil Engineering program at the University of Michigan are expected to acquire the following skills:

- 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.

Civil Engineering Focus Areas

The Civil Engineering curriculum offers elective courses in the following areas:

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 other disasters.

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.

Enrollment and Graduation Data

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally you can see recent degrees granted below:

Level	2021	2022	2023
Bachelors Degrees	48	42	55
Masters Degrees	32	20	34
Doctoral Degrees	16	6	16

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 set of objectives is consistent with ABET accreditation criteria and describes 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.

- Graduates will have a solid foundation in environmental engineering and achieve success in graduate education and a broad range of career opportunities.
- Our graduates will become leaders of interdisciplinary and culturally diverse teams, and will successfully address open-ended problems applying creativity and critical thinking.
- The U-M Environmental 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

Student outcomes describe what students are expected to know and be able to do by the time of graduation. Graduates of the Environmental Engineering program at the University of Michigan are expected to acquire the following skills:

- 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

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally you can see recent degrees granted below:

Level	**2021**	**2022**	**2023**
Bachelors Degrees	39	30	25
Masters Degrees	31	11	20

Doctoral Degrees	6	4	7

Accreditation

Our programs are accredited by the Engineering Accreditation Commission of ABET.

- Accreditation page for Civil Engineering
- Accreditation page for Environmental Engineering

Undergraduate Degree Program

B.S.E. in Civil Engineering

The Civil Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Civil and Similarly Named Engineering Programs.

Please see the PDF version of the sample schedule here. Additional information can be found on the Civil & Environmental Engineering Department website.

B.S.E. in Environmental Engineering

The Environmental Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Environmental Engineering and Similarly Named Engineering Programs.

Please see the PDF version of the sample schedule here. Additional information can be found on the Civil & Environmental Engineering Department website.

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 planet 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.

Civil Engineering Minor

Environmental Engineering Minor

Sequential Undergraduate/Graduate Study (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 meet eligibility set by Rackham may apply. Students earning dual bachelor's degrees are not eligible for SUGS. Please contact the department or see the Sequential Undergraduate/Graduate Studies (SUGS) Applicants website for more information.

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 Degrees

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 are 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

- Implication of emerging technologies on the planning, design, operations, and management of transportation systems

List of available 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 three 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 have 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 no longer required for application to the M.S.E. program. Letters of recommendation are 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 a minimum of 18 credit hours of courses offered by the Department of Civil and Environmental Engineering. For additional requirements, please refer to the information published on the Master's Programs page of the Civil & Environmental Engineering website.

Study programs are available in the following areas of specialization:

- Construction Engineering and Management
- Geotechnical Engineering
- Hydraulics and Hydrologic Engineering
- Intelligent Systems
- Structural and Materials 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 (CE&M). 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 12 hours of core courses and 9 hours of graduate construction electives in the M.S.E. (CE&M) program and 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. 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

Civil and Environmental Engineering Courses (CEE)

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

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)**

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; mass and area moments of inertia and principal directions. Dynamics: review of concepts of velocity and acceleration; dynamics of particles and rigid bodies; concepts of work, energy, momentum. **CourseProfile (ATLAS)**

CEE 212. Solid and Structural Mechanics
Advisory Prerequisite: None. Enforced Prerequisite: CEE 211. Minimum grade requirement of “C-” for enforced prerequisite. (No credit granted to those who have completed or are enrolled in MECHENG 211.) (3 credits)
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)**

CEE 230. Thermodynamics and the Environment
Advisory Prerequisite: MATH 116; CHEM 130 & 125/126 or CHEM 210 & 211. (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)**

CEE 265. Sustainable Engineering Principles
Advisory Prerequisite: CHEM 130, MATH 116. (Credit for only one: CEE 265 or MECHENG 489.) (3 credits)
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)**

300 Level Courses

CEE 303. Computational Methods for Engineers and Scientists
Prerequisite: (ENGR 101 or ENGR 151 or EECS 180 or EECS 183 or ROB 102) AND (MATH 215 or MATH 285 or MATH 385) AND (MATH 216 or MATH 286 or MATH 396). Minimum grade requirement of

“C-” for enforced prerequisites. (4 credits)
Applications of numerical methods to infrastructure and environmental problems. Development of mathematical models and computer programs. Formulation and solution of initial and boundary-value problems with emphasis on structural analysis, fluid flow, and transport of contaminants. Introduction to optimization and data science. **CourseProfile (ATLAS)**

CEE 307 (Environ 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
Advisory Prerequisite: None. Enforced Prerequisite: CEE 265. Minimum grade requirement of “C-” for enforced prerequisite. (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 requirement of "C" 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 user 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
Advisory Prerequisite: CEE 325 and (CEE 345 or CEE 366). (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 (C or better; NO OP/F) or graduate standing. Minimum grade requirement of "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; Projects are overseen and graded by faculty and may also involve mentoring by representatives from external organizations. **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
Advisory Prerequisite: CEE 373 or equivalent. Enforced Prerequisite: MATH 215 or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Fundamentals of planning, design and operation of transportation infrastructure. Topics covered include driver and vehicle performance characteristics, roadway design principles, multimodal system design, traffic flow modeling and traffic operations analysis, transportation planning and forecasting, and the impacts of emerging technologies (e.g., connected and automated vehicle) on 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
Advisory Prerequisite: CEE 465. (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 requirement of "C-" 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
Advisory Prerequisite: CHEM 130. (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 **CourseProfile (ATLAS)**

CEE 503. Infrastructure Project Finance
Advisory Prerequisite: CEE 504. (3 credits)
Financing models across infrastructure use cases. Public, private and public-private partnership contract structures Data markets for performance, operational, and infrastructure health metadata. Pricing and veracity of data offtake mechanisms. Blockchain financing and tokenization models. Risk allocation models for public and private investors. Term project focused on smart infrastructure systems. **CourseProfile (ATLAS)**

CEE 504. Engineering Economics and Finance
Advisory Prerequisite: ECON 101 and CEE 373 or equivalent. (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)
Basic equations of three-dimensional elasticity. Derivation of relevant variational principles. Finite element approximation. Convergence requirements. Isoparametric elements in two and three dimensions. Implementational considerations. Locking phenomena. Problems involving non-linear material behavior. **CourseProfile (ATLAS)**

CEE 511. Dynamics of Structures
Prerequisite: CEE 412 or equivalent. (3 credits)
Dynamic equilibrium of structures. Response of a single degree of freedom system to dynamic excitation: free vibration, harmonic loads, pulses and earthquakes. Response spectra. Response of multi-degree-of-freedom systems. Seismic behavior of buildings and the basis for seismic building codes. **CourseProfile (ATLAS)**

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)**

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)**

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)**

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)**

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)**

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)**

CEE 518. Deployable and Reconfigurable Structures
Enforced Prerequisite: None. Advisory Prerequisite: Course equivalent to CEE 412, CEE 510, or ME 305. (3 credits)
Covers theory, analysis, and design of deployable and reconfigurable structures, including linkage-based, origami, and inflatable systems. Students will learn about kinematics, geometric constraints, stability, stiffness,
energy behaviors, design, material systems, fabrication, and actuation. Includes a student project to explore and
design practical deployable structures. **CourseProfile (ATLAS)**

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)**

CEE 520. Physical Processes of Land-Surface Hydrology
Prerequisite: CEE 421 or graduate standing. (3 credits)
Key elements of land-surface hydrology. Water in the atmosphere; dry adiabatic and pseudoadiabatic processes. Vapor turbulent transfer. Heat fluxes and surface energy budgets. Mass transfer and energy budget methods for estimating evapotranspiration. Soil 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
Advisory Prerequisite: CEE 325 or equivalent and CEE 421. (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
Advisory Prerequisite: CEE 325 or equivalent. Enforced Prerequisite: CEE 325 or MECHENG 330 or CHE 341 or NAVARCH 320 or CLIMATE/EARTH 401 (C or better; No OP/F). Minimum grade requirement of "C" for enforced prerequisite. (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 pipe systems; includes pump design, operation, cavitation, water hammer, control valves, and flow metering. Hydropower systems design; hydraulic control structures, turbines, motor and generator operational principles, gravity dam stability analysis, and penstocks. Also covered are pumped hydro, powerhouses, economics, and pipe optimization. **CourseProfile (ATLAS)**

CEE 527. Flood, Tsunami, and Hurricane Hydraulics, Damage, and Countermeasures
Advisory Prerequisite: None. Enforced Prerequisite: CEE 325 or ME 320 or NAVARCH 320 or CHE 341 or NERS 344 or AEROSP 225. (3 credits)
Practical concepts for inland and coastal flood risk reduction. Physics of natural hazards, damage prediction, effects of climate change, structural and land use planning methods. Numerical modeling, hydraulic design tools for rainfall, hurricane storm surge and waves, and tsunami hazards. Geotechnical and structural fundamentals of floodwall, breakwater, building damage. **CourseProfile (ATLAS)**

CEE 530. Construction Professional Practice
Advisory Prerequisite: Permission of instructor. (3 credits)
Capstone project in CEM where student teams work with faculty or construction industry clients to investigate solutions to industry problems. Students compile professional report and video. Invited speakers discuss contemporary topics in CEM. Projects are overseen and graded by faculty and may also involve mentoring by representatives from external organizations. **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. Break-even and profit analyses. Equipment cost and procurement decisions. Construction financial accounting, cost accounting, cost control systems. Cost indices, parametric estimates, unit price proposals. Projects are overseen and graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

CEE 532. Advanced Construction Project Engineering
Prerequisite: Graduate standing and preceded or accompanied by CEE 539 or 331(or equivalent). (3 credits)
Advanced project management techniques and their applications to real-world projects focusing on project/company organizations, dealing with project complexity, performance measurement and improvement including productivity, quality, and safety, construction innovations, and an in-depth understanding of individual and organizational behavior with human factors and cultures. Examples and cases from construction. **CourseProfile (ATLAS)**

CEE 533. Engineering Process Modeling and Risk Analysis
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. **CourseProfile (ATLAS)**

CEE 534. Construction Engineering, Equipment, and Methods
Prerequisite: Junior standing. (3 credits)
Engineering principles of earthmoving equipment; Mobile and tower cranes; Concrete production, transportation, and placement; Formwork and reinforcement systems; Aggregate production; Concrete and steel bridge construction; Asphalt and concrete paving; Piled foundations. Projects are overseen and graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

CEE 535. Excavation and Tunneling
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. **CourseProfile (ATLAS)**

CEE 536 (MFG 536). Project Planning Scheduling and Control
Advisory Prerequisite: Senior or graduate standing. (3 credits)
Project planning and scheduling with arrow and precedence networks using the Critical Path Method (CPM). Advanced scheduling using overlapping networks. Project control, C/SCSC and earned-value systems. Scheduling under uncertainty, PERT, PNET, and Monte-Carlo simulation. Time-cost tradeoff, resource allocation, and resource leveling. Scheduling using the Repetitive Scheduling Method (RSM). **CourseProfile (ATLAS)**

CEE 537. Construction of Buildings
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. **CourseProfile (ATLAS)**

CEE 538. Computer-aided Project Management
Prerequisite: Preceded or accompanied by CEE 536/MFG 536. Minimum grade requirement of “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. **CourseProfile (ATLAS)**

CEE 539. Modern Construction Management
Prerequisite: None. Advisory Prerequisite: Graduate standing (3 credits)
Introduces modern construction management techniques and their applications to real-world construction projects focusing on how to organize, evaluate, and manage a construction project. Specific topics include project delivery methods, contracts, procurement, estimating, bidding, construction risk, bond, insurance, change orders, claims, dispute resolutions, and leadership. **CourseProfile (ATLAS)**

CEE 540. Advanced Soil Mechanics
Prerequisite: CEE 345 or equivalent. (3 credits)
Deformation and strength of soils; total and effective stress; drained and undrained behavior. Constitutive description: elastic-plastic, hardening/softening, Cam clay model, critical states. Stress paths, and testing of soils. Modeling of reinforced soil: multi-component model and homogenization approach; fiber-reinforced soil. Theorems of limit analysis; applications in stability assessment. **CourseProfile (ATLAS)**

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)
Finite element method formulation, constitute laws for geotechnical materials including elastic-perfectly plastic and nonlinear elasto-plastic. Critical state framework for modeling soil behavior. Finite element program PLAXIS for performing static analyses of earth structures. Soil structure interaction. Finite difference method and discrete element method. Advanced soil models. **CourseProfile (ATLAS)**

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 requirement of "C" 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 requirement of "C" for enforced prerequisites. (3 credits)
This course provides and 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 equivalent. (3 credits)
Fundamental engineering principles for preventing or reducing air pollutant emissions. Combustion modifications to prevent pollutant formation. Gas adsorption and absorption processes, including carbon capture and sequestration. Particle filtration processes. Emissions and control of metals and air toxins. Indoor air pollutants and their control. Selected case studies. Economics and cost estimation. **CourseProfile (ATLAS)**

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
Advisory Prerequisite: CEE 230 or MECHENG 336 or ChE 330 or equivalent. (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)
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability. **CourseProfile (ATLAS)**

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. Sensors, Data, and Automation
Advisory Prerequisite: PHYSICS 240. (3 credits)
Sensors and smart technologies across engineering and science. Fundamentals of sensor physics, demonstrating how to measure and convert physical processes into digital information. Topics include the theories behind leading sensing technologies, data acquisition, and internet-connected devices. Essential aspects of data processing and cloud computing for real-time sensor data. Students will be equipped to select sensors, design wireless networks, send data to the internet, process and analyze real-time data, and automate solutions across various applications. **CourseProfile (ATLAS)**

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)
Analysis of discrete- and continuous-time linear stochastic processes with primary application to engineering dynamics. Ito calculus and mean-square analysis. Continuous-time Poisson counters and Wiener processes. Stochastic response of nonlinear systems, and the Fokker-Planck Equation. Stationary analysis. Approximate techniques for nonlinear stochastic response. **CourseProfile (ATLAS)**

CEE 577 (MECHENG 545, ISD 546). Dynamics and Control of Connected Vehicles
Enforced Prerequisite: None. Advisory Prerequisite: MECHENG 360. (3 credits)
Ordinary differential equations and delay differential equations are used for modeling connected vehicle systems, which consist of human-driven vehicles and automated vehicles. Controllers are designed to

improve stability, safety, energy efficiency, and traffic flow. Students will use experimental data to design controllers and evaluate those via numerical simulations. **CourseProfile (ATLAS)**

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
Advisory Prerequisite: CHEM 130 and senior or graduate standing. Enforced Prerequisite: (CHEM 130; C- or better, and Senior Standing) or graduate standing. (Credit for only one: CEE 481 or CEE 581.) Minimum grade requirement of "C-" 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, 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 586 (NRE 557). Industrial Ecology
Advisory 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 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
Advisory 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)
Fundamentals of fluid mechanics applications to the environment. Gravity and tidal waves. Internal waves and stratified flow. Models for turbulent flow. Effects of the earth's rotation, wind-driven currents and boundary resistance. Mass transfer at interfaces, entrainment and mixing. Flocculation and settling of colloidal particles. Shear dispersion in stream and estuaries. **CourseProfile (ATLAS)**

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)**

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)
Elastic and inelastic behavior of beams and columns. Torsion of open and box members. Combined bending and torsion. Buckling of beams and beam-columns. Frame buckling. Behavior of steel and aluminum structural members in studies with reference to their code design procedures. **CourseProfile (ATLAS)**

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)
Transient, incompressible flow in three space dimensions. Reynolds averaging and large eddy simulation of turbulent flows. Kinematic and dynamic conditions at air-water interfaces. Numerical solution by finite element and finite volume methods. Algorithms for locating a free surface. Applications to river, lake and estuary models. **CourseProfile (ATLAS)**

CEE 622. Special Problems in Hydraulic Engineering or Hydrology
Prerequisite: Permission of instructor. (1-16 credits)
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)
Risk assessment: parametric and non-parametric approaches. Optimal estimates. Decision making in the face of uncertainty. Classification of categorical attributes. Stochastic spatial simulation: continuous and categorical environmental attributes. Propagation of uncertainty. Soil and water pollution data will be analyzed using geostatistical software. **CourseProfile (ATLAS)**

CEE 630. Directed Studies in Construction Engineering
Prerequisite: Graduate standing. (1-3 credits)
Selected reading in specific construction areas. **CourseProfile (ATLAS)**

CEE 631. Construction Decisions Under Uncertainty
Advisory Prerequisite: CEE 405 or a course in probability or statistics such as STATS 310 or STATS 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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

CEE 649. Civil Engineering Vibrations Laboratory
Prerequisite: 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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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
Prerequisites: None. (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
Advisory Prerequisite: Permission of instructor. (1-16 credits)
Special problems designed to develop perspective and depth of comprehension in selected areas of sanitary, environmental or water resources engineering. **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
Prerequisites: None. (1-16 credits)
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
Prerequisites: None. (1 credit)
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
Prerequisites: 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
Prerequisites: None. (1-16 credits)
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. (1-16 credits)
Assigned work in hydraulic and hydrological research; a wide range of matter and method permissible. **CourseProfile (ATLAS)**

CEE 930. Construction Engineering Research
Prerequisites: None. (1-16 credits)
Selected work from a wide range of construction engineering areas including planning, equipment, methods, estimating and costs. **CourseProfile (ATLAS)**

CEE 946. Soil Mechanics Research
Prerequisites: None. (1-16 credits)
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
Advisory Prerequisite: Permission of instructor. (1-16 credits)
Topics dealing with mechanics and engineering of structural materials. Assigned reading and student reports. **CourseProfile (ATLAS)**

CEE 955. Transportation Systems Engineering Research
Prerequisites: None. (1-16 credits)
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 **CourseProfile (ATLAS)**

CEE 970. Infrastructure Systems Engineering Research
Prerequisites: None. (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
Advisory Prerequisite: Permission of instructor. (1-16 credits)
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
Advisory Prerequisite: Election for dissertation work by doctoral student not yet admitted as a Candidate. (1-8 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
Prerequisites: None. (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)**

Climate & Space Engineering

Climate and Space Sciences and Engineering (CLaSP)

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.

Course Guide

Climate and Space Sciences Engineering Courses

Contact

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http://clasp.engin.umich.edu/

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1517 Climate and Space Research Building

For more specific information on contacting people, go to our **Contacts page.**

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 prepare graduates for employment in the National Weather Service, private weather forecasting companies, air-quality 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 the website for Climate & Space Sciences.

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 Climate & Space Sciences Department Advising website.

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 students for graduate studies, climate modeling, and a position in "value-added" industries that provide water resources, 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 students. 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 increasing 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 Climate & Space Sciences Department Advising website.

Concentrations

Space Science Concentration

The Space Sciences concentration is for students interested in space physics and allows students to develop the 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 in Climate & Space within the College of Engineering as a whole. This program is for undergraduate students in the College of Engineering, Ross, 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 their 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
  - Climate Science and Impacts Engineering
  - Space Sciences
  - Space Engineering

For additional information, visit the website for Climate & Space Sciences.

Enrollment and Graduation Data

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

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 gasses 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, 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.

Please review the website for the Climate & Space SUGS programs for the most up-to-date information on Climate & Space SUGS Programs, including example concentration course schedules. For more information, please contact the SUGS Advisor at **clasp-um-ss@umich.edu**.

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 subsystems including those involving human society;
- A set of tools and skills useful in practical engineering problem-solving in team environments;
- 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 the doctoral program 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 on the Graduate Studies page.

Certificate in Climate Change Solutions

In the Climate Change Solutions Graduate Certificate Program, students will address the physical basis of changing climate, its impacts on humanity and justice, and be introduced to solutions. We welcome and encourage applications from students from wide-ranging academic programs across the University of Michigan.

This certificate program will:

1. Train interdisciplinary students about the basics of climate change science and equip them to explore solutions needed to mitigate climate change and adapt to future changes.
2. Develop skills in graduates to think in a systems way about the causes and consequences of climate change and enable innovative approaches that focus on climate adaptation and resilience.

The program consists of 12 credit hours (three 'core' mandatory courses and the remainder of credits from an approved list of electives). The core courses establish a knowledge of climate science and the effects of warming on society, strategies for slowing and reversing the amount of warming that will be realized, and methods for responding to the growing consequences of climate change. These three courses cross the formal framework of climate change, mitigation, and adaptation.

The Climate Change Solutions Graduate Certificate Program was developed in partnership between CLaSP and the School for Environment and Sustainability (SEAS), and is designed for students already enrolled in a graduate degree program at the University of Michigan. Master's or doctoral students from any field, CoE, SEAS, LSA and the professional schools, are welcome to apply.

Climate and Space Sciences and Engineering Courses (CLIMATE & SPACE)

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

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 (CHEM 105) (ENSCEN 105) (ENVIRON 105) (STS 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 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

CLIMATE 280 (SPACE 280). Undergraduate Research Experience
Prerequisite: 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

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
Advised 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 (SPACE 423). Data Analysis and Visualization for Geoscientists
Prerequisite: None. Advised Prerequisite: ENGR 101 and CLIMATE/SPACE 323. (4 credits)
Fundamental data science, data and error analysis, data-model comparison tests and metrics, and visualization techniques. By course end, students will be able to produce publication ready scientific data

visualization, process data sets using Python, perform large data set analysis, conduct data-model comparisons, and scientifically test hypotheses and interpret results. **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. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations **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 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, CO_2, 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)**

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)**

CLIMATE 485 (SPACE 485). Principles and Applications of Remote Sensing
Prerequisite: PHYSICS 240. Advisory Prerequisite: CLIMATE 323, CLIMATE 380. (3 credits)
Introduction to the use of electromagnetic remote sensing to study planetary atmospheres and surfaces from space. Topics include: 1) interactions between geophysical properties and propagating electromagnetic waves; 2) design of orbiting sensors to measure them; 3) interpreting the measurements to estimate the geophysical properties. **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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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)**

NERS 672 (SPACE 545). High Energy Density Physics
*Prerequisite: None. Advisory Prerequisite: MATH 450, PHYSICS 405 & PHYSICS 40*6. *(3 credits)*
Fundamental tools and discoveries of high-energy density physics, where pressures are above a million atmospheres. 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 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)**

SPACE 571. Space Plasma Measurement Techniques
Advisory Prerequisite: SPACE 310 or SPACE 370. (4 credits)
Identify, define, and practice the way to get from a science question to a set of measurements necessary to answer the question. Phases are: 1) highlight the relevant scientific themes, 2) practice with

the simulation tools available, and 3) carry out 4 hardware experiments in the lab. **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 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)**

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. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

SPACE 583 (AEROSP 583). Management of Space Systems Design
Prerequisite: None. (4 credits)
Students lead teams in high level project design of a space system. Modern methods of concurrent engineering manufacturing, marketing and finance, etc., are incorporated. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **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. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **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)
Maxwell-Boltzmann distribution, kinetic determination of equation of state, specific heats of gases. Dynamics of two-particle collisions. Elementary transport theory, molecular effusion, hydrodynamic transport coefficients, mean free path method. Advanced transport theory, the Boltzmann equation, collision terms, Champman-Enskog transport theory. Aerodynamics of free-molecular flow. Shock waves. **CourseProfile (ATLAS)**

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 690 (SPACE 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. Special Problems in Climate and Space Sciences
Supervised analysis of selected problems in various areas of climate and space sciences. **CourseProfile (ATLAS)**

CLIMATE 746 (SPACE 746). CLaSP Graduate Professional Development
Prerequisite: None. (1 credit)
Introduction to professional skills which support graduate student success within the CLaSP Department. Topics include advisor relationships, student rights, personal finances, scientific communication, project definition and planning, attending conferences, reading journal articles, mentoring others, and code and data management. **CourseProfile (ATLAS)**

CLIMATE 747 (SPACE 747). Proposal Development
Prerequisite: None. (1 credit)
Students will learn to write and submit a successful proposal to a US funding agency, and to deliver a successful conference talk on their proposed research. The proposal topic will be chosen by the student. Proposals will be prepared for academically relevant programs. **CourseProfile (ATLAS)**

CLIMATE 748 (SPACE 748). Student Presentation
Prerequisite: None. (1 credit)
Students will develop the skills to deliver a successful talk and present their research. Each student will deliver two talks (one about the student research, the other is a critique of a scientific article) and one AGU-like poster presentation, with extended question/answer sessions. **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)**

900 Level Courses

CLIMATE 990 (SPACE 990). Dissertation/Pre-Candidate
Advisory Prerequisite: Advanced Doctoral Student. Enforced Prerequisite: Graduate Standing. *(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)**

CLIMATE 995 (SPACE 995). Dissertation/Candidate Graduate School
Prerequisite: 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)**

Electrical Engineering & Computer Science

Electrical Engineering and Computer Science (EECS)

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.); a data science program leading to a Bachelor of Science in Engineering (Data Science) – B.S.E (D.S.). The College of LS&A also offers degrees in Computer Science and Data Science. (Please consult the LS&A Bulletin for information about completing a computer science or data science degree through LS&A.)

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

Division Chair, CSE Division
Michael Wellman, Lynn A. Conway Collegiate Professor
3713 Bob & Betty Beyster Building

Division Chair, ECE Division
Dennis Sylvester , Interim Chair, Electrical and Computer Engineering
3303A Electrical Engineering & Computer Science Building

For more specific information on contacting people, go to our **Contacts page** (CSE) or **Contacts page** (ECE)**.**

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.

Course Guide

Electrical Engineering and Computer Science Courses

Contact

Departmental Website: https://eecs.engin.umich.edu/

Computer Science & Engineering Division
2260 Hayward St.
Ann Arbor, MI 48109-2121
Undergraduate Advising: 2808 Beyster Building
Email:
ugadmin@eecs.umich.edu
Phone: (734) 763-6563
CS Undergraduate Admissions:
Email:
csugadmissions@umich.edu
Phone: (734) 764-9500
Graduate programs: 3909 Beyster Building
Email:
csegradstaff@umich.edu
Phone: (734) 647-8047

Electrical & Computer Engineering Division
1301 Beal Avenue
Ann Arbor, MI 48109-2122
Undergraduate advising: 3415 EECS Building
Email:
eceadvising@umich.edu
Phone: (734) 763-2305
Graduate programs: 3400 EECS Building
Email:
ece-grad-program@umich.edu
Phone: (734) 764-2390

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, communicate in written and oral form, practice life-long learning, and develop the professional responsibility needed for successful technical leadership positions.

Outcomes

The outcome we desire is that our graduates 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.

Students should also have knowledge of discrete mathematics, probability and statistics, mathematics through differential and integral calculus; sciences; and engineering topics (including computing science) necessary to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components.

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 to 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 an 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, 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 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

Computer 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**. Additionally you can see recent degrees granted below:*

Level	**2021**	**2022**	**2023**
Bachelors Degrees	110	116	104

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**. *Additionally you can see recent degrees granted below:*

Level	**2021**	**2022**	**2023**
Bachelors Degrees	543	598	609
Masters Degrees	123	113	132
Doctoral Degrees	36	32	37

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**.

Level	**2021**	**2022**	**2023**
Bachelors Degrees	0	54	40
Masters Degrees	0	36	40
Doctoral Degrees	0	0	0

Electrical 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**. *Additionally you can see recent degrees granted below:*

Level	**2021**	**2022**	**2023**
Bachelors Degrees	128	119	96
Masters Degrees	1	1	–
Doctoral Degrees	12	5	–

Electrical and Computer Engineering

Level	**2021**	**2022**	**2023**
Masters Degrees	262	233	459
Doctoral Degree	21	46	55

Accreditation

Electrical Engineering

The Electrical Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Electrical, Computer, Communications, Telecommunication(s) and Similarly Named Engineering Programs.

Computer Engineering

The Computer Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Electrical, Computer, Communications, Telecommunication(s) and Similarly Named Engineering Programs.

Program Outcomes

The matrix maps how each course in our curriculum addresses our program outcomes. Only the outcomes tracked are noted below.

Course	Student Outcomes (Black – High)						
	Apply math and science	Design	Communicate	Ethics	Teams	Experiments, Analyze, and Interpret Data	Lifelong Learning
EECS200							
EECS215							

EECS300							
EECS301							
EECS411							
EECS413							
EECS425							
EECS427							
EECS430							
EECS438							
EECS452							
EECS470							

EECS473							
EECS496							
TCHNCLCM300							
TCHNCLCM496							

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.

Students who are admitted to the University of Michigan in Fall 2023 or later must first be selected for the Computer Science major before they can declare. Visit the CSE website to learn more.

C Rule

A grade of C or higher is required among science, engineering and mathematics courses. Pass/Fail is not permitted for these requirements.

Repeat Policy

Students can attempt each of the three 200-level courses (EECS 203, EECS 280, EECS 281) no more than two times. 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 Declaration. For more information see: "Academic Rules," then "Declare/Change Major" 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. Please see the PDF version of the **sample schedule.** Additional information can be found on the EECS Department Advising website.

B.S.E. in Computer Science

The Computer Science program is not an ABET accredited program. Please see the PDF version of the **sample schedule**. Additional information can be found on the CSE Department Advising website.

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 for students who matriculate to the University of Michigan Fall 2024 or later (**F24 sample schedule**) or for students who matriculate to the University of Michigan prior to Fall 2024 (**Pre-F24 sample schedule**). Additional information can be found on the CSE Department Advising website.

B.S.E. in Electrical Engineering

The Electrical Engineering program is accredited by the Engineering Accreditation Commission of ABET. Please see the PDF version of the **sample schedule**. Additional information can be found on the EECS Department Advising website.

Concentrations

Computer Engineering

The program in Computer Engineering (CE) 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.

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.

Minors

Computer Science Minor

Electrical Engineering Minor

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 Degrees

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 (M.Eng.) in Electrical & Computer Engineering
- Doctor of Philosophy (Ph.D.) in Electrical & Computer Engineering
- Graduate Certificate for Computational Discovery and 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 EECS Departmental website.)

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 Graduate Program Guide 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. A maximum of 6 credit hours of S/U credits will be accepted toward the degree, with up to 3 of those 6 credits being allowed from non-directed study coursework. 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.

M.Eng. in Electrical & Computer Engineering

The Master of Engineering (M.Eng.) 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), Autonomous systems (AS), or Microelectronics and Integrated Circuits (MI).

The M.Eng. 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 M.Eng. 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 M.Eng. 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 M.Eng. 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 Computer Science and Engineering doctoral degree is primarily intended for students desiring a career in research and/or collegiate teaching. The focus is on advanced CSE topics, on learning to perform research and to write research papers, and on making fundamental new contributions to a CSE topic. Students take advanced course work and write a *doctoral dissertation*, also called a *thesis*.

Students newly admitted to the doctoral program are classified as *precandidates*. There is a Ph.D. qualifying process, normally completed during the first two years. After all requirements except the dissertation are completed, students become *candidates*.

Students entering a CSE doctoral program with a bachelor’s degree typically become candidates in the third year and are strongly encouraged to complete the degree within five years. Such students ordinarily complete the requirements for a master's degree along the way and receive this degree in addition to the Ph.D. A master's thesis is optional. Students who enter a CSE doctoral program with a master's in the field of their program typically become candidates in their second year and are strongly encouraged to complete the degree within four years. Such students are not ordinarily eligible to receive a CSE master's degree.

Please refer to the CSE Graduate Program Guide for details on degree requirements and program policies.

Ph.D. in Electrical & Computer Engineering

The Ph.D. 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, Quantum Engineering Science & Technology, Power & Energy, Robotics, Signal and Image Processing & Machine Learning, and Solid State & Nanotechnology.

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 3 credit hours in courses outside of ECE. A maximum of 6 credit hours of S/U courses will be accepted toward the degree. At most 3 of the 6 credit hours of non-directed study coursework 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, 3 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 in 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

Please review the Graduate Data Science Certificate Program website for further details.

Graduate Certificate for Plasma Science and Engineering

Michigan Institute for Plasma Science and Engineering (MIPSE) is administering the graduate certificate in Plasma Science and Engineering (PSE). The graduate certificate provides an opportunity for students conducting research in the fundamentals or applications of PSE to both broaden and deepen that experience. The components of the graduate program include:

1. Coursework in the fundamentals and applications of PSE:
    - Plasma courses
    - Supporting courses
    - Download a list of courses (PDF)
2. Participation in the MIPSE Graduate Research Symposium.
3. Research on a topic related to PSE.
4. Opportunity to use internship experiences for laboratory credit.

Information for students interested in pursuing the graduate certificate in PSE

- Overview, Requirements and Admission Procedures
- Application for Admission

Who is eligible?

University of Michigan graduate students from any field are eligible to enroll.

Program Requirements

The requirements for the Graduate Certificate in Plasma Science and Engineering (GPSE) are as follows.

1. Coursework in the fundamentals and applications of PSE. (Required)

    14 Graduate Credit Hours are required for the GPSE. Since the students entering the GPSE are from many different departments and have quite varied backgrounds, specific courses will not be required. Instead, a course of study will be proposed by the student and his/her advisor(s) for discussion and approval by the GPSE Program Committee. The GPSE approved list of courses appears below. Other courses may be approved by request. The recommended breadth requirements are:

    - 1 course in plasma fundamentals
    - 1 course in plasma technology
    - 1 laboratory course
    - 1 course in supporting sciences

2. Of the 14 hours required, 1 course (or 3 hours) may be doubled counted from another Rackham graduate degree. This double counting is consistent with Rackham requirements that at most 1/6 of the credits for a graduate degree can be double counted.

3. The laboratory requirement may be satisfied by an appropriate extramural research experience (e.g., internship at a national laboratory, company or collaborating university) that has a substantial laboratory component. Approval must be obtained by petition from the GPSE Program Committee. The extramural experience may satisfy the laboratory requirement but does not count towards the 14 hours required for the certificate unless the student is simultaneously enrolled in an appropriate University of Michigan special topics course.

4. Research on a topic closely related to PSE. (Required) This option may be met in one of two ways:

- Completion of a PhD thesis on a topic closely related to PSE. The appropriate- ness of the thesis topic will be approved by the GPSE Program Committee.

or

- Completion of at least a 1-semester research project on a topic approved by the GPSE Program Committee. The course credits for the research project may count towards the 14 credits required for the certificate.

5. Participation in the GPSE Annual Research Symposium on at least one occasion to report on the results of PSE related thesis research or a PSE related research project. (Required)

The Annual Research Symposium will provide graduate students with an opportunity to present the results of their research in talks and poster sessions, and interact with GPSE faculty and students.

Program Director

Professor Mark Kushner

Please review the Graduate Certificate in Plasma Science and Engineering website for further details.

Electrical Engineering and Computer Science Courses (EECS)

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

EECS 110. Discover Computer Science
Enforced Prerequisite: None. (2 credits).
Introduction to basic CS concepts (variables, conditionals, loops, functions) using an introductory programming language, such as Python. Students interact with researchers and computing professionals to learn about real-world, interdisciplinary applications of CS. Intended for students without prior programming experience to (optionally) take prior to EECS 183 or ENGR 101. **CourseProfile (ATLAS)**

EECS 180. Exam/Transfer Introductory Computer Programming Credit
Cannot receive credit if student has credit for EECS 183 or ENGR 101 or ENGR 151 (3-4 credits).
Credit for college-level introductory programming coursework based on a satisfactory score on an approved exam (e.g., a score of 5 on the AP Computer Science A exam) or on transfer credit for an approved introductory programming course at another college. Indicates preparedness to proceed to EECS 280. **CourseProfile (ATLAS)**

EECS 183. Elementary Programming Concepts
Prerequisite: None. (Credit for only one: EECS 180, EECS 183, ENGR 101 or ENGR 151) (4 credits)
Fundamental concepts and skills of programming in a high-level language. Flow of control: selection, iteration, subprograms. Data structures: strings, arrays, records, lists, tables. Algorithms using selection and iteration (decision making, finding maxima/minima, searching, sorting, simulation, etc.) Good program design, structure and style are emphasized. Testing and debugging. Not intended for Engineering students (who should take ENGR 101), nor for CS majors in LSA who qualify to enter EECS 280. **CourseProfile (ATLAS)**

EECS 198. Special Topics
Advisory Prerequisite: Permission of instructor. (1-4 credits) Topics of current interest selected by the faculty. Lecture, seminar, or laboratory. **CourseProfile (ATLAS)**

200 Level Courses

EECS 200. Electrical Engineering Systems Design I
Advisory Prerequisite: ENGR 100 or ENGR 101 or ENGR 151 or EECS 180 or EECS 280. Preceded or accompanied by: EECS 215 Minimum grade requirement of "C" for advised prerequisites. (2 credits)
Gain a systems engineering perspective of electrical engineering centered around a design competition to address a societally-relevant challenge. Apply electrical engineering concepts in circuits, computing, control, sensors, optics, power, signal processing, and wireless communications to a system such as a robot, and adapt the system to achieve competition objectives within defined engineering constraints. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

EECS 201. Computer Science Pragmatics
Prerequisite: EECS 180 or EECS 183 or ENGR 101 or ENGR 151 or ROB 102 or preceded or accompanied by (EECS 280 or EECS 281). Minimum grade requirement of "C" for enforced prerequisites.

(1 credit)
Essential tools for computer programming: Shells, environments, scripting, Makefiles, compilers, debugging tools, and version control. **CourseProfile (ATLAS)**

EECS 203. Discrete Mathematics
Enforced Prerequisite: (MATH 115 or 116 or 119 or 120 or 121 or 156 or 175 or 176 or 185 or 186 or 214 or 215 or 216 or 217 or 255 or 256 or 285 or 286 or 295 or 296 or 417 or 419). Minimum grade requirement of "C" for enforced prerequisites. (4 credits) [Fewer than two previous elections of EECS 203 (incl. grades of W.I, VI, and AUD)]
Introduction to the mathematical foundations of computer science. Topics covered include: propositional and predicate logic, set theory, function and relations, growth of functions and asymptotic notation, introduction to algorithms, elementary combinatorics and graph theory and discrete probability theory. **CourseProfile (ATLAS)**

EECS 215. Introduction to Electronic Circuits
Prerequisite: (MATH 116 or 121 or 156) and (ENGR 101 or 151 or EECS 180 or 183 or preceded or accompanied by EECS 280) and (preceded or accompanied by: PHYSICS 240 or 260); (C or better, No OP/F) Cannot receive credit for both EECS 314 and EECS 215. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Introduction to electronic circuits. Basic Concepts of voltage and current; Kirchhoff's voltage and current laws; Ohm's law; voltage and current sources; Thevenin and Norton equivalent circuits; DC and low frequency active circuits using operational amplifiers, diodes, and transistors; small signal analysis; energy and power. Time- and frequency-domain analysis of RLC circuits. Basic passive and active electronic filters. Laboratory experience with electrical signals and circuits. **CourseProfile (ATLAS)**

EECS 216. Introduction to Signals and Systems
Prerequisite: EECS 215 or EECS 314 or BIOMEDE 211. Advisory Prerequisite: Preceded or accompanied by MATH 216. (4 credits).
Theory and practice of signals and systems engineering in continuous and discrete time. Continuous-time linear time-invariant systems, impulse response, convolution. Fourier series, Fourier transforms, spectrum, frequency response and filtering. Sampling leading to basic digital signal processing using the discrete-time Fourier and the discrete Fourier transform. Laplace transforms, transfer functions, poles and zeros, stability. Applications of Laplace transform theory to RLC circuit analysis. Introduction to communications, control and signal processing. Weekly recitations and hardware/Matlab software laboratories. **CourseProfile (ATLAS)**

EECS 230. Electromagnetics I
Prerequisite: (MATH 215 and PHYSICS 240; C or better, No OP/F) or (Co-requisite: EECS 215; C or better, No OP/F). (4 credits).
Vector calculus. Electrostatics. Magnetostatics. Time-varying fields: Faraday's Law and displacement current. Maxwell's equations in differential form. Traveling waves and phasors. Uniform plane waves. Reflection and transmission at normal incidence. Transmission lines. Laboratory segment may include experiments with transmission lines, the use of computer-simulation exercises, and classroom demonstrations. **CourseProfile (ATLAS)**

EECS 250 (NAVSCI 202). Electronic Sensing Systems
Prerequisite: Preceded or accompanied by EECS 230 or PHYSICS 240. (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. **CourseProfile (ATLAS)**

EECS 270. Introduction to Logic Design
Prerequisite: EECS 180 or 183 or ENGR 101 or 151 or ROB 102; or (preceded or accompanied by EECS 280)*. Minimum grade requirement of "C" for enforced prerequisites. (4 credits).*
Boolean algebra, digital design techniques, logic gates, logic and state minimization, standard

combinational circuits, latches and flip-flops, sequential circuits, synthesis of synchronous sequential circuits, state machines, FPGAs, memories, arithmetic circuits, and computer-aided design. Laboratory involves CAD-based design implemented on an FPGA including elementary interfacing. **CourseProfile (ATLAS)**

EECS 280. Programming and Introductory Data Structures
Prerequisite: ENGR 101 or ENGR 151 or EECS 180 or EECS 183 or ROB 102. Minimum grade requirement of "C" for enforced prerequisites. (4 credits) [Fewer than two previous elections of EECS 280 (incl. grades of W.I, VI, and AUD)]
Algorithm development and effective programming, top-down analysis, structured programming, testing and program correctness. Program language syntax and static and runtime semantics. Scope, procedure instantiation, recursion, abstract data types and parameter passing methods. Structured data types, pointers, linked data structures, stacks, queues, arrays, records and trees. **CourseProfile (ATLAS)**

EECS 281. Data Structures and Algorithms
Prerequisite: (EECS 203 or Math 465 or Math 565) and EECS 280. Minimum grade requirement of "C" for enforced prerequisites. Advisory Prerequisite: Minimum GPA of 2.5 over the best grade for each enforced prerequisite. (4 credits) [(EECS 203 or MATH 465 or 565) and EECS 280; (C or better, NO OP/F)] and [Fewer than two previous elections of EECS 281 (incl. grades of W, I, VI, and AUD)]
Introduction to algorithm analysis and O-notation; Fundamental data structures including lists, stacks, queues, priority queues, hash tables, binary trees, search trees, balanced trees and graphs; searching and sorting algorithms; recursive algorithms; basic graph algorithms; introduction to greedy algorithms and divide and conquer strategy. Several programming assignments. **CourseProfile (ATLAS)**

EECS 285. Practical Programming in Java
Prerequisite: EECS 280. Minimum grade requirement of "C" for enforced prerequisites. (2 credits)
Introduction to Java programming, including language features, design principles, and programming practices. Topics include: Java syntax and semantics, object-oriented design, exception handling, graphical user interfaces, mobile-application development, asynchronous programming, and unit testing. **CourseProfile (ATLAS)**

EECS 298. Special Topics
Advisory Prerequisite: Permission of instructor. (1-4 credits)
Topics of current interest selected by the faculty and pilot versions of new courses. Lecture, seminar, or laboratory. **CourseProfile (ATLAS)**

300 Level Courses

EECS 300. Electrical Engineering Systems Design II
Prerequisite: EECS 200, at least 3 of 4 (215, 216, 230, 280), Co-requisite EECS: 4th of 4 (215, 216, 230, 280) Minimum grade requirement of "C" for enforced prerequisites. (3 credits)
Principles of engineering design for electrical engineering systems. Integration of electrical engineering foundational concepts to address system-level objectives. Semester-long, open-ended design based on a societally-relevant challenge. Technical topics include embedded systems fundamentals, sensing, power and energy tradeoffs, and addressing realistic constraints of project requirements. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 301. Probabilistic Methods in Engineering
Advisory Prerequisite: Preceded or accompanied by EECS 216. (4 credits)
Basic concepts of probability theory. Random variables: discrete, continuous and conditional probability distributions; averages; independence. Statistical inference: hypothesis testing and estimation. Introduction to discrete and continuous random processes. **CourseProfile (ATLAS)**

EECS 311. Analog Circuits
Prerequisite: EECS 215 and EECS 216. (4 credits)
DC and AC circuit models for diodes, bipolar junction transistors and field-effect transistors; small-signal and piecewise analysis of nonlinear circuits; analysis and design of single-stage and multi-stage transistor amplifiers: gain, biasing and frequency response; op-amp based filter design; non-ideal op-amps. Design projects. Lecture and laboratory. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 312. Digital Integrated Circuits
Prerequisite: EECS 215 and Math 216. Minimum grade requirement of "C" for enforced prerequisites. (4 credits).
Review of MOSFET device operation. Design of digital circuits, including static CMOS, ratioed, dynamic, and pass-transistor logic. Memory structures, including static and dynamic RAM; sequential elements; and interconnects. Analysis of circuit delay, power, and noise margins. Use of circuit simulation in analysis and design. Design project(s). **CourseProfile (ATLAS)**

EECS 314. Electrical Circuits, Systems, and Applications
Prerequisite: MATH 214 or MATH 216, PHYSICS 240. Credit for only one: EECS 215, or EECS 314. Not open to CE or EE students. (4 credits).
Students will learn about electrical systems operation, specifications and interactions with other modules. Theory will be motivated by the use of examples taken from a variety of fields. Topics covered include circuit fundamentals, frequency response and transients, analog and digital electronics. In lab, students will build and analyze circuits including amplifiers, filters and temperature controllers. **CourseProfile (ATLAS)**

EECS 320. Introduction to Semiconductor Devices
Prerequisite: EECS 215 and PHYSICS 240 or 260. (4 credits)
Introduction to semiconductors in terms of atomic bonding and electron energy bands. Equilibrium statistics of electrons and holes. Carrier dynamics; continuity, drift and diffusion currents; generation and recombination processes, including important optical processes. Introduction to: PN junctions, metal-semiconductor junctions, light detectors and emitters; bipolar junction transistors, junction and MOSFETs. **CourseProfile (ATLAS)**

EECS 330. Introduction to Antennas and Wireless Systems
Prerequisite: EECS 230. (4 credits)
Electromagnetic fields and waves applied to antennas and wireless systems. The course covers wave reflection and transmission, dipoles, arrays, horn and patch antennas, waveguides, microstrip lines, resonators, and their applications in communication and radar systems. Introduction to advanced electromagnetics, communication systems, sensor systems, remote sensing and global navigation systems. **CourseProfile (ATLAS)**

EECS 334. Principles of Optics
Prerequisite: PHYSICS 240. A student can receive credit for only one: EECS 334 or PHYSICS 402. (4 credits)
Basic principles of optics: light sources and propagation of light; geometrical optics, lenses and imaging; ray tracing and lens aberrations; interference of light waves, coherent and incoherent light beams; Fresnel and Fraunhofer diffraction. Overview of modern optics with laboratory demonstrations. **CourseProfile (ATLAS)**

EECS 351. Introduction to Digital Signal Processing
Prerequisite: EECS 216. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
DSP methods and applications. Sampling and reconstruction, difference equations, convolution, stability, z-transform, transfer function, frequency response, FIR and IIR, DTFT, DFT, FFT, windows, spectrogram, computer-aided filter design, correlation, multi-rate, basic image processing, discrete time wavelets, filter banks. Applications: filtering, denoising, deconvolution, classification, others. Projects are

overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 367 (ROB 380). Introduction to Autonomous Robotics
Prerequisite: EECS 281 and (MATH 214 or 217 or 296 or 417 or 419, or ROB 101; (C or better; No OP/F). Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C " for enforced prerequisites. Credit Exclusions: Only 1 course may earn credit from ROB 320, ROB 380, ROB 511, and EECS 367. (4 credits)
A computational introduction to the modeling and control of autonomous robots and mobile manipulators. Programming projects and lectures cover 3D coordinate systems, axis-angle rotation, forward and inverse kinematics, physical simulation and numerical integration, motion control, path planning, high-dimensional motion planning, and robot software systems. Emphasizes portable programming of general robots. **CourseProfile (ATLAS)**

EECS 370. Introduction to Computer Organization
Prerequisite: (EECS 203 or Math 465 or Math 565 or EECS 270) and EECS 280. (4 credits)
Basic concepts of computer organization and hardware. Instructions executed by a processor and how to use these instructions in simple assembly-language programs. Stored-program concept. Datapath and control for multiple implementations of a processor. Performance evaluation, pipelining, caches, virtual memory, input/output. **CourseProfile (ATLAS)**

EECS 373. Introduction to Embedded System Design
Prerequisite: EECS 270 and EECS 370 and junior standing or higher. Minimum grade requirement of "C" for enforced prerequisites. (4 credits).
Principles of designing application-specific computer systems that interact with the physical world. Covers memory-mapped I/O, interrupts, analog interfacing, microprocessors, reconfigurable hardware, sensors, and actuators. Complex hardware/software system design and implementation. Substantial student-defined team design project. **CourseProfile (ATLAS)**

EECS 376. Foundations of Computer Science
Prerequisite: EECS 280 and (EECS 203 or Math 465 or Math 565). Minimum grade requirement of "C" for enforced prerequisites. (4 credits).
Introduction to theory of computation. Models of computation: finite state machines, Turing machines. Decidable and undecidable problems. Polynomial time computability and paradigms of algorithm design. computational complexity emphasizing NP-hardness. Coping with intractability. Exploiting intractability: cryptography. **CourseProfile (ATLAS)**

EECS 388. Introduction to Computer Security
Advisory Prerequisite: EECS 201 and 370. Enforced Prerequisite: EECS 281; (C or better, No OP/F). Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Introduction to the principles and practices of computer security as applied to software, host systems, and networks. Covers the foundations of building, using and managing secure systems. Topics include standard cryptographic functions and protocols, threats and defenses for real-world systems, incident response, and computer forensics. **CourseProfile (ATLAS**

EECS 390. Programming Paradigms
Prerequisite: EECS 281; (C or better, No OP/F). Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Survey of programming language features and paradigms and how to effectively use them. Introduces common features for program execution, data, and resource management. Exploration of paradigms including imperative, functional, object-oriented, and declarative programming, as well as advanced programming techniques. Students will gain experience in large projects that incorporate these paradigms. **CourseProfile (ATLAS)**

EECS 398. Special Topics
Advisory Prerequisite: permission of instructor. (1-4 credits)
Topics of current interest selected by the faculty. Lecture, seminar, or laboratory. **CourseProfile (ATLAS)**

EECS 399. Directed Study
Prerequisite: Sophomore or Junior Standing, and Permission of Instructor. (1-4 credits)
This course provides an opportunity for undergraduate students to work on research problems in EECS or areas of special interest such as design problems. **CourseProfile (ATLAS)**

400 Level Courses

EECS 402. Computer Programming For Scientists and Engineers
Prerequisite: Graduate standing.
Advisory Prerequisite: Intended for graduate students in science or engineering fields. Not available for credit to undergraduate students; will not substitute for Eng. 101. (4 credits)
(May not be taken if student has credit for or is currently enrolled in EECS 180, EECS 183, ENGR 101, ENGR 151, EECS 280 or EECS 282.)
Presents concepts and hands-on experience for designing and writing programs using one or more programming languages currently important in solving real-world problems. **CourseProfile (ATLAS)**

EECS 403. Graduate Foundations of Data Structures and Algorithms
Prerequisite: Graduate Standing and [EECS 402 and (EECS 203 or MATH 403 or 465 or 565); (C or better; No OP/F)] Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Introduction to algorithm analysis and O-notation; Fundamental data structures including lists, stacks, queues, priority queues, hash tables, binary trees, search trees, balanced trees and graphs; searching and sorting algorithms; recursive algorithms; basic graph algorithms; introduction to greedy algorithms and divide and conquer strategy. Several programming assignments. **CourseProfile (ATLAS)**

EECS 406 (ENGR 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 financing models are covered, including angel or VC funding and small business (SBIR) funding. **CourseProfile (ATLAS)**

EECS 409. Data Science Seminar
Prerequisite: None. (1 credit)
The MIDAS Seminar Series features leading data scientists from around the world and across the U-M campuses addressing a variety of topics in data science, and sharing their vision regarding the future of the field. These thought leaders are invited from academia, industry and government. A satisfactory grade is obtained in this course by regular attendance at the weekly seminar. **CourseProfile (ATLAS)**

EECS 410 (ENGR 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 covered include litigation, ethics and licensing. **CourseProfile (ATLAS)**

EECS 411. Microwave Circuits I
Prerequisite: EECS 311 or 330, or graduate standing. (4 credits)
Transmission-line theory, microstrip and coplanar lines, S-parameters, signal-flow graphs, matching networks, directional couplers, low-pass and band-pass filters, diode detectors. Design, fabrication and measurements (1-10GHz) of microwave-integrated circuits using CAD tools and network analyzers.

Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 413. Monolithic Amplifier Circuits
Prerequisite: EECS 311 and EECS 320 or graduate standing. (4 credits)
Analysis and design of BJT and MOS multi-transistor amplifiers. Feedback theory and application to feedback amplifiers. Stability considerations, pole-zero cancellation, root locus techniques in feedback amplifiers. Detailed analysis and design of BJT and MOS integrated operational amplifiers. Lectures and laboratory. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 414. Introduction to MEMS
Prerequisite: MATH 215 and MATH 216 and PHYSICS 240 or graduate standing. (4 credits)
Micro electro mechanical systems (MEMS), devices and technologies. Micro-machining and microfabrication techniques, including planar thin-film processing, silicon etching, wafer bonding, photolithography, deposition and etching. Transduction mechanisms and modeling in different energy domains. Analysis of micromachined capacitive, piezoresistive and thermal sensors/actuators and applications. Computer-aided design for MEMS layout, fabrication and analysis. **CourseProfile (ATLAS)**

EECS 417 (BIOMEDE 417). Electrical Biophysics
Prerequisite: EECS 215 and 216 or graduate standing. (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)**

EECS 418. Power Electronics
Prerequisite: (EECS 215 and EECS 216 and preceded or accompanied by EECS 320) or graduate standing. (4 credits)
AC-DC, DC-DC switch-mode power converter topologies. Power converter topologies. Power Semiconductor devices, inductors, capacitors. Loss mechanisms, thermal analysis. Drive, snubber circuits. Laboratory experience with power electronic circuits. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 419. Electric Machinery and Drives
Prerequisite: ((Phys 240 or 260) and EECS 215 and EECS 216) or graduate standing. (4 credits)
Generation of forces and torques in electromechanical devices. Power electronic drives, motion control. DC machines. AC machines, surface mount permanent magnet machines, induction machines. Applications examined include electric propulsion drives for electric/hybrid vehicles, generators for wind turbines, and high-speed motor/alternators for flywheel energy storage systems. Laboratory experience with electric drives. **CourseProfile (ATLAS)**

EECS 421. Properties of Transistors
Prerequisite: EECS 320 or graduate standing. (4 credits)
In depth understanding of the device physics and working principle of some basic IC components: metal-semiconductor junctions, P-N junctions, metal-oxide-semiconductor junctions, MOSFETs and BJTs. **CourseProfile (ATLAS)**

EECS 423. Micro/Nano Device Fabrication and Characterization
Prerequisite: Senior undergraduate or graduate standing. (4 credits)
Basic principles and hands-on experience with semiconductor micro/nano-fabrication technologies. Students will perform computer simulations of fabrication steps, and will practice some of the key processing steps used in fabricating different devices in modern IC manufacturing. Students will test

and/or analyze electrical properties of various devices and compare results to theory. **CourseProfile (ATLAS)**

EECS 425. Integrated Microsystems Laboratory
Prerequisite: EECS 311 or EECS 312 or EECS 414 or graduate standing. (4 credits)
Development of a complete integrated microsystem, from functional definition to final test. MEMS-based transducer design and electrical, mechanical and thermal limits. Design of MOS interface circuits. MEMS and MOS chip fabrication. Mask making, pattern transfer, oxidation, ion implantation and metallization. Packaging and testing challenges. Students work in interdisciplinary teams. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 427. VLSI Design I
Prerequisite: (EECS 270 and EECS 312) or graduate standing. Minimum grade requirement of “C” for enforced prerequisites. (4 credits)
Design techniques for full-custom VLSI circuits. Design rule checking, logic and circuit simulation. CMOS circuit delay and power analysis. High performance and low power VLSI systems. CMOS logic circuit families, adders, multipliers, memory arrays, sequential circuits, and interconnects. Clock and power distribution. Major design project to implement a RISC processor. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 428. Introduction to Quantum Nanotechnology
Advisory Prerequisite: PHYSICS 240, MATH 215, MATH 216. (3 credits)
This course introduces students to the emerging new field of quantum base nanotechnology. The course includes a range of topics such as the quantum vibrator, resonant tunneling, quantum circuits, a quantum flip flop, quantum information, quantum vacuum, and the role of quantum behavior in nano-devices and materials. **CourseProfile (ATLAS)**

EECS 429. Semiconductor Optoelectronic Devices
Prerequisite: EECS 320 or graduate standing. (4 credits)
Materials for optoelectronics, optical processes in semiconductors, absorption and radiation, transition rates and carrier lifetime. Principles of LEDs, lasers, photodetectors, modulators and solar cells. Optoelectronic integrated circuits. Designs, demonstrations and projects related to optoelectronic device phenomena. **CourseProfile (ATLAS)**

EECS 430 (SPACE 431)(CLIMATE 431). Wireless Link Design
Prerequisite: EECS 330 (“C” or better) or graduate standing. (4 credits)
Fundamentals of electromagnetic radiation and propagation (near earth, troposphere, ionosphere, indoor and urban); antenna parameters; practical antennas; link analysis; system noise; fading and multipath interference; applications. Course includes informative labs and a team project in practical wireless system design. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 434. Principles of Photonics
Prerequisite: EECS 330 or EECS 334 or permission of instructor or graduate standing. (4 credits)
Introduction to photonics, opto-electronics, lasers and fiber-optics. Topics include mirrors, interferometers, modulators and propagation in waveguides and fibers. The second half treats photons in semiconductors, including semi-conductor lasers, detectors and noise effects. System applications include fiber lightwave systems, ultra-high-peak power lasers and display technologies. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 435. Fourier Optics
Prerequisite: EECS 216. (3 credits)
Basic physical optics treated from the viewpoint of Fourier analysis. Fourier-transform relations in optical

systems. Theory of image formation and Fourier transformation by lenses. Frequency response of diffraction-limited and aberrated imaging systems. Coherent and incoherent light. Comparison of imagery with coherent and with incoherent light. Resolution limitations. Optical information processing, including spatial matched filtering. **CourseProfile (ATLAS)**

EECS 438. Advanced Lasers and Optics Laboratory
Prerequisite: EECS 334 or EECS 434 or graduate standing. (4 credits)
Construction and design of lasers; gaussian beams; nonlinear optics; fiber optics; detectors; dispersion; Fourier optics; spectroscopy. Project requires the design and set-up of a practical optical system. **CourseProfile (ATLAS)**

EECS 440. Extended Reality for Social Impact
Advisory Prerequisite: None. Enforced Prerequisite: EECS 281; (C or better, No OP/F). Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Design, development, and application of virtual and augmented reality software for social impact. Topics include: virtual reality, augmented reality, game engines, ethics / accessibility, interaction design patterns, agile project management, stakeholder outreach, XR history / culture, and portfolio construction. Student teams develop and exhibit socially impactful new VR / AR applications. **CourseProfile (ATLAS)**

EECS 441. Mobile App Development for Entrepreneurs
Prerequisite: Senior standing, EECS 281, and at least four credit hours of Upper Level Electives from list in either Computer Science or Computer Engineering. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Best practices in the software engineering of mobile applications and best practices of software entrepreneurs in the design, production and marketing of mobile apps. Students will engage in the hands-on practice of entrepreneurship by actually inventing, building and marketing their own mobile apps. **CourseProfile (ATLAS)**

EECS 442. Computer Vision
Prerequisite: [(EECS 281 and (MATH 214 or 217 or 296 or 417 or 419, or ROB 101)); (C or better, No OP/F)] or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (4 credits) (Credit cannot be obtained for both EECS 442 and EECS 504.)
An introduction to 2D and 3D computer vision. Topics include: cameras models, the geometry of multiple views; shape reconstruction methods from visual cues; low-level image processing techniques such as feature detection; high-level vision problems such as object recognition and scene understanding. **CourseProfile (ATLAS)**

EECS 443. Senior Thesis
Prerequisite: Senior standing. (3 credits)
Students develop and carry out a research plan in collaboration with a sponsoring faculty member. Students present a research proposal to be approved by both the faculty member and the chief program advisor or designate. Students submit and present a thesis to be evaluated by the sponsoring faculty member and second reader. Eligibility is limited to students who have a concentration GPA of 3.5 or better. **CourseProfile (ATLAS)**

EECS 444. Analysis of Societal Networks
Prerequisite: EECS 301 or MATH 425 or STATS 425. Minimum grade requirement of "C" for enforced prerequisites. (4 credits) (Credit cannot be obtained for both EECS 444 and EECS 544.)
In the modern world we depend on the efficiency of a myriad of societal networks to transact many activities. This course analyzes them (how they are connected, how they form, and how processes and transactions occur on them) using mathematical tools from graph theory, linear algebra, probability and game theory. **CourseProfile (ATLAS)**

EECS 445. Introduction to Machine Learning
Prerequisite: [(EECS 281 and (MATH 214 or 217 or 296 or 417 or 419, or ROB 101)); (C or better, No OP/F)]. Enrollment in one minor elective allowed for Computer Science Minors. Advisory Prerequisite: STATS 250 or equivalent. Minimum grade requirement of "C" for enforced prerequisites. (Credit Exclusions: No credit to a student who has taken EECS 453 or 545 or 553.) (4 credits)
Theory and implementation of state-of-the-art machine learning algorithms for large-scale real-world applications. Topics include supervised learning (regression, classification, kernel methods, neural networks, and regularization) and unsupervised learning (clustering, density estimation, and dimensionality reduction). For each topic, mathematical principles, key algorithmic ideas, and implementation will be highlighted. **CourseProfile (ATLAS)**

EECS 448. Applied Machine Learning for Modeling Human Behavior
Enforced Prerequisite: EECS 281 and (MATH 214 or 217 or 296 or 417 or 419, or ROB 101); (C or better; No OP/F) or Graduate Standing in CSE. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Machine learning, with a focus on human behavior, across multiple modalities including speech and text. Teams complete projects based primarily on their individual interests centered on modeling an aspect of human behavior. Prior experience with speech/language or other data modeling is not needed. **CourseProfile (ATLAS)**

EECS 449. Conversational Artificial Intelligence
Prerequisite: EECS 281; (C or better, No OP/F). Advisory Prerequisite: EECS 485 or EECS 493. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
The science and art of creating conversational AI spans multiple areas in computer science. Students will learn about and leverage advances in these areas to create conversational virtual assistants spanning natural
language processing, dialogue management, response generation, and other applications. **CourseProfile (ATLAS)**

EECS 452. Digital Signal Processing Design Laboratory
Prerequisite: EECS 280, and (EECS 351 or EECS 455) or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Architecture features of single-chip DSP processors are introduced in lecture. Laboratory exercises using two different state-of-the-art fixed-point processors include sampling, A/D and D/A conversion, digital waveform generators, real-time FIR and II filter implementation. The central component of this course is a 12-week team project in real-time DSP Design (including software and hardware development). Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

EECS 453. Principles of Machine Learning
Prerequisite: EECS 280 and (STATS 250 or STATS 280 or STATS 412 or STATS 426 or EECS 301 or IOE 265 or TO 301) and (EECS 351 or MATH 214 or 217 or 296 or 417 or 419 or ROB 101). (C or better, No OP/F). Minimum grade requirement of "C" for enforced prerequisites. (Credit Exclusions: No Credit to a student who has taken EECS 445 or 545 or 553). (4 credits)
Covers fundamental principles of machine learning, including unsupervised learning (e.g., clustering, mixture models, dimension reduction), supervised learning (e.g., regression, classification, neural networks & deep learning), and reinforcement learning. For each topic, mathematical principles, key algorithmic ideas, and basic theoretical insights will be highlighted. **CourseProfile (ATLAS)**

EECS 455. Wireless Communications Systems
Prerequisite: EECS 216 and EECS 301 or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Digital communication signals and systems; fundamental limits on reliable communications, energy and bandwidth efficiency trade-offs; optimum receiver principles, modulation techniques including phase shift keying, quadrature modulation and OFDM; block and convolutional coding and decoding; applications to

wireless communication systems; optional topics include synchronization, quantization and lossless compression of signals, fundamental limits of compression, role of entropy. **CourseProfile (ATLAS)**

EECS 456. Internet Foundations
Prerequisite: EECS 300 or EECS 270 or graduate standing or permission of instructor. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Fundamentals of the internet are introduced. Four layers of the internet are described, including the application, transport, network and link layers. TCP and UDP protocols in the transport layer are studied, along with IP in the network layer. Routers are described that perform the IP functions. Ethernet, WiFi and cellular technologies are covered for the link layer. **CourseProfile (ATLAS)**

EECS 458 (BIOMEDE 458). Biomedical Instrumentation and Design
Prerequisite: EECS 215 or EECS 314 or consent of instructor 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 or respiratory volume and flow rates, biopotentials (electrocardiogram), and optical analysis of arterial blood oxygen saturation (pulse-oximetry). **CourseProfile (ATLAS)**

EECS 460. Control Systems Analysis and Design
Prerequisite: EECS 216 or graduate standing. (4 credits)
Basic techniques for analysis and design of controllers applicable in any industry (e.g. automotive, aerospace, computer, communication, chemical, bioengineering, power, etc.) are discussed. Both time- and frequency-domain methods are covered. Root locus, Nyquist and Bode plot-based techniques are outlined. Computer-based experiment and discussion sessions are included in the course. **CourseProfile (ATLAS)**

EECS 461. Embedded Control Systems
Prerequisite: EECS 216 (C or better, No OP/F), or graduate standing. Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Basic interdisciplinary concepts needed to implement a microprocessor based control system. Sensors and actuators. Quadrature decoding. Pulse width modulation. DC motors. Force feedback algorithms for human computer interaction. Real time operating systems. Networking. Use of MATLAB to model hybrid dynamical systems. Autocode generation for rapid prototyping. **CourseProfile (ATLAS)**

EECS 463. Power Systems Design and Operation
Prerequisite: ((Phys 240 or 260) and EECS 215 and EECS 216) or graduate standing. (4 credits)
Power systems overview; Fundamentals: phasors, complex power, three phases; transformer modeling; Transmission line modeling; Power flow analysis; Power system control; Protection; Economic operation and electricity markets; Impact of renewable generation on grid operation and control. **CourseProfile (ATLAS)**

EECS 464 (ROB 464). Hands-on Robotics
Prerequisite: EECS 216 or EECS 281 or ME 360 or CEE 212 or IOE 333 or Graduate Standing. Minimum grade requirement of "C" 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)**

EECS 465 (ROB 422). Introduction to Algorithmic Robotics
Prerequisite: EECS 280 and MATH 215 and (junior standing or senior standing) or graduate standing). Minimum grade requirement of "C" for enforced prerequisites. Advisory Prerequisite: EECS 281 and (MATH 214 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)**

EECS 467. Autonomous Robotics Design Experience
Prerequisite: EECS 281 and (MATH 214 or 217 or 296 or 417 or 419, or ROB 101) and (EECS 367 or EECS 373); (No OP/F). Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Software methods and implementation for robot perception, world mapping, and control, using physical robots. Topics include: sensors, sensor processing, control, motion planning, localization and mapping, and forward and inverse kinematics. Multiple team projects, culminating in a major design experience (MDE) project. **CourseProfile (ATLAS)**

EECS 470. Computer Architecture
Prerequisite: EECS 370 and EECS 270 or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Topics include out-of-order processors and speculation, memory hierarchies, branch prediction, virtual memory, cache design, multi-processors, and parallel processing including cache coherence and consistency. Emphasis on power and performance trade-offs. Groups design an advanced (e.g. out-of-order, multi-core, SMT) processor using an HDL. **CourseProfile (ATLAS)**

EECS 471. Applied Parallel Programming with GPUs
Prerequisite: EECS 281 and EECS 370; (C or better, No OP/F) or Graduate Standing in CSE. Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Parallel computing and application development for massively parallel processors such as GPUs. Focuses on forms of parallelism, programming models such as CUDA, mapping computations to parallel hardware, efficient data structures, and paradigms for efficient parallel algorithms. Students will gain hands-on experience in programming assignments and projects. **CourseProfile (ATLAS)**

EECS 473. Advanced Embedded Systems
Prerequisite: EECS 373 and EECS 215 or EECS 281 or graduate standing. (4 credits)
Design of hardware and software for modern embedded systems. Real-time operating systems. Device drivers for general operating systems. PCB design including power integrity and electromagnetic interference. Radio frequency and wireless communication. Low-power design. DC/DC converter design for PCBs. Rapid prototyping of embedded systems. Groups will design a complete embedded system. **CourseProfile (ATLAS)**

EECS 475. Introduction to Cryptography
Prerequisite: EECS 376; (C or better, No OP/F) or Graduate Standing in CSE. Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Covers fundamental concepts, algorithms, and protocols in cryptography. Topics: ancient ciphers, Shannon theory, symmetric encryption, public key encryption, hash functions, digital signatures, key distribution. Emphasizes attack models, precise definitions of security, reductions, and proof techniques. ***CourseProfile (ATLAS)***

EECS 476. Data Mining
Prerequisite: [EECS 281 and (MATH 214 or MATH 217 or MATH 296 or MATH 417 or MATH 419, or ROB 101) (minimum grade of C)] or [EECS 403 (minimum grade of B)] or graduate standing in CSE. Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisites. (4 credits).
Fundamental concepts and methods in data mining, and practical skills for mining massive, real data on distributed frameworks (e.g., Hadoop). Topics include big data systems, frequent itemsets, similarity and

cluster analysis, classification, dimensionality reduction, mining of networks, time series and data streams, and applications (e.g., social network analysis, web search). ***CourseProfile (ATLAS)***

EECS 477. Introduction to Algorithms
Prerequisite: EECS 281 and EECS 376; (C or better, No OP/F). Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisites. (Credit Exclusions: No credit to a student who has taken EECS 586). (4 credits)
Fundamental techniques for designing efficient algorithms and basic mathematical methods for analyzing their performance. Paradigms for algorithm design: divide-and-conquer, greedy methods, graph search techniques, dynamic programming. Design of efficient data structures and analysis of the running time and space requirements of algorithms in the worst and average cases. **CourseProfile (ATLAS)**

EECS 478. Logic Circuit Synthesis and Optimization
Prerequisite: EECS 203, EECS 270, and senior standing or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Advanced design of logic circuits. Technology constraints. Theoretical foundations. Computer-aided design algorithms. Two-level and multilevel optimization of combinational circuits. Optimization of finite-state machines. High-level synthesis techniques: modeling, scheduling and binding. Verification and testing. Emerging technologies. Lab projects on CAD software development. **CourseProfile (ATLAS)**

EECS 480. Social Computing Systems
Prerequisite: EECS 485 or 493. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Design and creation of computing systems that mediate, facilitate , or augment social interactions. Introduces social computing research, and relevant web-based tools for creating systems that allow multiple users to interact. A team project provides experience designing a system with multiple stake holders and constraints, and building a complex interactive multi-user system. **CourseProfile (ATLAS)**

EECS 481. Software Engineering
Prerequisite: EECS 281; (C or better, No OP/F) or Graduate Standing in CSE. Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Pragmatic aspects of the production of software systems, dealing with structuring principles, design methodologies and informal analysis. Emphasis is given to development of large, complex software systems. A term project is usually required. **CourseProfile (ATLAS)**

EECS 482. Introduction to Operating Systems
Prerequisite: EECS 281 and EECS 370 or graduate standing in CSE. Minimum grade requirement of "C" for enforced prerequisites. Enrollment in one minor elective allowed for Computer Science Minors. (4 credits)
Operating system design and implementation: multi-tasking; concurrency and synchronization; inter-process communication; deadlock; scheduling; resource allocation; memory and storage management; input-output; file systems; protection and security. Students write several substantial programs dealing with concurrency and synchronization in a multi-task environment, with file systems and with memory management. **CourseProfile (ATLAS)**

EECS 483. Compiler Construction
Prerequisite: EECS 281 and EECS 370 or graduate standing in CSE. Minimum grade requirement of "C" for enforced prerequisites. Enrollment in one minor elective allowed for Computer Science Minors. (4 credits)
Introduction to compiler construction. Topics covered will include the following: lexical scanning, parsing (top-down and bottom-up), abstract syntax trees, semantic analysis, code generation and optimization. Students will build a working compiler for a high-level programming language. **CourseProfile (ATLAS)**

EECS 484. Database Management Systems
Prerequisite: EECS 281 (minimum grade of "C") or EECS 403 (minimum grade of "B") or graduate standing in CSE. Enrollment in one minor elective allowed for Computer Science Minors. (4 credits)
Concepts and methods for the design, creation, query and management of large enterprise databases. Functions and characteristics of the leading database management systems. Query languages such as SQL, forms, embedded SQL, and application development tools. Database design, integrity, normalization, access methods, query optimization, transaction management and concurrency control and recovery. **CourseProfile (ATLAS)**

EECS 485. Web Systems
Prerequisite: EECS 281 or graduate standing in CSE. Minimum grade requirement of "C" for enforced prerequisites. Enrollment in one minor elective allowed for Computer Science Minors. (4 credits) (EECS major or Informatics major only)
Concepts surrounding web systems, applications, and internet scale distributed systems. Topics covered include client/server protocols, security, information retrieval and search engines, scalable data processing, and fault tolerant systems. The course has substantial projects involving development of web applications and web systems. **CourseProfile (ATLAS)**

EECS 486. Informational Retrieval and Web Search
Prerequisite: EECS 281; (C or better, No OP/F) or Graduate Standing in CSE. Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Covers background and recent advances in information retrieval (IR): indexing, processing, querying, classifying data. Basic retrieval models, algorithms, and IR system implementations. Focuses on textual data, but also looks at images/videos, music/audio, and geospatial information. Web search, including Web crawling, link analysis, search engine development, social media, and crowdsourcing. **CourseProfile (ATLAS)**

EECS 487. Introduction to Natural Language Processing
Prerequisite: EECS 281; (C or better, No OP/F). Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisite. (Credit Exclusion: No credit to a student who has taken EECS 595.) (4 credits)
Fundamental theories and practical methods in natural language processing (NLP). Topics include syntax and parsing, lexical semantics and compositional semantics, discourse analysis, as well as applications in information extraction, sentiment analysis, question answering, summarization, dialogue systems, machine translation, and text generation. **CourseProfile (ATLAS)**

EECS 489. Computer Networks
Prerequisite: EECS 281 and EECS 370 or Graduate Standing in CSE. Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Protocols and architectures of computer networks with a specific focus on the Internet. Topics include socket programming, naming and addressing, video streaming and content distribution, flow and congestion control, routing, and cloud, datacenter, and software-defined networks. Students write several substantial programs implementing protocols at different layers of the network stack. **CourseProfile (ATLAS)**

EECS 490. Programming Languages
Prerequisite: EECS 281 or graduate standing in CSE. Minimum grade requirement of "C" for enforced prerequisite. Enrollment in one minor elective allowed for Computer Science Minors. (4 credits)
Programming languages are rich mathematical structures and powerful user interfaces. Student will learn about modern languages from the perspective of both language designers and users, building up from mathematical first principles, and covering human factors in language design, language prototyping, and techniques for reasoning about program behavior. **CourseProfile (ATLAS)**

EECS 491. Introduction to Distributed Systems
Enforced Prerequisite: EECS 281; (C or better, No OP/F) or graduate standing in CSE. Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Design and implementation of scalable, performant, and reliable distributed systems. Covers abstractions for simplifying development of distributed systems, techniques used to implement these abstractions, and case studies on the use of these techniques in real-world systems. Includes topics such as replicated state machines, reasoning about time in distributed systems, replication, concurrency control, data consistency models, techniques for scaling, and multi-tenancy. **CourseProfile (ATLAS)**

EECS 492. Introduction to Artificial Intelligence
Prerequisite: EECS 281. Minimum grade requirement of "C" for enforced prerequisite. Enrollment in one minor elective allowed for Computer Science Minors. (4 credits) (Not for graduate credit)
Introduction to the core concepts of AI, organized around building computational agents. Emphasizes the application of AI techniques. Topics include search, logic, knowledge representation, reasoning, planning, decision making under uncertainty, and machine learning. **CourseProfile (ATLAS)**

EECS 493. User Interface Development
Prerequisite: EECS 281 or graduate standing in CSE. Minimum grade requirement of "C" for enforced prerequisite. Enrollment in one minor elective allowed for Computer Science Minors. (4 credits)
Concepts and techniques for designing computer system user interfaces to be easy to learn and use, with an introduction to their implementation. Task analysis, design of functionality, display and interaction design, and usability evaluation. Interface programming using an object-oriented application framework. Fluency in a standard object-oriented programming language is assumed. **CourseProfile (ATLAS)**

EECS 494. Computer Game Design and Development
Prerequisite: EECS 281. Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Design, development, and application of digital games. Topics include: game engines, design patterns, shaders and graphics programming, agile development methods, iterative game/experience design, project management and resource allocation, virtual reality, classic games, multidisciplinary relationships, product exhibition, and portfolio construction. Students work in teams to develop and exhibit new games. **CourseProfile (ATLAS)**

EECS 495. Accessible Computing
Prerequisite: EECS 281 (C or better, No OP/F). Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Team-based development of technology systems focused on disability, accessibility, or chronic illness. Students work closely with people with disabilities to develop technologies addressing a specific need. Covers design methods and problem-solving strategies; human factors; human-machine interfaces; community perspectives; social and ethical aspects; and accessible technology for disability or chronic illness. **CourseProfile (ATLAS)**

EECS 496. Major Design Experience Professionalism
Prerequisite: Senior standing. (2 credits)
Design principles for multidisciplinary team projects, team strategies, entrepreneurial skills, ethics, social and environmental awareness, and life long learning. **CourseProfile (ATLAS)**

EECS 497. Human-Centered Software and Design and Development
Prerequisite: EECS 281. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Team-based, user-centered design and development of complex software systems incorporating effective design strategies and project management methodologies. Topics include customer discovery, contextual inquiry, prototyping, process models, creative problem solving, inclusive thinking, team dynamics, social concerns, and testing strategies. Teams of 3-5 students complete projects based primarily on their individual interests. **CourseProfile (ATLAS)**

EECS 498. Special Topics
Prerequisite: Permission of instructor. (1-4 credits)
Topics of current interest selected by the faculty. Lecture, seminar or laboratory. **CourseProfile (ATLAS)**

EECS 499. Directed Study
Prerequisite: Senior standing in EECS. (1-4 credits)
Provides an opportunity for undergraduate students to work on substantial research problems in EECS or areas of special interest such as design problems. For each hour of credit, it is expected that the student will work an average of three or four hours per week and that the challenges will be comparable with other 400 level EECS classes. Oral presentation and/or written report due at end of term. Not open to graduate students. **CourseProfile (ATLAS)**

500 Level Courses

ECE 500. Tutorial Lecture Series in System Science
Prerequisite: Graduate standing; mandatory satisfactory/unsatisfactory. (1 credit)
Students are introduced to the frontiers of System Science research. Sections 01, 02 and 03 are devoted, respectively, to Communications, Control, and Signal Processing. The tutorials are delivered by leaders of the respective research fields, invited from academia and industry. The presentations are self-contained and accessible to all graduate students in System Science. **CourseProfile (ATLAS)**

ECE 501. Probability and Random Processes
Prerequisite: EECS 301 or graduate standing. (4 credits)
Introduction to probability and random processes. Topics include probability axioms, sigma algebras, random vectors, expectation, probability distributions and densities, Poisson and Wiener processes, stationary processes, autocorrelation, spectral density, effects of filtering, linear least-squares estimation and convergence of random sequences. **CourseProfile (ATLAS)**

ECE 502. Stochastic Processes
Prerequisite: ECE 501. (3 credits)
Correlations and spectra. Quadratic mean calculus, including stochastic integrals and representations, wide-sense stationary processes (filtering, white noise, sampling, time averages, moving averages, autoregression). Renewal and regenerative processes, Markov chains, random walk and run, branching processes, Markov jump processes, uniformization, reversibility and queuing applications. **CourseProfile (ATLAS)**

ECE 503. Introduction to Numerical Electromagnetics
Prerequisite: EECS 330. (3 credits)
Introduction to numerical methods in electromagnetics including finite difference, finite element and integral equation methods for static, harmonic and time dependent fields; use of commercial software for analysis and design purposes; applications to open and shielded transmission lines, antennas, cavity resonances and scattering. **CourseProfile (ATLAS)**

EECS 504. Foundations of Computer Vision
Prerequisite: Undergraduate Calculus, Linear Algebra, Probability and Programming. (Credit Exclusions: No credit to a student who has taken EECS 442 or EECS 504.) (3 credits)
The course lays a framework for the extraction of useful information from images. Topics include representations of visual content (e.g., functions, points, graphs); visual invariance; mathematical and computational models of visual content; optimization methods for vision. Theoretical treatment and concrete examples, e.g., feature learning, segmentation image stitching, both covered. **CourseProfile (ATLAS)**

ECE 505. Computational Data Science and Machine Learning
Prerequisite: EECS 301 or MATH 425 or STATS 250 or STATS 412 or STATS 426 or IOE 265 or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (Credit Exclusions: No credit to a student who has taken ECE 551 or ECE 505.) (4 credits)
Introduction to computational methods for identifying patterns and outliers in large data sets. Topics include the singular and eigenvalue decomposition, independent component analysis, graph analysis, clustering, linear, regularized, sparse and non-linear model fitting, deep, convolutional and recurrent neural networks. Students program methods; lectures and labs emphasize computational thinking and reasoning. **CourseProfile (ATLAS)**

ECE 506. Design of Power Electronics
Prerequisite: EECS 418 or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (3 credits)
The course presents both the theoretical and practical design, analysis, construction, and measurement of circuits and components in different types of power converters. The course will teach concepts and present case studies through lectures, homework, design problems, and a final project. **CourseProfile (ATLAS)**

EECS 507. Introduction to Embedded System Research
Advisory Prerequisites: A prior >= 400-level course on computer system or sensor design and analysis. Sufficient time to read and understand two 30-page research papers per week. (3-4 credits)
Establish a foundation in research related to embedded system analysis, design, and synthesis. Lectures, assigned reading, and student presentations used to survey fundamental embedded systems topics. The second half-semester focuses on an important and timely research topic. Survey-only (3 credit) and project (4 credit) versions. **CourseProfile (ATLAS)**

ECE 508. Control and Modeling of Power Electronics
Prerequisite: EECS 418 or graduate standing. Minimum grade requirement of "C" for enforced prerequsites. (3 credits)
The course presents both the theoretical and practical modeling and control of power converters. Topics include small-signal models; digital and analog control; switched, sampled-data, and averaged models; large signal considerations; distributed power; and tools for computer modeling and simulation. **CourseProfile (ATLAS)**

ECE 509. BioMEMS
Prerequisite: None. (3 credits)
Covers the latest advances in bioMEMS, with specific attention to Microsystems targeting development biology and cell culture. We will use an organism's development –from genome to multicellular tissue–as a framework for teaching bioMEMS devices: from microPCR chips to microfluidic mixers to tissue scaffolds. The aim is to provide students familiar with microfabrication and Microsystems with a context from which to view and evaluate bioMEMS devices and innovations. We will cover implantable and diagnostic microsystems in the later part of the course. **CourseProfile (ATLAS)**

ECE 510 (NERS 675). Plasma Chemistry and Plasma Surface Interactions
Prerequisite: ECE 517, permission of instructor, or graduate standing. (3 credits)
Focuses on the plasma chemistry and plasma-surface interactions occurring in low temperature plasmas as used in, for example, materials processing, chemical conversion, biotechnology, environmental remediation, and photon sources. Emphasis is on the atomic and molecular processes that produce chemically reactive species by electron and ion-molecule collisions, neutral-neutral reactions; and reactions with inorganic, organic and liquid surfaces. Plasma-surface interactions will be addressed that result in deposition, etching and sputtering. Radiation transport producing photoionization and photodissociation, and trapping will be discussed. **CourseProfile (ATLAS)**

ECE 511. Integrated Analog/Digital Interface Circuits
Prerequisite: EECS 413 or permission of instructor. (4 credits)

Covers most of the well known analog to digital conversion schemes. These include the flash, folding, multi-step and pipeline Nyquist rate, architectures. Oversampling converters are also discussed. Practical design work is a significant part of this course. Students design and model complete converters. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

ECE 512. Amorphous and Microcrystalline Semiconductor Thin Film Devices
Prerequisite: EECS 421 and/or permission of instructor. (3 credits)
Introduction and fundamentals of physical, optical and electrical properties of amorphous and microcrystalline semiconductor based devices: MIM structures, Schottky diodes, p-i-n junctions, heterojunctions, MIS structures, thin-film transistors, solar cells, threshold and memory switching devices and large area x-ray radiation detectors. **CourseProfile (ATLAS)**

ECE 513. Flat Panel Displays
Prerequisite: EECS 423, ECE 512 and/or permission of instructor. (3 credits)
Introduction and fundamentals to the passive, active, reflective and emissive flat panel display technologies. This course will discuss the physics, operating principles, properties and technology of the flat panel displays. **CourseProfile (ATLAS)**

ECE 514. Advanced MEMS Devices and Technologies
Prerequisite: EECS 414. (4 credits)
Advanced micro electro mechanical systems (MEMS) devices and technologies. Transduction techniques, including piezoelectric, electrothermal, and resonant techniques. Chemical, gas, and biological sensors, microfluidic and biomedical devices. Micromachining technologies such as laser machining and microdrilling, EDM, materials such as SiC and diamond. Sensor and actuator analysis and design through CAD. **CourseProfile (ATLAS)**

ECE 515. Integrated Microsystems
Prerequisite: EECS 414. (4 credits)
Review of interface electronics for sense and drive and their influence on device performance, interface standards, MEMS and circuit noise sources, packaging and assembly techniques, testing and calibration approaches and communication in integrated microsystems. Applications, including RF MEMS, optical MEMS, bioMEMS, and microfluidics. Design project using CAD and report preparation. **CourseProfile (ATLAS)**

ECE 516 (BIOMEDE 516). Medical Imaging Systems
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 ultra-sound. **CourseProfile (ATLAS)**

ECE 517 (NERS 578). Low Temperature Plasmas
Advisory Prerequisite: (Physics 240 or Physics 260) and (Math 216 or Math 286 or Math 396). Enforced Prerequisite: None. (3 credits)
Addresses the science and technology of low temperature, partially ionized, non-equilibrium plasmas as used for materials processing, biotechnology/medicine, environment/energy, lasers, displays and lighting. The course topics include the fundamentals of electron-atom/molecule collisions, electron and ion transport; and electrostatic, magnetostatic and electromagnetic interactions with plasmas. Fundamental aspects of the kinetics of plasmas, electron energy distributions and diagnostics are addressed. Applications of these fundamentals to electrical discharges and plasma sources are discussed. **CourseProfile (ATLAS)**

ECE 518 (SPACE 595). Magnetosphere and Solar Wind
Prerequisite: Graduate standing. (3 credits)
General principles of magnetohydrodynamics; theory of the expanding atmospheres; properties of solar wind, interaction of solar wind with the magneto-sphere of the Earth and other planets; bow shock and magnetotail, trapped particles, auroras. **CourseProfile (ATLAS)**

ECE 519 (NERS 575). 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 includes: high voltage-DC, radio frequency and electron beam sustained 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. **CourseProfile (ATLAS)**

ECE 520. Solid State Physics
Prerequisite: PHYSICS 453 or graduate standing. (4 credits)
Crystal structure; Phonons; Introduction to Quantum Mechanics, Free electron Fermi gas; Low dimensional conductor; Electronic structure – Energy bands; Properties of semiconductors; Dielectrics response; Light absorption and emission; Magnetic effects; Superconductivity. **CourseProfile (ATLAS)**

ECE 521. Solid State Devices
Prerequisite: EECS 421. (3 credits)
Physics of operation of three terminal device structures important for high frequency analog or high speed digital applications. Emphasis on proven field-effect and bipolar-junction transistors, also including current and speculative nanoelectronic devices. Detailed study of static current-voltage characteristics and models for small and large signal behavior. **CourseProfile (ATLAS)**

EECS 522. Analog Integrated Circuits
Prerequisite: EECS 413. (4 credits)
Review of integrated circuit fabrication technologies and BJT and MOS transistor models. Detailed analysis and design of analog integrated circuits, including power amplifiers, voltage references, voltage regulators, rectifiers, oscillators, multipliers, mixers, phase detectors and phase-locked loops. Design projects. Lectures and discussion. **CourseProfile (ATLAS)**

EECS 523. Digital Integrated Technology
Prerequisite: (EECS 423 or EECS 425) and EECS 311 and EECS 320. (4 credits)
Integrated circuit fabrication overview, relationships between processing choices and device performance characteristics. Long-channel device I-V review, short-channel MOSFET I-V characteristics including velocity saturation, mobility degradation, hot carriers, gate depletion. MOS device scaling strategies, silicon-on-insulator, lightly-doped drain structures, on-chip interconnect parasitics and performance. Major CMOS scaling challenges. Process and circuit simulation. **CourseProfile (ATLAS)**

ECE 524 (APPPHYS 524). Organic Electronic Devices and Applications
Prerequisite: Permission of instructor or graduate standing. (3 credits)
Organic semiconductors optical/electrical properties, how organics are deposited/patterned to achieve thin-film device structures, device physics, engineering and applications (light emission from OLEDs, various structures/adaptations for high efficiency displays/lighting), organic thin-film transistor physics, applications and organic solar cells: status, efficiency limits, reliability, as an energy harvesting technology. **CourseProfile (ATLAS)**

ECE 525. Advanced Solid State Microwave Circuits
Prerequisite: EECS 411 and (EECS 421 or ECE 521). (3 credits)
General properties and design of linear and nonlinear solid state microwave circuits including: amplifier gain blocks, low-noise, broadband and power amplifiers, oscillators, mixer and multiplier circuits,

packaging, system implementation for wireless communication. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

ECE 526. Plasmonics
Advisory Prerequisite: EECS 230, PHYSICS 240, graduated standing or permission of instructor. (3 credits)
Introduction to power semiconductor devices. Analysis of DC and switching behavior of power MOSFETs, IGBT, HEMT, thyristor, Schottky diode, PiN diode, and emerging devices. Power semiconductor materials, device fabrication, packaging, and thermal modeling. Use of commercial numerical simulation software to model power device performance. **CourseProfile (ATLAS)**

ECE 527. Power Semiconductor Devices
Prerequisite: EECS 320 or EECS 421 or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Plasmonics is the study of optical phenomena related to the electromagnetic response of conductors. This course will provide basic knowledge to understand and apply principles of plasmonics. Students will be introduced to nanofabrication and characterization techniques. Optical, electronic, magnetic, thermal and biomedical applications of plasmonics will be discussed. **CourseProfile (ATLAS)**

ECE 528. Principles of Microelectronics Process Technology
Prerequisite: EECS 421 and EECS 423. (3 credits)
Theoretical analysis of the chemistry and physics of process technologies used in micro-electronics fabrication. Topics include: semiconductor growth, material characterization, lithography tools, photo-resist models, thin film deposition, chemical etching, plasma etching, electrical contact formation, micro-structure processing and process modeling. **CourseProfile (ATLAS)**

ECE 529. Semiconductor Lasers and LEDs
Prerequisite: EECS 429. (3 credits)
Optical processes in semiconductors, spontaneous emission, absorption gain, stimulated emission. Principles of light-emitting diodes, including transient effects, spectral and spatial radiation fields. Principles of semiconducting lasers; gain-current relationships, radiation fields, optical confinement and transient effects. **CourseProfile (ATLAS)**

ECE 530 (APPPHYS 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)**

ECE 531. Antenna Theory and Design
Prerequisite: EECS 330. (3 credits)
Theory of transmitting and receiving antennas. Reciprocity. Wire antennas: dipoles, loops and traveling-wave antennas. Analysis and synthesis of linear arrays. Phased arrays. Input impedance and method of moments. Mutual impedance. Aperture antennas: slot, Babinet's principle. Microstrip antennas. Horns, reflector and lens antennas. **CourseProfile (ATLAS)**

ECE 532 (CLIMATE 587) (SPACE 587). Microwave Remote Sensing I: Radiometry
Prerequisite: EECS 330, graduate standing. (3 credits)
Theory, systems and applications of active and passive microwave remote sensing: radiative transfer; blackbody radiation; microwave radiometry; atmospheric propagation and emission; radiometer receivers; surface and volume scattering and emission; radar systems; resolution techniques; calibration; synthetic aperture radar; scatterometers; applications to meteorology, oceanography and hydrology. **CourseProfile (ATLAS)**

ECE 533. Microwave Measurements Laboratory
Prerequisite: EECS 330, graduate Standing. (3 credits)
Advanced topics in microwave measurements: power spectrum and noise measurement, introduction to state-of-the-art microwave test equipment, methods for measuring the dielectric constant of materials, polarimetric radar cross section measurements, near field antenna pattern measurements, electromagnetic emission measurement (EM compatibility). Followed by a project that will include design, analysis, and construction of a microwave subsystem. **CourseProfile (ATLAS)**

ECE 534. Analysis of Electric Power Distribution Systems and Loads
Advisory Prerequisite: EECS 463 or graduate standing. (3 credits)
This course covers the fundamentals of electric power distribution systems and electric loads, including distribution grid components, topologies, and operational strategies; three-phase unbalanced power flow; electric load modeling, analysis, and control; and emerging topics such as photovoltaic and electric vehicle interconnection, distribution automation, and advanced metering infrastructure. **CourseProfile (ATLAS)**

ECE 535. Power System Dynamics and Control
Advisory Prerequisite: EECS 463, or permission of instructor or graduate standing. (3 credits)
The course introduces angle and voltage stability concepts and considers control strategies for improving dynamic performance. It provides an overview of nonlinear dynamical systems, Lyapunov methods and bifurcation analysis. Models of dynamical devices are developed. Small disturbance (linear) analysis techniques are presented, along with methods for assessing large disturbance (nonlinear) behavior. **CourseProfile (ATLAS)**

ECE 536. Power System Markets & Optimization
Prerequisite: EECS 463, or permission of instructor or graduate standing. Minimum grade requirement of "C" for enforced prerequisites. (3 credits)
This course covers the fundamentals of electric power system markets, including the economic principles they are based upon. It also covers the optimization methods required to solve planning and operational problems including economic dispatch, optimal power flow, and unit commitment. Problems are placed in the context of real electricity markets. **CourseProfile (ATLAS)**

ECE 537 (APPPHYS 537). Classical Optics
Prerequisite: EECS 330 and EECS 334. (3 credits)
Theory of electromagnetic, physical, and geometrical optics. Classical theory of dispersion. Linear response, Kramers-Kronig relations, and pulse propagation. Light scattering. Geometrical optics and propagation in inhomogeneous media. Dielectric waveguides. Interferometry and theory of coherence. Diffraction, Fresnel and Fraunhofer. Gaussian beams and ABCD law. **CourseProfile (ATLAS)**

ECE 538 (APPPHYS 550) (PHYSICS 650). Optical Waves in Crystals
Prerequisite: EECS 434. (3 credits)
Propagation of laser beams: Gaussian wave optics and the ABCD law. Manipulation of light by electrical, acoustical waves; crystal properties and the dielectric tensor; electro-optic, acousto-optic effects and devices. Introduction to nonlinear optics; harmonic generation, optical rectification, four-wave mixing, self-focusing and self-phase modulation. **CourseProfile (ATLAS)**

ECE 539 (APPPHYS 551) (PHYSICS 651). Lasers
Prerequisite: ECE 537 and ECE 538 and Graduate Standing. (3 credits)
Complete study of laser operation: the atom-field interaction; homogeneous and inhomogeneous broadening mechanisms; atomic rate equations; gain and saturation; laser oscillation; laser resonators, modes, and cavity equations; cavity modes; laser dynamics, Q-switching and modelocking. Special topics such as femto-seconds lasers and ultrahigh power lasers. **CourseProfile (ATLAS)**

ECE 540 (APPPHYS 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)**

ECE 541 (APPPHYS 541). Applied Quantum Mechanics II
Prerequisite: 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)**

EECS 542. Advanced Topics in Computer Vision
Advisory Prerequisite: EECS 442 or EECS 504 or permission of instructor. (3 credits)
The course discusses advanced topics and current research in computer vision. Topics will be selected from various subareas such as physics based vision, geometry, motion and tracking, reconstruction, grouping and segmentation, recognition, activity and scene understanding, statistical methods and learning, systems and applications. **CourseProfile (ATLAS)**

CSE 543 (ROB 543). Ethics for AI and Robotics
Prerequisite: Graduate standing.
Advisory Prerequisite: Coursework in artificial intelligence or robotics. *(4 credits)*
Ethical issues raised by AI and Robotics. Foundations in philosophical ethics and game theory; trust, cooperation, and the well-being of society; safety and autonomous vehicles; privacy and surveillance; fairness and bias; jobs and economic inequality; regulation of AI. **CourseProfile (ATLAS)**

ECE 544. Analysis of Societal Networks
Advisory Prerequisite: EECS 301 or MATH 425 or STATS 425 or Graduate standing. Minimum grade requirement of "C" for advised prerequisite. (Credit Exclusions: No credit to a student who has taken EECS 444 and EECS 544.) (3 Credits)
In the modern world we depend on the efficiency of a myriad of societal networks to transact many activities. This course analyzes them (how they are connected, how they form, and how processes and transactions occur on them) using mathematical tools from graph theory, linear algebra, probability and game theory. **CourseProfile (ATLAS)**

EECS 545. Machine Learning (CSE)
Advisory Prerequisite: Coursework in probability, linear algebra, and programming. (Credit Exclusions: No credit to a student who has taken EECS 445, 453, or 553.) (3 credits)
Fundamentals of supervised, unsupervised, and sequential learning, including linear and nonlinear regression, logistic regression, support vector machines and kernel methods, decision trees, ensemble methods, neural networks and deep learning, dimension reduction, clustering, and probabilistic models. Emphasis on implementation and application to real-world data. Includes algorithms and derivations from fundamental principles. **CourseProfile (ATLAS)**

ECE 546 (APPPHYS 546). Ultrafast Optics
Prerequisite: EECS 537. (3 credits)
Propagation of ultrashort optical pulses in linear and nonlinear media, and through dispersive optical elements. Laser mode-locking and ultrashort pulse generation. Chirped-pulse amplification. Experimental techniques for high time resolution. Ultrafast Optoelectronics. Survey of ultrafast high field interactions. **CourseProfile (ATLAS)**

CSE 547 (SI 652). Incentives and Strategic Behavior in Computational Systems
Prerequisite: None. (3 credits)
Modeling and analysis of strategic decision environments from combined computational and economic perspectives. Essential elements of game theory, including solution concepts and equilibrium computation. Design and analysis of mechanisms for problems motivated by areas such as electronic commerce, social computing, social choice, and information elicitation. **CourseProfile (ATLAS)**

CSE 548 (SI 649). Information Visualizaiton
Advisory Prerequisite: SI 582, 618 and 622 are strongly encouraged. EECS 493 or graduate standing and (C or better) or equivalent. Prerequisite: {[SI 506; (C- or better) or SI 506 Waiver] and [Co-requisite: SI 507; (C- or better) or SI Waiver]} or SI 508; (C- or better); or Graduate Standing. Minimum grade requirement of "C" for enforced prerequisite. (3 credits)
Introduction to information visualization. Topics include data and image models, multidimensional and multivariate data, design principles for visualization, hierarchical, network, textual and collaborative visualization, the visualization pipeline, data processing for visualization, visual representations, visualization system interaction design, and impact of perception. Emphasizes construction of systems using graphics application programming interfaces (APIs) and analysis tools. **CourseProfile (ATLAS)**

CSE 549 (SI 650). Information Retrieval
Prerequisite: SI 507 or SI 507 Waiver or Graduate Standing. (3 credits)
Information is everywhere. We encounter it in our everyday lives in the form of E-mail, newspapers, television, the Web, and even in conversations with each other. Information is hidden in a variety of media: text, images, sounds, videos. While casual information consumers can simply enjoy its abundance and appreciate the existence of search engines that can help them find what they want, information professionals are responsible for building the underlying technology that search engines use. Building a search engine involves a lot more than indexing some documents — information retrieval is the study of the interaction between users and large information environments. It covers concepts such as information need, documents and queries, indexing and searching, retrieval evaluation, multimedia and hypertext search, Web search, as well as bibliographical databases. In this course, students go over some classic concepts of information retrieval and then quickly jump to the current state of the art in the field, where crawlers, spiders, and hard-of-hearing personal butlers roam. **CourseProfile (ATLAS)**

ECE 550. Information Theory
Prerequisite: ECE 501. (3 credits)
Measures of information, such as entropy, conditional entropy, mutual and directed information and Kullback-Leibler divergence; fundamental limits to the performance of communication systems, including source coding (data compression) and channel coding (reliable transmission through noisy media); elementary source and channel coding techniques; information theoretic bounds on the performance of estimation/decision systems. **CourseProfile (ATLAS)**

ECE 551. Matrix Methods for Signal Processing, Data Analysis and Machine Learning
Prerequisite: EECS 351 or Graduate Standing. Minimum grade requirement of "C" for enforced prerequisites. (Credit Exclusions: No credit to a student who has taken ECE 505 or ECE 551.) (4 credits)
Theory and application of matrix methods to signal processing, data analysis and machine learning. Theoretical topics include subspaces, eigenvalue and singular value decomposition, projection theorem, constrained, regularized and unconstrained least squares techniques and iterative algorithms. Applications such as image deblurring, ranking of webpages, image segmentation and compression, social networks, circuit analysis, recommender systems and handwritten digit recognition. Applications and theory are covered in greater depth than in EECS 453. **CourseProfile (ATLAS)**

ECE 552 (APPPHYS 552). Fiber Optics: Internet to Biomedical Applications
Prerequisite: Any one of EECS 334, EECS 429, EECS 434, ECE 529, ECE 537, ECE 538, ECE 539 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, bio-medical 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 opthamology. **CourseProfile (ATLAS)**

EECS 553. Machine Learning (ECE)
Advisory Prerequisite: Graduate coursework in probability and linear algebra. (3 credits) (Students may not receive credit for both EECS 553 and EECS 545)
Fundamentals of supervised, unsupervised, and sequential learning, including linear and nonlinear regression, logistic regression, support vector machines and kernel methods, decision trees, ensemble methods, neural networks and deep learning, dimension reduction, clustering, and probabilistic models. Emphasis on algorithms and their derivation from fundamental principles, includes applications to real-world data. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

ECE 554. Introduction to Digital Communication and Coding
Prerequisite: EECS 216 and EECS 301. (3 credits)
Digital transmission of information across discrete and analog channels. Sampling; quantization; noiseless source codes for data compression: Huffman's algorithm and entropy; block and convolutional channel codes for error correction; channel capacity; digital modulation methods: PSK, MSK, FSK, QAM; matched filter receivers. Performance analysis: power, bandwidth, data rate and error probability. **CourseProfile (ATLAS)**

ECE 555. Digital Communication Theory
Prerequisite: ECE 501, ECE 554. (3 credits)
Theory of digital modulation and coding. Optimum receivers in Gaussian noise. Signal space and decision theory. Signal design. Bandwidth and dimensionality. Fundamental limits in coding and modulation. Capacity and cutoff rate. Block, convolutional and trellis coding. Continuous phase modulation. Filtered channels and intersymbol interference. Equalization. Spread-spectrum. Fading channels. Current topics. **CourseProfile (ATLAS)**

ECE 556. Image Processing
Advisory Prerequisite: ECE 501; Corequisite: EECS 453 or ECE 551. (3 credits)
Theory and application of digital image processing. Sampling, filtering, 2D Fourier transforms, interpolation, edge detection, enhancement, denoising, restoration, segmentation, random field models of images, Bayesian methods, wavelets and sparsity models. Applications include optical imaging, biomedical images, video and image compression. Student projects based on recent image processing literature. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

ECE 557. Communication Networks
Prerequisite: Graduate standing, preceded by EECS 431 or accompanied by ECE 501. (3 credits)
System architectures. Data link control: error correction, protocol analysis, framing. Message delay: Markov processes, queuing, delays in statistical multiplexing, multiple users with reservations, limited service, priorities. Network delay: Kleinrock independence, reversibility, traffic flows, throughput analysis, Jackson networks. Multiple access networks: ALOHA and splitting protocols, carrier sensing, multi-access reservations. **CourseProfile (ATLAS)**

ECE 558. Stochastic Control
Prerequisite: ECE 501, ECE 560. (3 credits)
Analysis and optimization of controlled stochastic systems. Models: linear and nonlinear stochastic controlled systems, controlled Markov chains. Optimization of systems described by Markov processes; dynamic programming under perfect and imperfect information, finite and infinite horizons. System identification: off-line, recursive. Stochastic adaptive control: Markov chains, self-tuning regulators, bandit problems. **CourseProfile (ATLAS)**

ECE 559. Optimization Methods in Signal Processing and Machine Learning
Advisory Prerequisite: ECE 551 or ECE 501. (3 credits)
Theory and application of optimization methods for signal and image processing and machine learning problems. Algorithms include gradient-based methods, proximal methods, and duality-based methods. Applications include signal denoising, compressed sensing, matrix completion, robust regression, and classifier design. **CourseProfile (ATLAS)**

ECE 560 (AEROSP 550) (CEE 571) (MECHENG 564). Linear Systems Theory
Prerequisite: Graduate standing. (4 credits)
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability. **CourseProfile (ATLAS)**

ECE 561 (MECHENG 561). Design of Digital Control Systems
Prerequisite: EECS 460 or MECHENG 461. (3 credits)
Sampling and data reconstruction. Z-transforms and state variable descriptions of discrete-time systems. Modeling and identification. Analysis and design using root locus, frequency response and state space techniques. Linear quadratic optimal control and state estimation. Quantization and other nonlinearities. **CourseProfile (ATLAS)**

ECE 562 (AEROSP 551). 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)**

ECE 563. Hybrid Systems, Analysis, and Control
Advisory Prerequisite: (EECS 562) or (ECE 560 and permission of instructor.) (3 credits)
Introduction to analysis and design of hybrid systems and hybrid control systems. Hybrid system modeling formalisms, specifications (automata theory, temporal logics), verification (barrier certificates, reachable sets, abstraction-based methods) and control synthesis. Stability of switched/hybrid systems. Applications of convex geometry and convex optimization in control. Model-predictive control of hybrid systems. **CourseProfile (ATLAS)**

ECE 564. Estimation, Filtering, and Detection
Prerequisite: ECE 501. (3 credits)
Principles of estimation, linear filtering and detection. Estimation: linear and nonlinear minimum mean squared error estimation, and other strategies. Linear filtering: Wiener and Kalman filtering. Detection: simple, composite, binary and multiple hypotheses. Neyman-Pearson and Bayesian approaches. **CourseProfile (ATLAS)**

ECE 565. Linear Feedback Control Systems
Prerequisite: EECS 460 or AEROSP 348 or MECHENG 461 and AEROSP 550 (ECE 560). (3 credits)
Control design concepts for linear multivariable systems. Review of single variable systems and extensions to multivariable systems. Purpose of feedback. Sensitivity, robustness, and design tradeoffs. Design formulations using both frequency domain and state space descriptions. Pole placement/observer design. Linear quadratic Gaussian based design methods. Design problems unique to multivariable systems. **CourseProfile (ATLAS)**

ECE 566. Discrete Event Systems
Prerequisite: Graduate standing (3 credits)

Modeling, analysis, and control of discrete event dynamical systems. Modeling formalisms considered include state machines, Petri nets, and recursive processes. Supervisory control theory; notions of controllable and observable languages. Analysis and control of Petri nets. Communicating sequential processes. Applications to database, management, manufacturing, and communication protocols. **CourseProfile (ATLAS)**

EECS 567 (MFG 567) (MECHENG 567) (ROB 510). 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)**

EECS 568 (NAVARCH 568) (ROB 530). Mobile Robotics: Methods and Algorithms
Prerequisite: Graduate Standing or permission of instructor. (4 credits)
Theory and applications 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. **CourseProfile (ATLAS)**

ECE 569 (MFG 564). Production Systems Engineering
Prerequisite: None. (3 credits)
Production Systems Engineering (PSE) investigates fundamental laws that govern production systems and utilizes them for analysis, design, and continuous improvement. the topics covered include quantitative methods for analysis and design, improvability, measurement-based management, and the PSE Toolbox. the skills acquired will make students marketable as engineering managers of manufacturing organizations. **CourseProfile (ATLAS)**

EECS 570. Parallel Computer Architecture
Prerequisite: EECS 470. (4 credits)
Architectures for explicit parallelism. Multithreaded processors, small- and large-scale multiprocessor systems. Shared-memory coherence and consistency. Effect of architecture on communication latency, bandwidth, and overhead. Latency tolerance techniques. Interconnection networks. Case studies. Term projects. **CourseProfile (ATLAS)**

EECS 571. Principles of Real-Time Computing
Prerequisite: EECS 470, EECS 482 or permission of instructor. (4 credits)
Principles of real-time computing based on high performance, ultra reliability and environmental interface. Architectures, algorithms, operating systems and applications that deal with time as the most important resource. Real-time scheduling, communications and performance evaluation. **CourseProfile (ATLAS)**

CSE 572. Randomness and Computation
Prerequisite: EECS 376 (B+ or better, No OP/F); or Graduate Standing. Advisory Prerequisite: Coursework in probability and algorithms. (4 credits)
Fundamentals of randomness and its pervasive use in computer science, including the probabilistic method, the design and analysis of algorithms, computational complexity, cryptography, combinatorics, logic and proof systems, and related topics. **CourseProfile (ATLAS)**

EECS 573. Microarchitecture
Prerequisite: EECS 470 or permission of instructor. (3 credits)
Graduate-level introduction to the foundations of high performance microprocessor implementation. Problems involving instruction supply, data supply and instruction processing. Compile-time vs. run-time

tradeoffs. Aggressive branch prediction. Wide-issue processors, in-order vs. out-of-order execution, instruction retirement. Case studies taken from current microprocessors. **CourseProfile (ATLAS)**

CSE 574. Computational Complexity
Prerequisite: EECS 376 (B+ or better, No OP/F); or Graduate Standing. Advised Prerequisite: Coursework in probability and algorithms. (4 credits)
Fundamentals of the theory of computation and complexity theory. Computability, undecidability, and logic. Relations between complexity classes, NP-completeness, P-completeness, and randomized computation. Applications in selected areas such as cryptography, logic programming, theorem proving, approximation of optimization problems, or parallel computing. **CourseProfile (ATLAS)**

CSE 575. Advanced Cryptography
Prerequisite: EECS 376 (B+ or better, No OP/F); or Graduate Standing. (4 credits)
A rigorous introduction to the design of cryptosystems and to cryptanalysis. Topics include cryptanalysis of classical cryptosystems; theoretical analysis of one-way functions; DES and differential cryptanalysis; the RSA cryptosystem; ElGamal, elliptic, hyperelliptic and hidden monomial cryptosystems; attacks on signature schemes, identification schemes and authentication codes; secret sharing; and zero knowledge. **CourseProfile (ATLAS)**

CSE 576. Advanced Data Mining
Advisory Prerequisite: EECS 281 and (MATH 214 or 217 or 296 or 417 or 419 or ROB 101) and (STATS 412 or MATH 425), or graduate standing. (4 credits)
Advanced topics in data mining. A mix of lectures, readings, and a semester-long group project will familiarize the students with recent methods for analyzing large-scale, real-world data and networks, and applications in various domains (e.g., web science, social science, neuroscience). **CourseProfile (ATLAS)**

EECS 578. Correct Operation for Processors and Embedded Systems
Prerequisite: EECS 470 or graduate standing or permission of instructor. Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Graduate-level introduction to topics in correctness of modern processors, embedded systems, and accelerator designs (e.g., GPUs). Robust and reliable design techniques. Hardware security assurance. Design verification: simulation, formal techniques, and post-silicon validation. Quality of services and energy management for correctness of implementation. Term projects. **CourseProfile (ATLAS)**

EECS 579. Digital System Testing
Prerequisite: Graduate standing. (4 credits)
Overview of fault-tolerant computing. Fault sources and models. Testing process. Combinational circuit testing. D-Algorithm and PODEM. Sequential circuit testing. Checking experiments. RAM and microprocessor testing. Fault simulation. Design for testability. Testability measures. Self-testing circuits and systems. ***CourseProfile (ATLAS)***

CSE 582. Advanced Operating Systems
Prerequisite: EECS 482. (4 credits)
Course discusses advanced topics and research issues in operating systems. Topics will be drawn from a variety of operating systems areas such as distributed systems and languages, networking, security and protection, real-time systems, modeling and analysis, etc. **CourseProfile (ATLAS)**

CSE 583. Advanced Compilers
Prerequisite: EECS 281 and 370 (EECS 483 is also recommended) (4 credits)
In-depth study of compiler back-end design for high-performance architectures. Topics include control-flow and data-flow analysis, optimization, instruction scheduling, register allocation. Advanced topics include memory hierarchy management, instruction-level parallelism, predicated and speculative

execution. The class focus is processor-specific compilation techniques, thus familiarity with both computer architecture and compilers is recommended. **CourseProfile (ATLAS)**

CSE 584. Advanced Database Systems
Prerequisite: EECS 484 or permission of instructor. (4 credits)
Advanced topics and research issues in database management systems. Distributed databases, advanced query optimization, query processing, transaction processing, data models and architectures. Data management for emerging application areas, including bioinformatics, the internet, OLAP and data mining. A substantial course project allows in-depth exploration of topics of interest. **CourseProfile (ATLAS)**

CSE 585. Advanced Scalable Systems
Advisory Prerequisite: Students are expected to have systems programming skills and must have taken at least one undergraduate-level systems-related course. Enforced Prerequisite: EECS 482 or 483 or 484 or 485 or 489 or 491; (C or better, No OP/F) or Graduate Standing in CSE. Minimum grade requirement of "C" for enforced prerequisite. (4 credits)
Advanced topics and research issues in cloud computing that deal with massive computation, data, and user base. Topics include challenges faced when designing, developing, and deploying web-scale distributed systems for emerging systems for Big Data and AI/ML workloads running in the cloud, observed through diverse perspectives such as operating systems, networking, distributed systems, compiler and programming language, database, security/privacy, etc. **CourseProfile (ATLAS)**

CSE 586. Design and Analysis of Algorithms
Prerequisite: EECS 376 (B+ or better, No OP/F); or Graduate Standing. *Advised Prerequisites: EECS 281 or EECS 403. (Credit Exclusions: No credit to a student who has taken EECS 477*). *(4 credits)*
Design of algorithms for nonnumeric problems involving sorting, searching, scheduling, graph theory and geometry. Design techniques such as approximation, branch-and-bound, divide-and-conquer, dynamic programming, greed and randomization applied to polynomial and NP-hard problems. Analysis of time and space utilization. **CourseProfile (ATLAS)**

CSE 587. Parallel Computing
Prerequisite: EECS 281 and graduate standing. (4 credits)
The development of programs for parallel computers. Basic concepts such as speedup, load balancing, latency, system taxonomies. Design of algorithms for idealized models. Programming on parallel systems such as shared or distributed memory machines, networks. Grid Computing. Performance analysis. Course includes a substantial term project. **CourseProfile (ATLAS)**

CSE 588. Computer and Network Security
Prerequisite: EECS 482 or EECS 489 or graduate standing. (4 credits)
Survey of advanced topics and research issues in computer and network security. Topics will be drawn from a variety of areas such as mandatory and discretionary security policies, secure storage, security kernels, trust management, preventing software vulnerabilities, applied cryptography, network security. **CourseProfile (ATLAS)**

CSE 589. Advanced Computer Networks
Prerequisite: EECS 489. (4 credits)
Advanced topics and research issues in computer networks. Topics include routing protocols, multicast delivery, congestion control, quality of service support, network security, pricing and accounting and wireless access and mobile networking. Emphasis is placed on performance trade-offs in protocol and architecture designs. Readings assigned from research publications. A course project allows in-depth exploration of topics of interest. **CourseProfile (ATLAS)**

CSE 590. Advanced Programming Languages
Prerequisite: EECS 281 or equivalent. (4 credits)

Fundamental concepts in Programming Languages (PL) as well as recent topics and trends in PL research. Topics include semantics, type systems, program verification using theorem provers, software model checking, and program analysis. Course focuses on applying PL concepts to improve software reliability. Course includes a semester-long individual research project. **CourseProfile (ATLAS)**

CSE 591. Distributed Systems
Prerequisite: EECS 482 and graduate standing. (4 credits)
Principles and practice of distributed system design. Computations, consistency semantics and failure models. Programming paradigms including group communication, RPC, distributed shared memory, and distributed objects. Operating system kernel support; distributed system services including replication, caching, file system management, naming, clock synchronization and multicast communication. Case studies. **CourseProfile (ATLAS)**

CSE 592. Foundations of Artificial Intelligence
Advisory Prerequisite: Graduate standing. (4 credits) (Credit Exclusions: No credit to a student who has taken both EECS 492 and EECS 592.)
An advance introduction to AI emphasizing its theoretical underpinnings. Topics include search, logic, knowledge representation, reasoning planning, decision making under uncertainty, and machine learning. **CourseProfile (ATLAS)**

CSE 593. Human-Computer Interaction
Prerequisite: Graduate standing. (3 credits)
Principles (e.g., human-centered systems design, usability, accessibility) and methods (e.g., requirements gathering, functional prototyping, user study evaluation) of technical Human-Computer Interaction (HCI) research. Survey of HCI research threads including Human-AI Interaction, Social Computing, Behavior Modeling, Education Technologies. Group assignments give students exposure to HCI research methods. **CourseProfile (ATLAS)**

CSE 595 (LING 541) (SI 561). Natural Language Processing
Prerequisite: Senior Standing. (3 credits)
Linguistic fundamentals of natural language processing (NLP), part of speech tagging, hidden Markov models, syntax and parsing, lexical semantics, compositional semantics, word sense disambiguation, machine translation. Additional topics such as sentiment analysis, text generation, and deep learning for NLP. **CourseProfile (ATLAS)**

ECE 596. Master of Engineering Team Project
Prerequisite: Enrollment in the Masters of Engineering program in ECE. (1-6 credits)
To be elected by ECE students pursuing the Master of Engineering degree. Students are expected to work in project teams. May be taken more than once up to a total of 6 credit hours. **CourseProfile (ATLAS)**

CSE 597 (SI 565) (LING 702). Language and Information
Advisory Prerequisite: Background in computation and probability. (3 credits)
This course introduces a body of quantitative techniques for modeling and analyzing natural language and for extracting useful information from texts. The theory includes Hidden Markov Models and the noisy channel model, information theory, supervised and unsupervised machine learning, and probabilistic context-free and context-sensitive grammars. Aspects of natural language analysis include phrasal lexicon induction, part of speech assignment, entity recognition, parsing, and statistical machine translation. **CourseProfile (ATLAS)**

CSE 598. Special Topics
Prerequisite: Permission of instructor or counselor. (1-4 credits)
Topics of current interest in computer science and engineering. Lectures, seminar or laboratory. Can be taken more than once for credit. **CourseProfile (ATLAS)**

ECE 598. Special Topics
Prerequisite: Permission of instructor or counselor. (1-4 credits)
Topics of current interest in electrical computer and engineering. Lectures, seminar or laboratory. Can be taken more than once for credit. **CourseProfile (ATLAS)**

CSE 599. Directed Study
Prerequisite: Prior arrangement with instructor; mandatory satisfactory/unsatisfactory. (1-4 credits)
Individual study of selected advanced topics in computer science and engineering. May include experimental work or reading. Primarily for graduate students. To be graded on satisfactory/unsatisfactory basis ONLY. **CourseProfile (ATLAS)**

ECE 599. Directed Study
Prerequisite: Prior arrangement with instructor. (1-4 credits)
Individual study of selected advanced topics in electrical and computer engineering. May include experimental work or reading. Primarily for graduate students. To be graded on satisfactory/unsatisfactory basis ONLY. **CourseProfile (ATLAS)**

600 Level Courses

ECE 600 (IOE 600). Function Space Methods in System Theory
Prerequisite: (ECE 551 or MATH 419) or MATH 451. (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)**

CSE 601. Introduction to CSE Graduate Research
Prerequisite: Graduate Standing. (1 credit)
An introduction for incoming Ph.D. students and research-focused Master's students to a wide range of topics critical to academic research. Rotating speakers will give perspective on the research process, time management, publishing in CS, managing the highs and lows of grad school, advisor interactions, career paths, etc. **CourseProfile (ATLAS)**

ECE 602. Reinforcement Learning Theory
Prerequisite: None. Advisory Prerequisite: ECE 501. (3 credits)
Basic theories and principles of reinforcement learning, and model-based and model-free reinforcement learning algorithms. Topics: Value iteration, policy iteration, Q-learning, SARSA, policy-gradient, variance reduction, linear and nonlinear function approximation, deep reinforcement learning, exploration-exploitation, convergence analysis, regret analysis. **CourseProfile (ATLAS)**

ECE 605. Data Science and Machine Learning Design Laboratory
Advisory Prerequisite: ECE 505 or ECE 551 or graduate equivalent. (4 credits)
This course uses a sequence of hands-on projects to bring into sharper focus the following concepts in the data-to-decision cycle: 1. how smart (or bad) data can positively (or negatively) affect decisions in the design and operation of an engineering system; 2. how to acquire such data, clean and store it via appropriate pre-processing and post-processing it for aiding reproducibility; 3. how to display, render, deploy and interpret it in the context of a real or simulated close-up loop type cloud based engineering system; and finally, 4. how to communicate the shortcomings and vulnerabilities of such systems, including plug-and-play systems using pre-trained off-the-shelf deep learning models, when integrated into a decision-making system; 5. conceptualization and execution of an open-ended, reproducible cloud-based design project. **CourseProfile (ATLAS)**

ECE 620. Electronic and Optical Properties of Semiconductors
Prerequisite: ECE 520 or ECE 540. (4 credits)

The course discusses in detail the theory behind important semiconductor-based experiments such as Hall effect and Hall mobility measurement; velocity-field measurement; photoluminescence; gain; pump-probe studies; pressure and strain-dependent studies. Theory will cover: Bandstructure in quantum wells; effect of strain on bandstructure; transport theory; Monte Carlo methods for high field transport; excitons, optical absorption, luminescence and gain. **CourseProfile (ATLAS)**

EECS 627. VLSI Design II
Prerequisite: EECS 427. (4 credits)
Advanced very large scale integrated (VLSI) circuit design. Design methodologies (architectural simulation, hardware description language design entry, silicon compilation, and verification), microarchitectures, interconnect, packaging, noise sources, circuit techniques, design for testability, design rules, VLSI technologies (silicon and GaAs) and yield. Projects in chip design. **CourseProfile (ATLAS)**

EECS 628. Advanced High Performance VLSI Design
Prerequisite: EECS 627 or equivalent. (3-4 credits)
Advanced issues in VLSI design addressing the areas of high performance, low power and reliability. Topics covered include recent approaches in leakage control, high speed on-chip communication, memory design, soft error failures, noise analysis and control, error tolerant design and new circuit families. (Students will complete an advanced project.) (A 4-credit option is available with addition of a substantial design and simulation component to the project.) **CourseProfile (ATLAS)**

ECE 631. Electromagnetic Scattering
Prerequisite: ECE 530 and graduate standing. (3 credits)
Boundary conditions, field representations. Low and high frequency scattering. Scattering by half plane (Wiener-Hopf method) and wedge (Maliuzhinets method); edge diffraction. Scattering by a cylinder and sphere: Watson transformation, Airy and Fock functions, creeping waves. Geometrical and physical theories of diffraction. **CourseProfile (ATLAS)**

ECE 633. Numerical Methods in Electromagnetics
Prerequisite: ECE 530. (3 credits)
Numerical techniques for antennas and scattering; integral representation: solutions of integral equations: method of moments, Galerkin's technique, conjugate gradient FFT; finite element methods for 2-D and 3-D simulations; hybrid finite element/boundary integral methods; applications: wire, patch and planar arrays; scattering composite structures. **CourseProfile (ATLAS)**

ECE 634 (APPPHYS 611) (Physics 611). Nonlinear Optics
Prerequisite: ECE 530 or ECE 537 or ECE 538, Graduate Standing. (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)**

ECE 638 (PHYSICS 542). Quantum Optics
Prerequisite: PHYSICS, Quantum mechanics, electrodynamics, atomic physics. (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)**

CSE 643 (PSYCH 643). Theory of Neural Computation
Prerequisite: Graduate standing and permission of instructor. (2-4 credits)
This is a graduate course introducing computational models of information processing in mammalian central nervous system. Following a brief overview, the course will examine: (1) Biological principles governing brain computation (e.g., population coding, computation maps, adaptive plasticity, self-

organization and modularization, etc.); (2) Mechanisms underlying single neuron computation, via either passive membrane properties (equivalent cylinder model and cable equation for dendrites; integrate-and-fire or Lapique model) or active membrane properties (Hodgkins-Huxley dynamics; F-N reduced system and phase-space analysis); (3) Architectures of artificial neural network (connectionism), including models of simple perception, multi-layered feed-forward network (with supervised, back-propagated error correction learning rule), associative network (Hopfield network and Boltman machine with unsupervised, Hebbian learning rule), and reinforcement (partially supervised) learning algorithms. **CourseProfile (ATLAS)**

CSE 644 (PSYCH 644). Computational Modeling of Cognition
Prerequisite: Graduate standing. (2-4 credits)
This course will examine computational models of human cognitive processes. Course goals include learning about important computational models of specific cognitive domains and evaluating the appropriateness and utility of different computational approaches to substantive problems in cognition. **CourseProfile (ATLAS)**

ECE 650. Channel Coding Theory
Prerequisite: ECE 501 and MATH 419. (3 credits)
The theory of channel coding for reliable communication and computer memories. Error correcting codes; linear, cyclic and convolutional codes; encoding and decoding algorithms; performance evaluation of codes on a variety of channels. **CourseProfile (ATLAS)**

ECE 659. Adaptive Signal Processing
Prerequisite: ECE 559 or ECE 564. (3 credits)
Theory and applications of adaptive filtering in systems and signal processing. Iterative methods of optimization and their convergence properties: transversal filters; LMS (gradient) algorithms. Adaptive Kalman filtering and least-squares algorithms. Specialized structures for implementation: e.g., least-squares lattice filters, systolic arrays. Applications to detection, noise canceling, speech processing and beam forming. **CourseProfile (ATLAS)**

ECE 662 (AEROSP 672) (MECHENG 662). Advanced Nonlinear Control
Prerequisite: ECE 562/AEROSP 551 or MECHENG 648. (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)**

CSE 670. Special Topics in Computer Architecture
Advisory *Prerequisite: CSE 570, graduate standing, and permission of instructor. (3 credits)*
Current topics of interest in computer architecture. This course may be repeated for credit. **CourseProfile (ATLAS)**

CSE 692. Advanced Artificial Intelligence
Prerequisites: CSE 592 or EECS 492 (C or better, No OP/F). Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Exploration of advanced topics in Artificial Intelligence, intended as preparation for research in the field. Emphasizes research methods and practice, through explicit instruction, analysis of current literature, and a term project devoted to replicating published findings. Coursework comprises extensive reading, research and writing assignments, presentations, quizzes, and the replication project. **CourseProfile (ATLAS)**

CSE 695 (PSYCH 740). Neural Models and Psychological Processes
Prerequisite: Graduate standing and permission of instructor. (3 credits)
Consideration of adaptively and biologically oriented theories of human behavior. Emphasis on both the

potential breadth of application and intuitive reasonableness of various models. There is a bias toward large theories and small simulations. **CourseProfile (ATLAS)**

CSE 698. Master's Thesis
Prerequisite: Election of a CSE, Master's Thesis Option. May be elected for a maximum of 6 credit hours. (1-6 credits)
To be elected by CSE students pursuing the master's thesis option. May be taken more than once up to a total of 6 credit hours. To be graded on a satisfactory/unsatisfactory basis ONLY. **CourseProfile (ATLAS)**

ECE 698. Master's Thesis
Prerequisite: Election of an ECE master's thesis option. (1-6 credits)
To be elected by ECE students pursuing the master's thesis option. May be taken more than once up to a total of 6 credit hours. To be graded on a satisfactory/unsatisfactory basis ONLY. **CourseProfile (ATLAS)**

CSE 699. Research Work in CSE
Prerequisite: Graduate standing, permission of instructor. (1-6 credits)
Students working under the supervision of a faculty member plan and execute a research project. A formal report must be submitted. May be taken for credit more than once up to a total of 6 credit hours. To be graded satisfactory/ unsatisfactory ONLY. **CourseProfile (ATLAS)**

ECE 699. Research Work in ECE
Prerequisites: None. (1-6 credits)
Students working under the supervision of a faculty member plan and execute a research project. A formal report must be submitted. May be taken for credit more than once up to a total of 6 credit hours. To be graded satisfactory/ unsatisfactory ONLY. **CourseProfile (ATLAS)**

700 Level Courses

ECE 700. Special Topics in System Theory
Prerequisite: Permission of instructor (to be arranged). (1-16 credits)
Special topics of current interest in system theory. **CourseProfile (ATLAS)**

ECE 720. Special Topics in Solid-State Devices, Integrated Circuits, and Physical Electronics
Prerequisite: Permission of instructor. (1-4 credits)
Special topics of current interest in solid-state devices, integrated circuits, microwave devices, quantum devices, noise, plasmas. This course may be taken for credit more than once. **CourseProfile (ATLAS)**

ECE 730. Special Topics in Electromagnetics
Prerequisite: Permission of instructor. (1-4 credits)
Special topics of current interest in electromagnetics. **CourseProfile (ATLAS)**

ECE 735. Special Topics in the Optical Sciences
Prerequisite: Graduate standing and permission of instructor. (1-4 credits)
Key topics of current research interest in ultrafast phenomena, short wavelength lasers, atomic traps, integrated optics, nonlinear optics and spectroscopy. This course may be taken for credit more than once under different instructors. **CourseProfile (ATLAS)**

ECE 750. Special Topics in Communication and Information Theory
Prerequisite: Permission of instructor. (1-16 credits)
Special topics of current interest related to communication and information theory. **CourseProfile (ATLAS)**

ECE 755. Special Topics in Signal Processing
Prerequisite: Permission of instructor. (1-4 credits)
Advanced topics in Signal and/or image processing. The specific topics vary with each offering. **CourseProfile (ATLAS)**

ECE 760. Special Topics in Control Theory
Prerequisite: Permission of instructor.
Special topics of current interest related to control theory. **CourseProfile (ATLAS)**

ECE 765. Special Topics in Stochastic Systems and Control
Prerequisite: Permission of instructor. (3 credits)
Advanced topics on stochastic systems such as stochastic calculus, nonlinear filtering, stochastic adaptive control, decentralized control and queuing networks. **CourseProfile (ATLAS)**

800 Level Courses

ECE 820. Seminar in Solid-State Electronics
Prerequisite: Graduate standing and permission of instructor. (1 credit)
Advanced graduate seminar devoted to discussing current research topics in areas of solid-state electronics. Specific topics vary each time the course is offered. Course may be elected more than once. **CourseProfile (ATLAS)**

900 Level Courses

CSE 990. Dissertation/Pre-Candidate
Prerequisite: Election for dissertation work by doctoral students not yet admitted as a 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)**

ECE 990. Dissertation/Pre-Candidate
Prerequisites: 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)**

CSE 995. Dissertation/Candidate
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)**

ECE 995. Dissertation/Candidate
Prerequisites: None. (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)**

Engineering Education Research

Engineering Education Research (EER)

ABOUT US

The University of Michigan's Engineering Education Research (EER) 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 structure allows the EER faculty and their research to be integrated well 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.

Vision and Mission

The vision of the UM EER Program is to be internationally known and respected for innovative research and expertise that impacts scholarship, practice, and policy in engineering and engineering education. The EER Program's mission is to improve engineering education at all levels by conducting rigorous and innovative engineering education research, preparing graduate students for successful, influential careers, and disseminating knowledge and expertise. The core values for the program include:

- Diversity, Equity, & Inclusion
- Holistic student support
- Innovation
- Interdisciplinarity
- Research to practice

Course Guide

Engineering Education Research Courses

Contact

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Admissions

Applicants to the EER program must have already earned a B.S. degree in a traditional engineering discipline, and they are encouraged to also have earned an M.S. degree in engineering. Admission to the EER graduate program is done annually based on a formal online application submitted to the Rackham Graduate School.

Application Materials (Ph.D. / Master's):

- Completed online application at Rackham Graduate School
- Personal statement
- Academic statement of purpose
- Three letters of recommendation

- Transcripts
- TOEFL – for non-native English speaker
- **GRE scores will not be accepted for any student applying for admissions after Fall 2022**

Application Materials (Rackham Certificate)

- Completed online application form
- **Within the online application form, students are expected to submit Statement of interest, Plan of study, Advisor's support and Transcript**

Graduate Certificate

The Rackham Certificate in Engineering Education Research provides a way for engineering doctoral students to learn and practice the skills needed to be proficient in the field of EER. 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.

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 793, EDUC 795**, or approved equivalent) or a course on qualitative methods for educational research (**EDUC 792** or approved equivalent) (3-5 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 as they plan and conduct their research.

Applications to the program can be submitted at the Rackham Certificate page.

Application materials and questions about the certificate should be emailed to the EER Graduate Program Coordinator at: eer-grad-coordinator@umich.edu.

Master’s Program

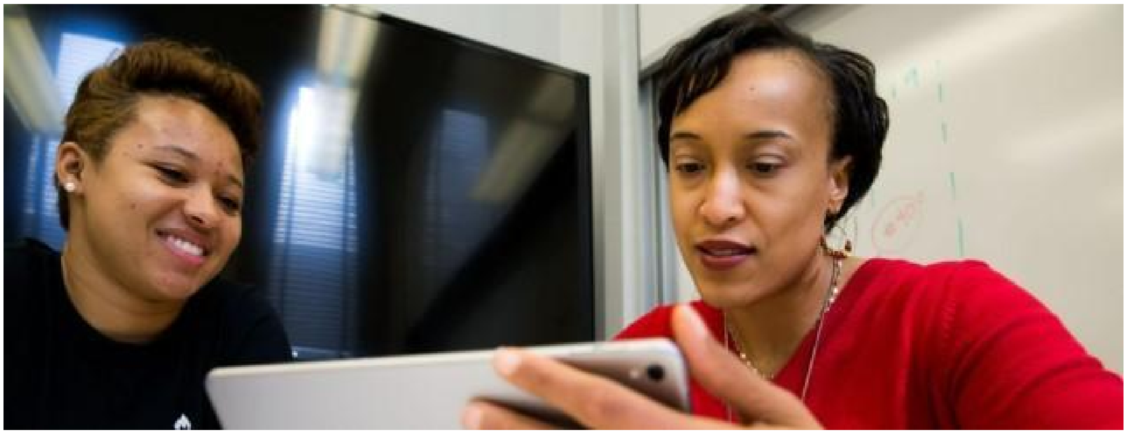
The EER M.S. Program provides foundational knowledge of EER topics, theories, and research methods as well as a specialization appropriate to students’ intended career paths. Students may earn the M.S. degree in the following ways. First, students may apply for and be admitted to the EER Program to earn 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.

Category	# courses	# credits
Engineering Education Core (EER 601 and EER 602)	2	6
Research Method Core	3	9 to 15
Specialization Electives	3 or more	Up to 15

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.

Ph.D. Program



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.

Category	# courses	# credits
Engineering Education Core (EER 601 and EER 602)	2	6
Research Methods Core	4	12 to 20
Specialization Electives	3 or more	Up to 15
Immersive Learning Experience (EER 610)	1	3

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 is required for a course 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 once each year)
- EER 602: Introduction to Theoretical Frameworks (3 credits, to be offered once each year)
- EER 610: Immersive Learning Experience (3 credits)

- Research methods core: 4 courses
- Specialization electives: 3 or more courses

For the full list of EER courses, please visit the EER Courses website.

Engineering Education Research Courses (EER)

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 end of term; may be elected for 1-4 credits (approximately 4 hours/week for each credit). **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

500 Level Courses

EER 598. Special Topics in Engineering Education Research
Prerequisite: None. (1-4 credits)
Topics of current interest in engineering education research. Lectures, seminar or laboratory. Topics vary from semester to semester. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

EER 610. Practicum – Immersive Learning Experience
Enforced Prerequisite: EER 601 and EER 602. Minimum grade requirement of "C". (3 credits)
Required for the EER Ph.D. degree and typically completed during a student's third year. It enables students to apply knowledge acquired from coursework to address real engineering education problems and connects students to academic and non-academic mentors. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

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

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, semiconductors, 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. Additionally, for those students that are seeking industry careers after their undergraduate degrees, the Engineering Physics curriculum offers the opportunity to focus in an advanced engineering area while developing a strong fundamental physics foundation.

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 quantum computing, data science, microprocessor design, plasma science and technology, electro-optics, 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, in both the engineering and science departments.

The Engineering Physics degree program is administered by the Nuclear Engineering and Radiological Sciences Department.

Program Administration

Undergraduate Program Chairs

Carolyn Kuranz
2911 Cooley Laboratory

YZ
2927 Cooley Laboratory

Undergraduate Program Manager

Michelle Sonderman
1919 Cooley Laboratory

For more specific information on contacting people – go to our **Contacts page**.

Mission Statement

Mission

To provide students with a high-quality education that prepares them for careers in engineering and science.

Goals

To educate students in the scientific fundamentals as well as in an engineering discipline of their choice, to provide the depth and breadth required to adapt to changes in technology.

Enrollment and Graduation Data

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

Contact

Undergraduate Program Chairs
Carolyn Kuranz
2911 Cooley
ckuranz@umich.edu
(734) 615-6282

YZ
2927 Cooley Laboratory
yzyz@umich.edu
734-647-4338

Undergraduate Program Manager
Michelle Sonderman
1919 Cooley
mlwhit@umich.edu
(734) 936-3130

Engineering Physics Undergraduate Program website

Undergraduate Degree Program

Sample Schedule

B.S.E. in Engineering Physics

Not an ABET-accredited program. Please see the PDF version of the sample schedule. Additional information can be found on the NERS Department website.

Entrepreneurship

Entrepreneurship (ENTR)

Overview

The Mission of the Center for Entrepreneurship (CFE) is to unlock the full entrepreneurial potential at the University of Michigan by helping people to understand, experience, practice, and refine the skills needed to successfully translate their knowledge, ideas, leadership, creativity, and enthusiasm into lasting value in the world. We achieve this potential by providing broad and inclusive access to a wide variety of educational opportunities, immersive learning experiences, timely and powerful mentorship, and meaningful connections to the global industry leaders that are building the future.

No matter your passion, interests, previous entrepreneurial experiences or ambitions, the CFE has specialized opportunities that will expose you to new ways of thinking and support your unique goals.

Since its inception in 2007, The Center has developed a rich and diverse set of offerings that cater first to the needs of the students and faculty at the University. Just like a startup, it continues to evolve and grow to meet the increasing demand for entrepreneurial curriculum and experiences.

ENTR courses at the CFE cover a wide range of topics, all taught by real entrepreneurs who teach from real-world 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.

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.

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, E+I meetups, ENTR abroad, mentoring/advising, and more, there is

something for everyone. Interested? Visit the Center for Entrepreneurship website or email entrepreneurship@umich.edu
for further information.

Course guide

Entrepreneurship Courses

Contact

CFE Website:
https://cfe.umich.edu/

General email:
entrepreneurship@umich.edu

Phone Number: 734-763-1021

Address: 2281 Bonisteel Boulevard
3350 Duderstadt Center
Ann Arbor MI 48109

CFE Team:

https://cfe.umich.edu/about/staff/

https://cfe.umich.edu/about/faculty-bios/

Entrepreneurship Courses (ENTR)

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/)

300 Level Courses

ENTR 390. Special Topics in Entrepreneurship
(1-15 credits)
Those topics with projects (i.e. TechLab; Reimagining Companies Through Innovation) are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

400 Level Courses

ENTR 407. Entrepreneurship Hour
(1 credit)
This weekly seminar series invites disruptive, influential and respected entrepreneurs, venture capitalists and business leaders to speak to students about their personal experiences founding, financing and managing a startup venture. Following the lecture, students will be able to meet the guest speaker and network with members of the entrepreneurial community. **CourseProfile (ATLAS)**

ENTR 408. Patent Law
(1 credit)
Inventors and entrepreneurs have four concerns related to patent law: protecting inventions during product development, determining invention patentability, avoiding infringement and leveraging a patent as a business asset. This course addresses these concerns through the application of case law and business cases to an invention of the student's choice. **CourseProfile (ATLAS)**

ENTR 409. Intro to Venture Capital
(1 credit)
Successful entrepreneurship and early stage venture capital appear to require a mixture of four very different traits and abilities: innovation/vision, evaluation, operation/management, and dedication. This course dives deep into these four pillars of success for the next generation of entrepreneurs and venture capitalists. **CourseProfile (ATLAS)**

ENTR 410. Finding Your Venture
(2 credits)
This course provides a framework for identifying clear, impactful opportunities. Every student will leave with a viable business opportunity to pursue in addition to a set of valuable and repeatable skills that will be an asset in any entrepreneurial setting. **CourseProfile (ATLAS)**

ENTR 411. Entrepreneurship Practicum
(3 credits)
The Practicum immerses students in the entrepreneurial process in a supportive classroom environment. Students critically evaluate and then pursue the development of their own ideas for new ventures. Throughout the course, students work closely with entrepreneurship faculty and mentors. **CourseProfile (ATLAS)**

ENTR 412. Advanced Entrepreneurship Practicum
Prerequisite: By application and permission of instructor. (3 credits)
The Advanced Entrepreneurship Practicum is the second part of the entrepreneurship practicum experience led by the Center for Entrepreneurship. In this course, you will experience running, growing, and leading a sustainable venture by applying fundamental and practical skills of entrepreneurship. **CourseProfile (ATLAS)**

ENTR 413. Entrepreneurial Marketing
(2 credits)
This course presents a pragmatic approach to marketing for new ventures. The course examines general marketing terms and principles, including the nature, dynamics, and strategies of marketing decision for new ventures. Students will apply these concepts to situations and problems relating to real ventures. **CourseProfile (ATLAS)**

ENTR 417. Entrepreneurship Hour Discussion Session
Prerequisite: Concurrent enrollment in ENTR 407 Entrepreneurship Hour. (1 credit)
In this faculty led discussion section for the Entrepreneurship Hour seminar series, students learn about, discuss and debate the key characteristics of entrepreneurship. Students also form small, multidisciplinary groups where they reflect on entrepreneurship and how it applies to their life goals. **CourseProfile (ATLAS)**

ENTR 490. Special Topics in Entrepreneurship
(1-15 credits)
Special topics of interest selected by entrepreneurial faculty. Those topics with projects (i.e. Climate Change; Defense and Security) are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

500 Level Courses

ENTR 500. An Introduction to Innovation: Tools for Career Success
Prerequisite: Senior or Graduate Standing. (3 credits)
Students will learn a wide range of concepts and skills to successfully navigate innovation-focused careers in small, medium, and large businesses and institutions. Students will study intellectual property, market and industry analysis, product-market fit, equity and stock options, program and project management, communication, securing investment and government funding, and more. **CourseProfile (ATLAS)**

ENTR 510. Compensation, Funding, and Ownership
Prerequisite: Senior or Graduate Standing. (3 credits)
Ownership in any size business is a continuum that ranges from 100% investor owned to 100% employee owned. Students will thoroughly deconstruct this continuum from all perspectives (as employees, founders, and investors) and learn by role playing how the myriad of models affects compensation and a company and society's culture. **CourseProfile (ATLAS)**

ENTR 520. Technology-Inspired Business Models
Prerequisite: Senior or Graduate Standing. (3 credits)
This course provides the framework that helps innovators understand the difference between innovative Value Creation and Innovative Value Capture. Built around a series of analytical tools, this course uses lectures, guest speakers, classroom discussions, group activities and personal research to explore the applications and interactions of these tools. **CourseProfile (ATLAS)**

ENTR 530. Innovation and Intellectual Property Strategy
Prerequisite: Senior or Graduate Standing. (3 credits)

The course examines intellectual property (IP) strategies for new ideas and startups, including barriers to entry for competitors and infringement risk reduction. Topics include IP procurement, technology transfer, due diligence, and preparing for and avoiding litigation. Students should have their own research to apply what's learned in the class. **CourseProfile (ATLAS)**

ENTR 550. Interpersonal Skills: Leveling Up to Leadership
Prerequisite: Senior or Graduate Standing. (3 credits)
Do you know how to give your best interview? Or talk to and lead people? Learn the Emotional Intelligence framework to better understand and manage yourself and others, and build strong relationships and lead teams. Develop your own Personal Leadership Plan to help you "level up" as a graduate professional. **CourseProfile (ATLAS)**

ENTR 560. Project Management and Consulting
Prerequisite: Senior or Graduate Standing. (3 credits)
Successful project managers and consultants possess skills to manage teams, clients, activities, communications and resources to produce desired outcomes. Students will be introduced to tasks and challenges fundamental to complex projects. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

ENTR 599. Special Topics for Entrepreneurship
Prerequisite: Senior or Graduate Standing. (1-4 credits)
Special topics of interest selected by Entrepreneurship faculty. Those topics with projects (i.e. TechLab; Climate Change) are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

Industrial & Operations Engineering

Industrial and Operations Engineering (IOE)

Industrial and operations engineers analyze data to design better systems and processes that improve the lives of all people. U-M IOE graduates are in high demand and make a positive impact across the globe in nearly every industry including business, consulting, energy, finance, healthcare, manufacturing, robotics, aerospace, automotive and more.

The U-M IOE curriculum emphasizes the use of data analytics, mathematics and business principles to create better, more efficient systems and processes that save time, money and resources. Through these foundational principles, students will learn to enhance people's everyday lives and make a positive difference in the world.

National polls consistently rank U-M IOE's undergraduate and graduate programs among the best in the United States. Exceptional faculty and graduate students bring high-impact research to the world while creating a hands-on learning environment for our outstanding undergraduate program. Our undergraduate graduates earn an impressive average of $85k right out of college and our master's earn $103k, backed by an unwavering demand for their expertise.

Course Guide

Industrial and Operations Engineering Courses

Contact

Departmental Website: ioe.engin.umich.edu

Department of Industrial and Operations Engineering
Industrial and Operations Engineering Building
1205 Beal Avenue
Ann Arbor, Michigan 48109-2117

Department Administration

Department Chair
Professor Julie Simmons Ivy
1877A Industrial and Operations Engineering Building

For more specific information, visit the IOE Department website.

Vision

U-M Industrial and Operations Engineering will lead the discovery and innovation of engineering knowledge to create and improve all types of systems. We will foster the next generation of engineering leaders who can achieve long-term impact for the common good.

Mission

We advance scientific and mathematical methods to help solve local and global challenges. We analyze data to improve decision-making and shape systems comprised of humans, machines, and processes. We educate and mentor students, emphasizing critical thinking, global citizenship, and the pursuit of the common good.

Values

Collaboration, Excellence, Creativity, Integrity, Respect

Goals

In addition, the IOE Program also has the following goals:

- To recruit, educate and support excellent, diverse students and prepare them to be leaders in the practice and further development of industrial and operations engineering.
- To have one of the leading undergraduate programs in the world in industrial and operations engineering.
- To engender the skills and desire to continually learn and grow through a lifelong professional career.

Objectives

- Launch a successful career by effectively practicing industrial and operations engineering or be successful in advanced graduate study in engineering, scientific, business, or related disciplines; practicing something other than IOE.
- Assume leadership roles in their career or graduate program.
- Contribute to the social and economic environments of their communities.
- Have the breadth of knowledge and motivation to continue to develop their career skills through ongoing learning.

Outcomes

- 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

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally, you can see recent degrees granted below:

Level	**2021**	**2022**	**2023**
Bachelors Degrees	187	170	138
Masters Degrees	97	64	120
Doctoral Degrees	12	13	8

Accreditation

The Industrial and Operations Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Industrial and Similarly Named Engineering Programs.

Program Outcomes

The matrix maps how each course in our curriculum addresses our program outcomes. Only the outcomes tracked are noted below.

Course	Student Outcomes (Black – High)						
	Apply math and science	Design	Communicate	Ethics	Teams	Experiments, Analyze, and Interpret Data	Lifelong Learning
IOE201							
IOE202							
IOE265							
IOE310							
IOE316							
IOE333							
IOE366							

IOE373							
IOE424							
IOE474							
IOE481							
TCHNCLCM380							

Undergraduate Degree Program

Industrial and Operations Engineers analyze data to improve decision-making and shape systems comprised of humans, machines, and processes. Since its inception in 1956, the Department of Industrial and Operations Engineering (IOE) at the University of Michigan (U-M) has advanced scientific and mathematical methods to help solve local and global challenges, expanding its research and teaching focus from the manufacturing industry into all sectors of the economy.

National polls consistently rank U-M IOE's undergraduate and graduate programs among the best; the undergraduate program is currently #5 in the United States while the graduate program is #2. Exceptional faculty and graduate students bring high-impact research to the world while creating a hands-on learning environment for our strong undergraduate program.

U-M IOE continues to break boundaries and evolve with the changing times. This is where students and faculty collaborate, thrive and optimize.

Sample Schedule

BSE in Industrial and Operations Engineering

The Industrial and Operations Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Industrial and Similarly Named Engineering Programs.

Please see the PDF version of the sample schedule. Additional information can be found on the IOE Department Advising website.

Areas

Computing & Analytics

Learn the data science concepts needed to create decision support systems using advanced analytic techniques that transform raw data into information to aid engineers, managers, and executives in making decisions.

Human Systems Integration

Understand the human factor— how our bodies and our minds impact our efficiency and our ability to work and how to use this knowledge to design safe and efficient workplaces and organizations.

Management Engineering

Learn how to apply administration, group dynamics, and human motivation to managerial problems critical for success in today's workplace.

Manufacturing & Service Systems

Learn how to use principles from lean manufacturing and Six Sigma to maximize benefits and minimize costs to achieve breakthrough performance in all sectors of the economy.

Operations Research

Learn advanced methods to describe, predict, and optimize system performance. Leverage techniques from math, statistics and computation to build data-driven models fundamental to all economic sectors.

Quality Engineering

Apply design techniques and reliability analysis to design quality control systems that are resilient to sources of uncertainty such as weather events, market uncertainty, and emergencies.

Sequential Undergraduate/Graduate Study (SUGS)

BSE in Industrial and Operations Engineering / MSE in Industrial and Operations Engineering

The IOE SUGS program is open to College of Engineering undergraduate students who have achieved senior standing (85 credit hours) with a minimum cumulative GPA of 3.5. SUGS students are allowed to "double count" six credit hours of graduate courses toward the BSE and MSE degrees. Students considering the SUGS program must "reserve" at least six undergraduate elective credit hours for courses that are eligible for credit in the IOE Master's degree program. SUGS students must enroll in Rackham for at least two (9 credit) terms, paying full Rackham tuition with no other U-M registration.

BSE in Industrial and Operations Engineering / MS in Biomedical Engineering

This SUGS program is open to all undergraduate students from Industrial and Operations Engineering who have achieved senior standing (85 credit hours) and have an overall cumulative GPA of 3.5 or higher. Please contact the Department of Biomedical Engineering for more complete program information.

Graduate Degrees

- Master of Science (MS) in Industrial and Operations Engineering
- Master of Science in Engineering (MSE) in Industrial and Operations Engineering
- Dual M.S. in Industrial and Operations Engineering/ Master of Business Administration (MBA)
- Doctor of Philosophy (PhD) in Industrial and Operations Engineering

MS and MSE in Industrial and Operations Engineering

The Master of Science degree in Engineering in Industrial and Operations Engineering is available to students who complete the MSE course requirements and have a bachelor's degree from a recognized program in engineering. The Master of Science degree in Industrial and Operations Engineering is available to students with a bachelor's degree from a recognized program in physics, mathematics or other fields related to engineering. Students who hold bachelor's degrees from other fields and who wish to receive an MS in Industrial and Operations Engineering should consult with the program advisor as specialized programs (usually involving additional credit hours over basic requirements) can be developed.

The basic requirements include 30 credit hours of approved graduate courses subject to the following restrictions:

1. At least 18 credit hours of IOE courses.
2. At least five courses (equal to or greater than 14 credit hours) must be at a 500 or greater level. At least four IOE courses (equal or greater than 12 credit hours) at a 500 or greater level. IOE 590 (Masters Directed Study, Research, and Special Problems)

may be used for at most 3 credit hours of the required 12 credit hours of IOE courses at the 500 level or above. Other directed study courses, courses graded S/U, and one- and two-credit seminar classes may not be used to satisfy 500-level requirements.

3. At least one cognate course (equal or greater than 3 credit hours) from outside the IOE Department.
4. No more than six credit hours of independent study.

An overall grade point average of "B" or higher in graduate courses taken in the program is required.

Special options, for which recommended courses have been defined, include:

1. Business Operations Engineering
2. Data Analytics & Applied Statistics
3. Health & Human Safety
4. Human Systems Integration
5. Operations Research & Analytics
6. Quality Control & Reliability Engineering

Health Engineering and Patient Safety Concentration:

The HEPS Concentration is a three-semester program with its own requirements, which is conducted while simultaneously fulfilling the IOE Master's requirements. It has its own additional application procedure after admission to the Master's program.

Requirements for Concentration in HEPS:

1. Fulfill all requirements for IOE master's program
2. 3 semesters (Fall, Winter, Fall)
3. Complete year-long, program-designed, hands-on project (3 credits in the second semester, full-time in the summer, 3 credits in the 3rd semester
4. Satisfy the following course requirements:
   - IOE 813: Seminars in Healthcare Systems Engineering — must be taken first semester (Fall 1)
   - Statistics/Data Analysis: 1 course
   - Intro to Healthcare: 2 courses
   - Technical Core: 2 courses
   - Methodology: 2 courses
   - Program Focus: 2 courses
5. Students may petition for special permission to count additional courses toward the HEPS requirements
6. Please review the HEPS Master's Concentration website for material describing these options and other details of the graduate programs.

PhD in Industrial and Operations Engineering

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad fields 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. There is no general course or credit requirement for the doctorate.

At the end of the first year in the program, a student must pass the qualifying review process to continue in the program. This qualifying review process is a holistic evaluation of the student's potential for scholarly research, and more details on the required coursework, GPA and research experience are provided on the IOE website. Most students, at the end of their second year, take a preliminary examination in their chosen area of concentration. The student must also satisfy a breadth requirement before taking the exam. After successfully passing this exam, the student is admitted to candidacy and selects a doctoral committee to supervise preparation of the dissertation. A defense of the dissertation in the presence of this committee is required.

Information that describes the general procedure leading to the doctorate is available on the Rackham Graduate School website.

Dual MBA / MS in Industrial and Operations Engineering

The Ross School of Business and the College of Engineering Department of Industrial and Operations Engineering offer a dual degree program enabling a student to pursue concurrent work in Business Administration and Industrial and Operations Engineering leading to the MBA and MS (IOE) degrees. The program is arranged so that all requirements for the degrees are completed in two and one-half years of enrollment with the required 65 credit hours completed.

Students interested in the MBA/MS (IOE) dual program must apply to, and be admitted by, both schools, using their respective application forms and indicating that application is being made to the joint program. Only one application fee is necessary. Students are expected to meet the prerequisites for each program. In particular, the statistics requirement for the IOE program should be discussed with an advisor prior to beginning either program. This program is not open to students who have earned either the MBA or MS (IOE) degrees. However, students registered in the first year of either program may apply.

Students admitted to this joint program must satisfy the following degree requirements:

1. The MBA 60-credit-hour degree program including:

- the 31.5-credit-hour MBA core (no credit is awarded for Business Administration core courses successfully waived; credit must be earned with Business electives);
- 5 elective hours in Business Administration (12 of the 13.5 must be approved by IOE);
- 15 credit hours of transferable electives from the Department of Industrial and Operations Engineering.

2. The 18 hours of graduate-level IOE courses, including at least twelve credit hours in courses numbered 500 or above. Directed study courses and seminar classes may not be counted toward the IOE 500-level or above requirement.
3. A 2-credit independent study in IOE or the Business School, which would lead to a paper integrating business and IOE perspectives on a particular area of interest.
4. A student must register for at minimum 15 credit hours using their Rackham registration. This usually occurs in the 4th semester.

The total credit hours for the joint degree program will be at least 65.

The dual program can begin with studies in either school; however, because of the sequential nature of the core courses in the MBA program, most students will find it advantageous to start the first year in the Business School. Students who wish to begin with Industrial Operations Engineering should consult a counselor in the Business School to work out an appropriate plan of study.

Industrial and Operations Engineering Courses (IOE)

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

IOE 101. IOE Career Seminars
Prerequisite: None. (1 credit)
Seminar to expose students to wide-ranging potential careers in industrial and operations engineering such as consulting, data science, healthcare, finance, supply chain management, energy, transportation, and others. Students will learn from industry affiliates about the nature of different careers and how to prepare for success after graduation. **CourseProfile (ATLAS)**

200 Level Courses

IOE 201. Economic Decision Making
Prerequisite: ENGR 100 or ENGLISH 124 or 125. Minimum grade of "C-" required for enforced prerequisite and Junior standing or Below. (2 credits) (7-week course)
Overview of business operations, public policy costs, financial valuation, cashflow analysis, and accounting principles. Time value of money and net present values. Practical team project experience. **CourseProfile (ATLAS)**

IOE 202. Operations Engineering & Analytics
Prerequisite: MATH 115, 120,175, 185, or 295 and Junior standing or Below. Corequisite: MATH 116, 121, 156, 176, 186, or 296. Minimum grade of "C-" required for enforced prerequisite. (2 credits) (7-week course)
Process of engineering & mathematically modeling decisions including the role of uncertainty in decision making. Basic tools for solving the resulting models, particularly optimization, statistical models and queueing processes. Applications from healthcare, public policy, manufacturing transportation, security, etc. **CourseProfile (ATLAS)**

IOE 265. Probability and Statistics for Engineers
Prerequisite: (Math 116, 119, 121, 156, 176, 186, or 296) and (ENGR 101, 101X, 151 or EECS 183 or 180) 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 or 216 or 256 or 286 or 316 or ROB 101) and IOE 202 and (ENGR 101 or 101x or 104 or 151 or EECS 100 or 183 or CMPTRSC 100 or 183) (C- or better). 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 or STATS 265) and (Math 214 or 216 or 256 or 286 or 316 or ROB 101) (C- or better). 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
Prerequisite: Preceded or accompanied by IOE 265. Minimum grade of "C-" for enforced prerequisite. (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. **CourseProfile (ATLAS)**

IOE 366. Introduction to Engineering Data Analytics
Enforced Prerequisite: (IOE 265 or STATS 250) and (Math 214 or 216 or 256 or 286 or 316 or ROB 101), (C- or better). Minimum grade of "C-" required for enforced prerequisites. (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. **CourseProfile (ATLAS)**

IOE 373. Data Analytics Tools and Techniques
Enforced Prerequisite: (ENGR 101 or 101x or 151) or (EECS 180 or 183) or ROB 102 (C- or better). Minimum grade of "C-: required 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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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 424. Practicum in Production and Service Systems
Prerequisite: IOE 310 and IOE 316 and IOE 333 and IOE 366 and IOE 373 and TCHNCLCM 380; C- or better and Senior Standing. Minimum grade of "C-" required for enforced prerequisite. Not for graduate credit. (4 credits)
Student teams with work on an externally sponsored IOE design project. The final report should demonstrate a mastery of the established technical communication skills. The report will be reviewed and edited to achieve this outcome. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **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 431. Human-Centered and User Experience Design
Advisory Prerequisite: IOE 333 or equivalent. Prerequisite: None. (3 credits)
Introduction to the core principles of human-centered and user experience design. Students learn user research techniques like interviews and observations, explore ideation and concept development through sketching and prototyping, and master the art of user testing to gather valuable feedback for iterative design improvements. **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 435 (ROB 435). Quantifying Human Motion Through Wearable Sensors
Prerequisite: (ROB 101 OR MATH 214) and IOE 265 and (IOE 333 OR ROB 204). Minimum grade of "C-" required for enforced prerequisites. (3 credits)
Hands-on introduction to inertial measurement units (IMUs) for measuring human motion strategies. Includes random processes, autocorrelation, cross-correlation, Fourier transforms, orientation representations, reference frames, and filters (low-pass, high-pass filters, Kalman). These concepts are applied to estimating biomechanical measures (e.g., body joint angles, torso posture, phases of gait, positions) and selecting metrics to support decision making reliant on human movement. **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
Advisory 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)
Fundamentals in developing efficient layouts for single-story and multi-story production and service

facilities. Manual procedures and microcomputer-based layout algorithms. Algorithms to determine the optimum location of facilities. Special considerations for multi-period, dynamic layout problems. **CourseProfile (ATLAS)**

IOE 449 (MFG 449). Material Handling Systems
Prerequisite: IOE 310, IOE 316 or Graduate standing. Minimum grade of "C-" required for enforced prerequisites. (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. (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)**

IOE 460. Decision Analysis and Bounded Rationality
Prerequisite: IOE 265, IOE 310. Minimum grade of "C-" required 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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

IOE 465. Design of Experiments.
Prerequisite: IOE 366 or graduate standing. Minimum grade of "C-" required for enforced prerequisite. (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. **CourseProfile (ATLAS)**

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 473. Advanced Data Analytics
Prerequisite: None. Advisory Prerequisite: IOE 310, IOE 366, IOE 373. (3 credits)
Introduction to fundamental computational methods in data analytics with case studies from real-world applications. Goal is to expose students to a variety of data analytics methods, and then demonstrate the applicability of these methods through a set of real-world problems in various engineering disciplines. **CourseProfile (ATLAS)**

IOE 474. Discrete-Event Simulation
Advisory Prerequisite: IOE 373. Enforced Prerequisite: IOE 316 and IOE 366, preceded or accompanied by IOE 373 or graduate standing. Minimum grade of "C-" required for enforced prerequisites. (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: IOE 310 and IOE 316 and IOE 333 and IOE 366 and IOE 373 and TCHNCLCM 380; and Senior Standing. Minimum grade of "C-" for enforced prerequisites. IOE undergraduates only; Not for graduate credit. (4 credits)
Project teams meet needs of hospital clients. Technical communications for presentations and reports, design processes, inclusive team functioning, project methodologies, data collection, data analysis, lean, operations research, project management, and ethics and standards. Projects will be overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **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 from areas of industrial and operations engineering. Student(s) must register for the individual section number of the instructor/advisor. Report is reviewed and edited. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

IOE 491. Special Topics in Industrial and Operations Engineering
(to be arranged)
Selected topics of current interest in industrial and operations engineering. Projects are overseen and

graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

IOE 499. Senior Design Projects
Advised Prerequisite: Senior standing, permission of advisor. (4 credits)
Selected design projects in industrial and operations engineering. The final report submitted by students should demonstrate a mastery of the established communication skills. The final project report will be reviewed to achieve this outcome. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

500 Level Courses

IOE 500. IOE MS Seminar
Prerequisite: None. Advisory Prerequisite: MSE IOE student or permission of instructor. (1 credit)
Seminars presented by academic speakers and industry leaders to describe contemporary applications of industrial and operations engineering models and techniques to master's students in IOE. The focus is on applications but research challenges are addressed as needed. Many speakers also address potential career opportunities for MS students in IOE. **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)**

IOE 513. Healthcare Operations Research: Theory and Applications
Prerequisite: IOE 316 or IOE 515 and IOE 310 or IOE 510 and IOE 366 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 525. Lean Principles and Scientific Thinking in Organizations
Advisory Prerequisites: IOE 425. (3 credits)
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
Advisory 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 535 (ROB 535). Quantifying Human Motion Through Wearable Sensors
Prerequisites: None. (3 credits)
Hands-on introduction to inertial measurement units (IMUs) for measuring human motion strategies. Includes random processes, autocorrelation, cross-correlation, Fourier transforms, orientation representations, reference frames, and filters (low-pass, high-pass filters, Kalman). These concepts are applied to estimating biomechanical measures (e.g., body joint angles, torso posture, phases of gait, positions) and selecting metrics to support decision making reliant on human movement. Graduate credit includes additional synergistic research components. **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 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, or Graduate Standing. Minimum grade of “C-” required for enforced prerequisites. (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 of "C-" required for enforced prerequisite. (3 credits)
Theory and applications of financial engineering. Designing, structuring and pricing financial engineering products (including options, futures, 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 of "C-" required for enforced prerequisite. (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 Itoís lemma, Itoís stochastic integrals, the Feynman-Kac theorem and Girsanovís theorem. **CourseProfile (ATLAS)**

IOE 561 (ISD 523). Risk Analysis I
Advisory 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 563. Advanced Work Design: Volunteer Work
Advisory Prerequisite: IOE 463 with a grade of C- or above or graduate standing. (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. **CourseProfile (ATLAS)**

IOE 565 (MFG 561). 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)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

IOE 574. Simulation Design and Analysis
Advisory Prerequisite: IOE 515. (3 credits)
Discrete event simulation for modeling and analysis. Development of simulations using a high-level programming language. Probabilistic and statistical aspects of simulation, including variate and process generation, variance reduction, and output analysis. Connections to stochastic models and queueing. Applications in services, healthcare, and manufacturing. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

IOE 588 (MECHENG 588) (MFG 588). Assembly Modeling for Design and Manufacturing
Prerequisite: MECHENG 381 and MECHENG 401 or equivalent. (3 credits)
Assembly on product and process. Assembly representation. Assembly sequence. Datum flow chain. Geometric Dimensioning & Tolerancing. Tolerance analysis. Tolerance synthesis. Robust design. Fixturing. Joint design and joining methods. Stream of variation. Auto body assembly case studies. **CourseProfile (ATLAS)**

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 industrial and operations engineering. Student(s) register for individual section number of instructor. Report is reviewed and edited. Maximum six credits of IOE 590/593. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

IOE 591. Special Topics
Prerequisite: Permission of instructor. (to be arranged)
Selected topics of current interest in industrial and operations engineering. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **CourseProfile (ATLAS)**

IOE 593. Ergonomics Professional Project
Prerequisite: Graduate Standing, permission of instructor. (2-4 credits)
Team design project applying ergonomic principles to enhance safety, productivity, and/or quality aspects of a human-machine system. Student(s) register for section number of instructor/advisor. Maximum six

credits of IOE 590/593. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (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)**

IOE 610 (Math 660). Linear Programming II
Prerequisite: IOE 510 (MATH 561). (3 credits)
Primal-dual algorithm. Resolution of degeneracy, upper bounding. Variants of simplex method. Geometry of the simplex method, application of adjacent vertex methods in non-linear programs, fractional linear programming. Decomposition principle, generalized linear programs. Linear programming under uncertainty. Ranking algorithms, fixed charge problem. Integer programming. Combinatorial problems. **CourseProfile (ATLAS)**

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)**

IOE 612. Network Flows
Prerequisite: IOE 510 (MATH 561). (3 credits)
Flow problems on networks. Maximum flow minimum cut theorem. Labeling algorithms. Circulation and feasibility theorems. Sensitivity analysis. Incidence matrices. Shortest routes. Minimum cost flows, out-of-kilter algorithm. Critical path networks, project cost curves. Multi-commodity flow problem, biflows. Matching problems in graph theory. **CourseProfile (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 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
Advisory 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 635. Research Methods Laboratory for Human Subjects
Prerequisite: None. Advisory Prerequisite: IOE 534, 533, 536 or other equivalent course with permission of instructor. (3 credits)
Knowledge in research methods is acquired to understand human-machine interaction and performance via
sensorimotor and cognitive concepts. Through laboratory experiments and research critiques students learn: 1)
muscle function, fatigue, vibration response, 2) movement analysis, 3) posture control, 4) controls-displays in
complex systems, 5) wearable technologies, 6) tactile perception, 7) psychophysics. **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. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **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)**

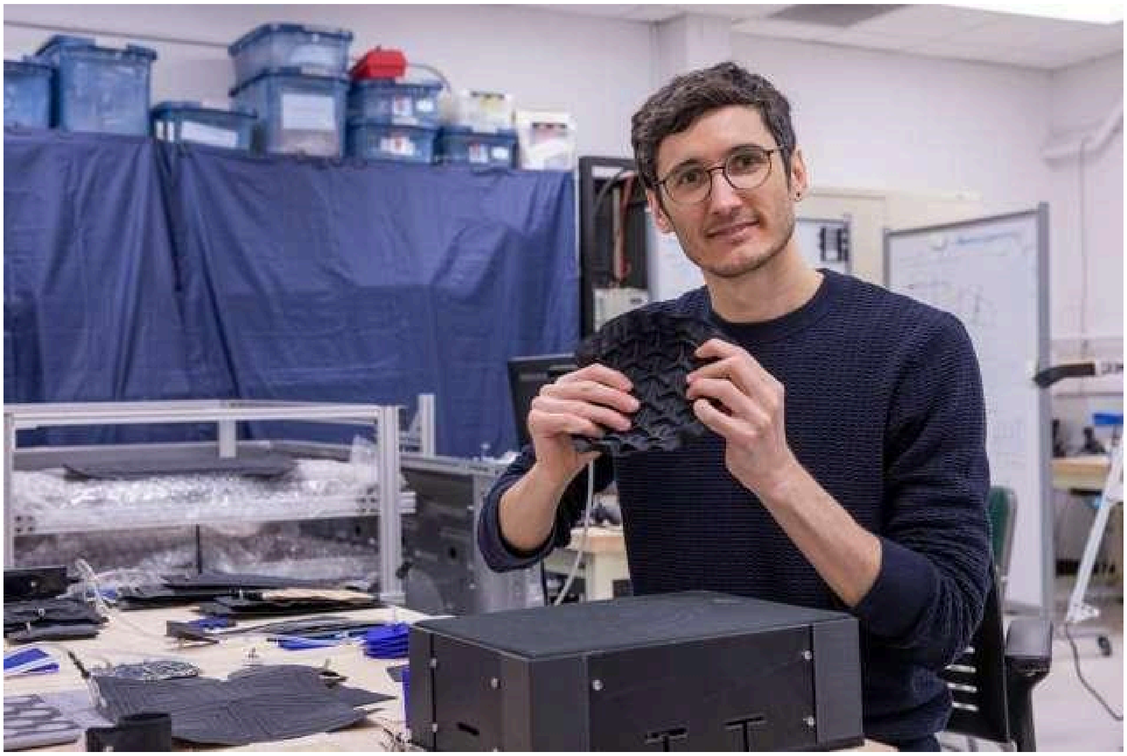
900 Level Courses

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 Engineering

Integrative Systems & Design (ISD)



Engineering is critically important in today's technology-driven society. Globalization, changing demographics, and rapidly evolving technologies are dramatically altering the nature of engineering practice, demanding broader skills than just the mastery of scientific and technological disciplines. These complex challenges call for an integrative approach that goes beyond a deep expertise in a single discipline and that blends engineering with behavioral, business, and social sciences. Integrative Systems + Design (ISD) addresses these challenges by providing versatile, interdisciplinary educational programs for lifelong learning, including graduate degrees and certificates, with an emphasis on systems and design thinking. ISD's programs horizontally integrate disciplinary knowledge across traditional fields of engineering with business and leadership skills.

An important element in each ISD degree program is the capstone project that students complete individually or in teams, locally or through virtual global collaborations. Sponsoring companies offer project topics, and work is conducted under faculty supervision. ISD degree programs are offered on campus and all Master of Engineering (MEng) degrees are also available through online learning, creating a diverse learning community of students on campus and at locations around the world. All students are taught by the same U-M faculty using the same syllabi and offering the same content in hybrid courses. ISD graduates possess deep strengths in their engineering discipline, with the ability to lead and innovate complex systems to address global wicked problems. Please visit the ISD Department website.

Course Guide

Integrative Systems & Design Courses

Contact

Departmental Website:
http://isd.engin.umich.edu/

Departmental Questions:
http://isd.engin.umich.edu/contact-us

Degree Programs
2214 SI-North
1075 Beal Avenue
Ann Arbor, MI 48109-2112
Phone: (734) 647-7179
Fax: (734) 763-2523

Department Contacts

Faculty Director, Integrative Systems + Design Professor Mihaela (Miki) Banu
2214 SI-North 1075 Beal Ave
Ann Arbor, MI 48109-2112

For more specific information on contacting the ISD, please go to our Contacts.

Enrollment and Graduation Data

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

Automotive Engineering

Degree Programs

- Master of Engineering in Automotive Engineering
- Sequential Undergraduate/Graduate Study (SUGS)
  - B.S.E. in Mechanical Engineering, B.S.E. in Materials Science and Engineering, or B.S.E. in Nuclear Engineering & Radiological Sciences
  - M. Eng. in Automotive Engineering

Master of Engineering in Automotive Engineering

The Master of Engineering (M. Eng.) in Automotive Engineering blends engineering fundamentals and practice with an emphasis on systems thinking and the latest advances in technologies. The program provides students with a systems perspective and knowledge that cuts across departments, drawing upon many different engineering disciplines, such as mechanical engineering, chemical engineering, electrical engineering, computer science engineering, materials science, and industrial engineering. Students will deepen their knowledge of traditional mechanical engineering, but they can also take courses in electric machines, electronics, control systems, software development, and business. Graduates of the Automotive Engineering program are prepared to move the automotive industry further into the 21st century and beyond. The M.Eng. in Automotive Engineering degree is available for on-campus or online study.

For more information, please visit the ISD Automotive Engineering website.

Launching Fall 2022, Integrative Systems + Design has introduced a new integrative curriculum designed to better meet today's industry demands and offer improved depth and breadth within specializations – all while leveraging U-M excellence across many disciplines. The curriculum is comprised of 4 segments:

- Integrative Science (6-9 credits): students integrate disciplines together by taking advantage of the breadth of U-M courses, including required ISD courses.
- Program Core (6-9 credits): these courses offer the core knowledge students need to excel in their chosen specialty by choosing courses across key foundational areas, each with its own set of key competencies.
- Career Pathways (9 credits): these courses are designed to help students gain expert knowledge in one specific knowledge area, strategically crafted by leading industry and government experts with an eye to their career trajectory.
- Immersive Practice (3-6 credits): students put their experience and education to work in a real-world environment by taking part in a culminating project in industry, research in cutting-edge labs, fieldwork with meaningful non-profits, and a wide range of entrepreneurial ventures.

Sequential Undergraduate / Graduate Study

- B.S.E. in Mechanical Engineering, B.S.E. Materials Science and Engineering, or B.S.E. Nuclear Engineering & Radiological Sciences
- M. Eng. in Automotive Engineering

This Sequential Undergraduate/Graduate Study (SUGS) program leads to a Master of Engineering in Automotive Engineering. University of Michigan students who are pursuing a B.S.E. in Mechanical Engineering or Nuclear Engineering & Radiological Sciences and who meet all the SUGS requirements may apply to the Automotive Engineering program to pursue the SUGS program, which allows them to complete their B.S.E. and M. Eng. in five years total.

For more detailed information about the program, please visit the ISD SUGS webpage.

Online Learning

The Master of Engineering degree in Automotive Engineering is offered either on-campus or online, with students from around the world taking part in the same high-quality experience whether in the classroom or online. The majority of courses offered in ISD programs are hybrid, combining on-campus and online students in the same course, with the same instructors, syllabi, and rigor, which provides an engaging blended learning environment. Earning this degree online is a valuable option for engineers who are currently working full-time.

Design Science

Degree Programs

- Master of Science in Design Science
- Doctoral Program in Design Science

The emerging field of Design Science demands an innovative paradigm for research, education, and practice. The Design Science Program at the University of Michigan engages in the systematic pursuit of design knowledge across all fields.

Our program is a unique interdisciplinary approach requiring students to integrate two or more traditional disciplines to tackle modern, complex design problems. The U-M Design Science Program challenges students to create, study, apply, and teach design principles using quantitative, qualitative, and analytical methods and processes.

Students choose from courses in engineering, business, medicine, information, social sciences, and the arts: the program leverages a multitude of top-ten departments across schools and colleges at the University of Michigan.

Master of Science in Design Science

The Master of Science in Design Science is the program for students who want to expand their career paths by meeting the growing need for the interdisciplinary design of complex products, devices, and systems. The program provides each student flexibility in exploring multiple disciplines to learn in-depth rigorous design methods and theories that drive the design process. Each student defines a custom program of study tailored to their background and design interests in consultation with a program advisor. This path integrates disciplines from top programs at the University of Michigan to balance rigorous coursework, trend-setting research and practica.

Doctoral Program in Design Science

The Design Science Ph.D. program leverages our novel integrative culture to produce unique leaders in design research, practice, and teaching.

Design Science is an interdisciplinary doctoral program. Design Science students must pursue an appropriate course of study with the right mix of disciplinary depth and interdisciplinary breadth. Each student defines a custom program of study tailored to their background and interests in consultation with faculty advisors and the program committee.

An individual student's curriculum is structured so that knowledge from at least two disciplines permeates their program of study. This is the guiding principle for the DESCI program requirements. This path integrates disciplines from top programs at the University of Michigan to balance rigorous coursework, trend-setting research and practicum.

For more information about both degree programs, please visit the ISD Design Science website.

Energy Systems Engineering

Degree Programs

- Master of Engineering in Energy Systems Engineering
- Sequential Undergraduate/Graduate Study (SUGS)
    - B.S.E. in Chemical Engineering, Mechanical Engineering, Materials Science and Engineering, or Nuclear Engineering & Radiological Sciences
    - M. Eng. in Energy Systems Engineering

Master of Engineering in Energy Systems Engineering

The Master of Engineering (M. Eng.) in Energy Systems Engineering (ESE) degree program is designed for students who are ready to accept the grand challenge of energy in all its diverse forms and applications. It provides critical engineering skills in interlocking energy disciplines. ESE is a multidisciplinary specialization that includes science, engineering, and the development of policies that promote sustainable systems. Students select from a wide array of courses to create an individual plan of study. The program also covers basic management issues and enables students to develop their ability to lead project teams. ESE graduates possess strengths in their engineering discipline, breadth in relevant engineering and science, and an understanding of the critical role of the environment in energy systems, including economic factors. The degree is available for on-campus and online study.

For more information, please visit the ISD ESE website.

Sequential Undergraduate/Graduate Study

- B.S.E. Chemical Engineering, B.S.E. Mechanical Engineering, or B.S.E. Nuclear Engineering & Radiological Sciences
- M. Eng. in Energy Systems Engineering

This Sequential Undergraduate/Graduate Study (SUGS) program leads to a Master of Engineering in Energy Systems Engineering. University of Michigan students who are pursuing a B.S.E. in Chemical Engineering, Mechanical Engineering, or Nuclear Engineering & Radiological Sciences and who meet all the SUGS requirements may apply to the Energy Systems Engineering program to pursue the SUGS program, which allows them to complete their B.S.E. and M. Eng. in five years total.

For more information, please visit the ISD SUGS webpage.

Online Learning

The Master of Engineering degree in Energy Systems Engineering is offered either on-campus or online, with students from around the world taking part in the same high-quality experience whether in the classroom or online. The majority of courses offered in ISD programs are hybrid, combining on-campus and online students in the same course, with the same instructors, syllabi, and rigor, which provides an engaging blended learning environment. Earning this degree online is a valuable option for engineers who are currently working full-time.

Global Automotive and Manufacturing Engineering

Degree Programs

- Master of Engineering in Global Automotive and Manufacturing Engineering
- Sequential Undergraduate/Graduate Study (SUGS)
  - B.S.E. in Mechanical Engineering, Materials Science & Engineering, or Nuclear Engineering & Radiological Sciences
  - M. Eng. in Global Automotive and Manufacturing Engineering

Master of Engineering in Global Automotive and Manufacturing Engineering

The Master of Engineering in Global Automotive and Manufacturing Engineering program (GAME) is a one-of-a-kind engineering master's program that blends product development and manufacturing into a curriculum to address the integration challenges arising from the globalization of the automotive industry. The aim of the program is to develop technical leaders who have a holistic understanding of product creation and manufacturing, breadth across relevant engineering disciplines, and business skills in cross-cultural management and leadership. In collaboration with a faculty advisor, students will develop a custom plan of study. GAME graduates possess a comprehensive knowledge of the product development and manufacturing of vehicles; a technical proficiency in automotive systems, systems integration, or manufacturing; an ability to apply sound business concepts to engineering applications; and competence in building and leading diverse teams in terms of culture, business environment, and disciplinary perspectives. The GAME degree is available for on-campus and online study.

For more information, please visit the ISD GAME website.

The integrative Global Automotive and Manufacturing Engineering curriculum is designed to better meet today's industry demands and offer improved depth and breadth within specializations – all while leveraging U-M excellence across many disciplines. The curriculum is comprised of 4 segments:

- Integrative Science (6-9 credits): students integrate disciplines together by taking advantage of the breadth of U-M courses, including required ISD courses.
- Program Core (6-9 credits): these courses offer the core knowledge students need to excel in their chosen specialty by choosing courses across key foundational areas, each with their own set of key competencies.
- Career Pathways (9 credits): these courses are designed to help students gain expert knowledge in one specific knowledge area, strategically crafted by leading industry and government experts with an eye to their career trajectory.
- Immersive Practice (3-6 credits): students put their experience and education to work in a real-world environment by taking part in a culminating project in industry,

research in cutting-edge labs, fieldwork with meaningful non-profits, and a wide range of entrepreneurial ventures.

Sequential Undergraduate / Graduate Study

- B.S.E. Mechanical Engineering, B.S.E. Materials Science & Engineering, B.S.E. Nuclear Engineering & Radiological Sciences
- M. Eng. in Global Automotive and Manufacturing Engineering

This Sequential Undergraduate/Graduate Study (SUGS) program leads to a Master of Engineering in Global Automotive and Manufacturing Engineering. University of Michigan students who are pursuing a B.S.E. in Mechanical Engineering, a B.S.E in Materials Science & Engineering, or a B.S.E. in Nuclear Engineering & Radiological Sciences and who meet all the SUGS requirements may apply to the Global Automotive and Manufacturing Engineering program to pursue the SUGS program, which allows them to complete their B.S.E. and M. Eng. in five years total.

For more detailed information about the program, please visit the SUGS webpage.

One option for applicants planning to pursue the program full-time is to apply to the Tauber Institute for Global Operations. The Tauber Institute assists students in finding projects in industry.

Online Learning

The Master of Engineering degree in Global Automotive and Manufacturing Engineering is offered either on-campus or online, with students from around the world taking part in the same high-quality experience whether in the classroom or online. The majority of courses offered in ISD programs are hybrid, combining on-campus and online students in the same course, with the same instructors, syllabi, and rigor, which provides an engaging blended learning environment. Earning this degree online is a valuable option for engineers who are currently working full-time.

Program in Manufacturing

Degree Programs

- Master of Engineering in Manufacturing
- Dual Degree: Master of Engineering in Manufacturing / MBA
- Doctor of Engineering in Manufacturing
- Sequential Undergraduate/Graduate Study (SUGS)
  - B.S.E. in Aerospace Engineering, Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Industrial & Operations Engineering, Materials Science & Engineering, Mechanical Engineering, Naval Architecture and Marine Engineering, or Nuclear Engineering & Radiological Sciences
  - Master of Engineering in Manufacturing

Master of Engineering in Manufacturing

Manufacturing is a bedrock of a strong economy, supporting a solid employment base in the manufacturing industry as well as in multiple related service industries. Now, more than ever, there is a critical need for leaders and engineers who are innovators in technology and have the broad knowledge and skills regarding how to streamline manufacturing processes and make managerial decisions.

Students in the Master of Engineering (M.Eng.) in Manufacturing program acquire the advanced engineering and management skills to become a dynamic leader in manufacturing. Students learn how to improve the quality and efficiency of manufacturing systems through advanced technologies and skills in their engineering discipline, acquiring knowledge across disciplines, leading project teams, and understanding the complete product development and manufacturing process, including its management. The Manufacturing degree is available for on-campus and online study.

For more information, please visit the Manufacturing site.

Sequential Undergraduate / Graduate Study

- B.S.E. in Aerospace Engineering, Chemical Engineering, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Computer Science, Industrial & Operations Engineering, Materials Science & Engineering, Mechanical Engineering, Naval Architecture and Marine Engineering, or Nuclear Engineering & Radiological Sciences
- Master of Engineering in Manufacturing

This Sequential Undergraduate/Graduate Study (SUGS) program leads to a Master of Engineering in Manufacturing. University of Michigan students who are pursuing a B.S.E. in an eligible department and who meet all the SUGS requirements may apply to the Manufacturing program to pursue the SUGS program, which allows them to complete their B.S.E. and M. Eng. in Mfg. in five years total.

For more detailed information about the program, please visit the SUGS webpage.

Online Learning

The Master of Engineering degree in Manufacturing program is offered either on-campus or online, with students from around the world taking part in the same high-quality experience whether in the classroom or online. The majority of courses offered in ISD programs are hybrid, combining on-campus and online students in the same course, with the same instructors, syllabi, and rigor, which provides an engaging blended learning environment. Earning this degree online is a valuable option for engineers who are currently working full-time.

Dual Master of Engineering in Manufacturing/M.B.A.

In this dual degree program, qualified students can pursue concurrent work in manufacturing engineering and business administration which leads to both a Master of Engineering in Manufacturing from the College of Engineering and a Master of Business

Administration (MBA) from the Ross School of Business. The program is arranged so that all requirements are satisfied simultaneously. The dual degree can be earned in two and one-half years by full-time students. It is also offered part-time through the Ross School of Business Evening Program.

Please visit the Manufacturing Program – Dual M. Eng. in Mfg. and MBA site for more information.

Doctor of Engineering in Manufacturing

The Doctor of Engineering in Manufacturing is a graduate professional degree in engineering for students who already have earned a bachelor's degree in engineering and a master's degree in any field of engineering or MBA. If the student does not have a Master's degree, the student may apply to the Doctor of Engineering in Manufacturing program directly and complete the Master of Engineering in Manufacturing along the way. Students work with a faculty advisor to develop a custom plan of study that blends engineering disciplines with management and business. Graduates of this doctoral program possess a depth of knowledge in manufacturing systems and the skills to carry out high-quality engineering research and development.

To learn more, please visit the Doctoral Program in Manufacturing site.

Systems Engineering + Design

Degree Programs

- Master of Engineering in Systems Engineering + Design
- Sequential Undergraduate/Graduate Study (SUGS)
  - B.S.E. in Mechanical Engineering, Materials Science & Engineering, or Nuclear Engineering & Radiological Sciences
  - M. Eng. in Systems Engineering + Design

Master of Engineering in Systems Engineering + Design

Systems engineering is the modern design process in government and industry that integrates the work of diverse specialists into complex products and processes. Systems engineering touches everything: from telescopes that orbit tens of thousands of miles above earth to the cars that we drive every day. Systems engineers and their work have a major impact on the modern world. In times of great change and major advancements in the way we work, think and travel, systems engineering has never been more important or more challenging.

The Master of Engineering (M.Eng.) in Systems Engineering + Design (SE+D) program was built upon the resources of the top-ranked University of Michigan's College of Engineering and was developed in collaboration with an interdisciplinary team of distinguished practitioners, faculty, and industry leaders. Adapting to rapid change has never been more vital, and this degree program accelerates the learning curve for engineers in design and systems fields.

Once students graduate from the program, they will be prepared for the exam leading to certification as an Associate Systems Engineering Professional.

This degree enhances careers in requirements management, systems integration, systems architecting, systems engineering management, technical project management, risk management, and related specialties. Skills and knowledge learned can be applied in fields such as aerospace, biomedical, defense, ground transportation, healthcare, infrastructure, software development, and more. Graduates of the program have gone on to careers leading multidisciplinary engineering teams at major global organizations. The SED degree is available for on-campus and online study.

For more information, please visit the ISD SE+D website.

The Integrative Systems Engineering + Design curriculum is designed to better meet today's industry demands and offer improved depth and breadth within specializations – all while leveraging U-M excellence across many disciplines. The curriculum is comprised of 4 segments:

- Integrative Science (6-9 credits): students integrate disciplines together by taking advantage of the breadth of U-M courses, including required ISD courses.
- Program Core (6-9 credits): these courses offer the core knowledge students need to excel in their chosen specialty by choosing courses across key foundational areas, each with its own set of key competencies.
- Career Pathways (9 credits): these courses are designed to help students gain expert knowledge in one specific knowledge area, strategically crafted by leading industry and government experts with an eye to their career trajectory.
- Immersive Practice (3-6 credits): students put their experience and education to work in a real-world environment by taking part in a culminating project in industry, research in cutting-edge labs, fieldwork with meaningful non-profits, and a wide range of entrepreneurial ventures.

Sequential Undergraduate / Graduate Study

- B.S.E. Mechanical Engineering, B.S.E. Materials Science & Engineering, and B.S.E. in Nuclear Engineering & Radiological Sciences
- M. Eng. in Systems Engineering + Design

This Sequential Undergraduate/Graduate Study (SUGS) program leads to a Master of Engineering in Systems Engineering + Design. University of Michigan students who are pursuing a B.S.E. in Mechanical Engineering, a B.S.E. in Materials Science & Engineering, or a B.S.E. in Nuclear Engineering & Radiological Sciences and who meet all the SUGS requirements may apply to the Systems Engineering + Design program to pursue the SUGS program, which allows them to complete their B.S.E. and M. Eng. in five years total.

For more detailed information about the program, please visit the SUGS webpage.

Online Learning

The Master of Engineering degree in Systems Engineering and Design program is offered either on-campus or online, with students from around the world taking part in the same high-quality experience whether in the classroom or online. The majority of courses offered in ISD programs are hybrid, combining on-campus and online students in the same course, with the same instructors, syllabi, and rigor, which provides an engaging blended learning environment. Earning this degree online is a valuable option for engineers who are currently working full-time.

Integrative Systems + Design Courses (AUTO, DESCI, ESENG, ISD, MFG)

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/***

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
Advisory Prerequisite: Basic knowledge of finite element analysis. (3 credits)
General procedures and state-of-the-art tools to evaluate vehicle crash safety. Application of fundamental principles to interpret injury mechanisms, safety concerns, and design benefits in different types of crashes. Assessment of 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 541 (ISD 541). Fundamentals of Vehicle Dynamics
Prerequisite: None. (3 credits)
Provides an overview of all major aspects of Vehicle Dynamics from longitudinal accelerations/moments to combined longitudinal, lateral and vertical accelerations/moments. Students will use state of the art simulation software to experiment with driver inputs and vehicle parameters to achieve the lowest time and lowest accelerations that relate to occupant comfort for a driving course. **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
Advisory 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
Advisory 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
Advisory 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
Advisory 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
Advisory 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
Advisory 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

ESENG 501. Seminars on Energy Systems, Technology and Policy
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
Advisory 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: 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
Advisory Prerequisite: Basic knowledge of finite element analysis. (3 credits)
General procedures and state-of-the-art tools to evaluate vehicle crash safety. Application of fundamental principles to interpret injury mechanisms, safety concerns, and design benefits in different types of crashes. Assessment of safety systems using finite element crash simulations. **CourseProfile (ATLAS)**

ISD 520. Introduction to Systems Engineering
Prerequisite: Graduate student. Advisory Prerequisite: 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
Advisory 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
Advisory Prerequisite: ISD 520, ISD 521, DESCI 501, DESCI 502. (3 credits)
Lean systems engineering from systems architecting through systems embodiment. Students 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
Advisory Prerequisite: Basic statistical distribution & models, product development proc & des experiment (3 credits).
Methods and analysis tools for preventing quality and warranty concerns. Applying the Design for Six Sigma Quality methodology to identify/define, design new systems, optimize, and validate. Using the IDDOV framework to examine 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
Advisory 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
Advisory 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 541 (AUTO 541). Fundamentals of Vehicle Dynamics
Prerequisite: None. (3 credits)
Provides an overview of all major aspects of Vehicle Dynamics from longitudinal accelerations/moments to combined longitudinal, lateral and vertical accelerations/moments. Students will use state of the art simulation software to experiment with driver inputs and vehicle parameters to achieve the lowest time and lowest accelerations that relate to occupant comfort for a driving course. **CourseProfile (ATLAS)**

ISD 546 (MECHENG 545, CEE 577). Dynamics and Control of Connected Vehicles
Prerequisite: None. Advised Prerequisite: MECHENG 360. (3 credits)
Ordinary differential equations and delay differential equations are used for modeling connected vehicle systems, which consist of human-driven vehicles and automated vehicles. Controllers are designed to improve stability, safety, energy efficiency, and traffic flow. Students will use experimental data to design controllers and evaluate those via numerical simulations. **CourseProfile (ATLAS)**

ISD 555 (MFG 555, MECHENG 555). Design Optimization
Advisory 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
Advisory 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
Advisory 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 585 (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)**

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)
Evolution of quality method. Fundamentals of statistics. Process Behavior over time. Concept of statistical process control (SPC). Design and interpretation of control charts. Process capability study. Tolerance. Measurement system analysis. Correlation. Independent t-test and paired t-test. Design and analysis of two-level factorial experiments. Fractional factorial experiments. Response model building. Taguchi Methods. Case studies. **CourseProfile (ATLAS)**

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)
Fundamentals in developing efficient layouts for single-story and multi-story production and service facilities. Manual procedures and microcomputer-based layout algorithms. Algorithms to determine the

optimum location of facilities. Special considerations for multi-period, dynamic layout problems. **CourseProfile (ATLAS)**

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 462 (NAVARCH 461). Marine Structures Construction
Prerequisite: None. Advisory Prerequisite: 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. **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)
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, Precontrol, Adaptive Schemes, Process Capability, Specifications and Tolerances, Gage Capability Studies, Acceptance Sampling by Attributes and Variables, International Quality Standards. **CourseProfile (ATLAS)**

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)
Design concepts. Engineering economics. Problems of scaling. Materials substitution. Competitive processes. Case histories. Professional and ethical considerations. Written and oral presentations of solutions to design problems. **CourseProfile (ATLAS)**

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)
Introduction to machining operations. Cutting tools and tool wear mechanisms. Cutting forces and mechanics of machining. Machining process simulation. Surface generation. Temperatures of the tool and workplace. Machining dynamics. Non-traditional machining. **CourseProfile (ATLAS)**

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). 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)**

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
Advisory Prerequisite: Basic statistical distribution & models, product development proc & des experiment. (3 credits)
Methods and analysis tools for preventing quality and warranty concerns. Applying the Design for Six Sigma Quality methodology to identify/define, design new systems, optimize, and validate. Using the

IDDOV framework to examine 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). Project Planning Scheduling and Control
Prerequisite: Senior or Graduate Standing. (3 credits)
Project planning and scheduling with arrow and precedence networks using the Critical Path Method (CPM). Advanced scheduling using overlapping networks. Project control, C/SCSC and earned-value systems. Scheduling under uncertainty, PERT, PNET, and Monte-Carlo simulation. Time-cost tradeoff, resource allocation, and resource leveling. Scheduling using the Repetitive Scheduling Method (RSM). **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
Advisory 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 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)
Basic concepts. Type synthesis – creative design of mechanisms; graph theory. Precision-point Burmester theory for dimensional synthesis of linkages. Applications. Cam and follower system synthesis. Joint force analysis and dynamic analysis formulations. Analytical synthesis of programmable and compliant mechanisms. Use of software for synthesis and analysis. Design projects. **CourseProfile (ATLAS)**

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)**

MFG 563 (NAVARCH 562). Marine Systems Production Business Strategy and Operations Management
Prerequisite: 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. **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. (credit(s) 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)
Brief review of probability and statistics. Mathematical methods of reliability analysis for systems with or without repairs. Reliability, availability, maintenance, replacement, and repair decisions. Safety and risk analysis. Risk assessment methods and case studies. FMEA, fault tree and event tree analysis. Marine, Automotive, Manufacturing, Health Care and other applications. **CourseProfile (ATLAS)**

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) (ISD 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)
Globalization and manufacturing paradigms. Product-process-business integration. Product invention strategy. Customized, personalized and reconfigurable products. Mass production and lean production. Mathematical analysis of mass customization. Traditional manufacturing systems. Reconfigurable manufacturing systems. Reconfigurable machines. System configuration analysis. Responsive business models. Enterprise globalization strategies. The global integrated enterprise. **CourseProfile (ATLAS)**

MFG 588 (MECHENG 588) (IOE 588). Assembly Modeling for Design and Manufacturing
Prerequisite: MECHENG 381 and 401 or equivalent. (3 credits)
Assembly as product and process. Assembly representation. Assembly sequence. Datum flow chain. Geometric Dimensioning and Tolerancing. Tolerance analysis. Tolerance synthesis. Robust design. Fixturing. Joint design and joining methods. Stream of variation. Auto body assembly case studies. **CourseProfile (ATLAS)**

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)
Application of lasers in materials processing and manufacturing. Laser principles and optics. Fundamental concepts of laser/material interaction. Laser welding, cutting, surface modification, forming, and rapid prototyping. Modeling of processes, microstructure and mechanical properties of processed materials. Transport phenomena. Process monitoring. **CourseProfile (ATLAS)**

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

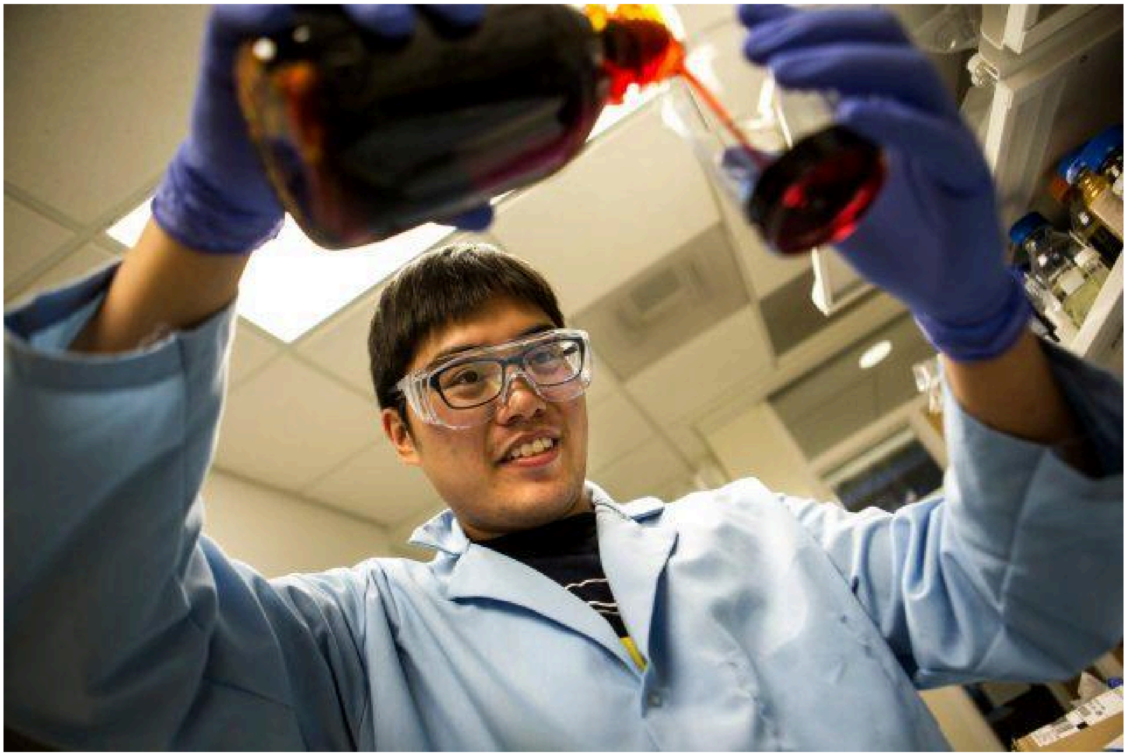
MFG 990. Dissertation/Pre-Candidate
Prerequisite: Permission of thesis committee; mandatory satisfactory/unsatisfactory. (2-8 credits); (1-4 credits)

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 (MACROMOL)



Macromolecular Science and Engineering is an interdisciplinary program that provides the academic and research basis for studies in the science and technology of synthetic and natural macromolecules. Such large molecules exhibit unusual and specific properties as compared to small molecules and a large field has developed in unraveling the scientific foundations of this behavior, both in the synthetic and the biological areas.

The program at U-M is one of the very few where students can achieve competence in both the traditional discipline of their choice and the interdisciplinary field of Macromolecular Science and Engineering. It is a unique graduate program structure that allows a tailor fitting by the students to their individual interests while permitting the faculty to train the students in the program to a high level of competence. A Ph.D. and Master's degrees are offered in Macromolecular Science and Engineering with concentrations in the areas of Biomaterials Engineering, Biomedical Engineering, Chemistry, Chemical Engineering, Materials Science and Engineering, Organic Electronics or Physics. Other areas of interest include Electrical Engineering and Computer Science and Mechanical Engineering.

The faculty members are drawn from the College of Engineering, College of Literature, Science, and the Arts, the Dental School, and the Medical School. The Macromolecular Science and Engineering program is an interdisciplinary endeavor, permitting students to acquire a broad understanding of macromolecular science. The faculty believes the approach taken permits the students to eventually make a more significant contribution to macromolecular science. It also allows the students to develop the self-confidence needed to adapt to the changes inherent in modern research and development.

Counseling on both the general and specific requirements is provided by a faculty advisor representing the Executive Committee of the Macromolecular Science and Engineering Program. The advisor is designated through a selection process during the student's first term. The student then chooses among several major options: Biomaterials Engineering, Biomedical Engineering, Chemistry (organic or physical), Chemical Engineering, Materials Science and Engineering, Organic Electronics or Physics. An individualized option is also available for students who have previously earned a Master's degree.

The progress to a Ph.D. is normally four- to five-years with coursework being emphasized during the first two years. Students are approved for candidacy after they have completed 18 credits of coursework which includes three specific Macromolecular courses, passing the comprehensive exam, and the Responsible Conduct of Research and Scholarship Workshops. Additionally, students are required to form a dissertation committee and pass a dissertation proposal oral preliminary examination.

There are also some general Ph.D. degree requirements set by the Rackham Graduate School.

Course Guide

Macromolecular Science and Engineering Courses

Contact

Department Website:
macro.engin.umich.edu

2800 Plymouth Road
3003E, Building 28, NCRC
Ann Arbor, MI 48109
Phone: 734-763-2316

Program Administration

Program Director
Jinsang Kim
Professor of Macromolecular Science & Engineering, Materials Science & Engineering, Chemical Engineering, Biomedical Engineering, and Chemistry

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Carolina Benn
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734-763-2316

Sequential Undergraduate Study (SUGS)

The Macromolecular Program offers SUGS degrees in collaboration with several participating departments (BiomedE, ChemE, Chemistry, MSE, ME and Physics). These degrees make it possible for students to receive both a B.S. and M.S. degree in an accelerated fashion.

Research

An early start in research is encouraged as soon as the students have demonstrated satisfactory progress in courses and have selected a research supervisor. The interdisciplinary nature of the Program allows for a wide range of research possibilities.

Representative Ph.D. Course Programs

It is recommended that in all the options an introductory course such as MACROMOL 412 be taken as part of these credits by all students who do not have a strong polymer background. The majority of the option courses taken should be 500- level or above. See "Course Descriptions" for individual course information. The following course plans are suggestions from Macromolecular faculty for good academic training.

Biomaterials Engineering Option

A minimum of 30 hours of coursework from Biomaterials Engineering and Macromolecular Science Courses. This must include a minimum of 12 hours from Biomaterials and 12 hours from MACROMOL. These courses must include a graduate course in biomaterials, biochemistry and biophysics.

Biomedical Engineering Option

A minimum of 30 hours of coursework from Biomedical Engineering and Macromolecular Science Courses. This must include a minimum of 12 hours from Biomedical Engineering and 12 hours from MACROMOL. These courses must include a graduate course in biomaterials, biochemistry and/or biophysics and biomedical engineering.

Chemical Engineering Option

A minimum of 30 hours of coursework from Chemical Engineering and Macromolecular Science courses. This must include a minimum of 12 hours from ChE and 12 hours from Macromolecular Science. These courses must include: MACROMOL 790, MACROMOL 800, MACROMOL 535 or MSE 412 or 512, MACROMOL 536, ChE 528, graduate courses in transport phenomena, numerical methods or mathematical modeling and polymer processing.

Chemistry Option (Synthetic or Physical)

A minimum of 30 hours of coursework from Chemistry and Macromolecular Science Courses. This must include a minimum of 12 hours from Chemistry and 12 hours from MACROMOL.

For a Synthetic option, these courses must include: MACROMOL 790, MACROMOL 800, MACROMOL 536, MACROMOL 538, two courses from CHEM 507, 540, 541 or 543, and one from CHEM 511, 542 or 616.

For a Physical option, these courses must include: MACROMOL 790, MACROMOL 800, MACROMOL 536, CHEM 571, CHEM 576, CHEM 580 and another approved Chemistry course.

Materials Science and Engineering Option

A minimum of 30 hours of coursework from Materials Science and Engineering and Macromolecular Science courses. This must include a minimum of 12 hours from MSE and 12 hours from MACROMOL.

These courses must include: MACROMOL 790, MACROMOL 800, MACROMOL 535 or MSE 412 or 512, MACROMOL 536, a graduate course in metals and a graduate course in ceramics.

Organic Electronics and Photonics Option

A minimum of 30 hours of coursework must be selected, including at least 9 hours in Macromolecular Science and Engineering and at least 9 hours in the field of organic electronics. Macromolecular courses should include MACROMOL 412, 512, and 538.

Organic Electronic courses should include a course in device physics, device applications, and device fabrication.

Physics Option

A minimum of 30 hours of coursework from Physics and Macromolecular Science courses. This must include a minimum of 12 hours from Physics and 12 hours from MACROMOL.

These courses must include: MACROMOL 790, MACROMOL 800, MACROMOL 536, graduate Physics or Applied Physics courses, and an advanced course in physical properties of polymers.

Individualized Options

An individualized option may be proposed by students. Such students must submit a detailed program in writing to the Executive Committee for approval.

Enrollment and Graduation Data

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program.

Macromolecular Science and Engineering Courses (MACROMOL)

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/***

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 506 (CHE 506) (MATSCIE 506). Soft Robotic Matter
Advisory Prerequisite: None. Enforced Prerequisite: Senior Standing or Graduate Standing. *(3 credits)*
Soft robotic matter consists of active materials that can sense, move within, and alter their working environment. Fundamentals and emerging approaches will be explored in soft active matter design, actuation, power, and fabrication across length scales, with focus on engineering their properties and structures for programmable robotic functions.

MACROMOL 509 (BIOMEDE 509) (CHE 509) (MATSCIE 509). Advanced Biomaterials
Advisory Prerequisite: MATSCIE 220 or MATSCIE 250. Enforced Prerequisite: None. (3 credits)
Applications of biomaterials in implants, regenerative medicine, tissue engineering, and drug delivery systems will be covered. Principles of biomaterials incorporating contemporary research related to rational design strategies for biomaterials, their processing and fabrication, biomimetics, immunomodulation, degradation, and in vivo responses will be included.

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, thermo-viscoelasticity, 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 (MSE)

Materials Science and Engineering is widely recognized as one of the most promising technical fields of the 21st century.

Materials scientists and engineers specialize in the characterization, development, processing, and use of metallic, ceramic, polymeric, and electronic materials that are employed in all fields of technology. To meet the needs of our modern technological society, they are developing important new materials. These include ultra-high-purity semiconductors for solid-state electronic devices; high-strength alloys for use at the extreme temperatures encountered in jet and rocket engines; strong, light alloys and composites for aerospace applications; specialized glasses and ceramics with high thermal, mechanical and chemical stability; and a host of polymeric materials: some with unique functional characteristics and others which replace metal, glass, wood and natural fibers in dozens of applications.

The future role of materials scientists and engineers promises to be even more important in addressing the current societal challenges such as energy shortage, clean energy, environment and sustainability, health care, transportation, national infrastructure and defense. Materials scientists and engineers are rising to this challenge through innovative approaches involving computational and data-driven design, development of novel materials, advanced characterization, and novel processing. They are also actively engaged in reducing the impact of modern society on our environment. They are at the forefront of recycling technologies and more energy-efficient ways of processing materials.

A tremendous range of career opportunities exist for Materials Science and Engineering graduates who are employed in research, development, and manufacturing. They support the creation of new materials and processes or the improvement of old ones with the aim of tailoring properties to applications. Often the work involves cooperating with mechanical, chemical, aeronautical, automotive, and other types of engineers in selecting appropriate materials in the design of various devices, evaluating the performance of materials in service, and determining the causes and cures for in-service failures. We also prepare our graduates for all kinds of supervisory, research, teaching, and management activities.

The undergraduate major and minor programs in Materials Science and Engineering at the University of Michigan have been carefully designed to prepare students for all the activities described above, as well as for supervisory, research, teaching, and management responsibilities. Thanks to its flexibility, students have an opportunity to tailor their program of study to their own interests or continue their academic work to acquire a master's or doctoral degree.

Course Guide

Materials Science and Engineering Courses

Contact

Departmental Website:
http://www.mse.engin.umich.edu/

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For more specific information on contacting people, go to our Contacts page.

Mission

Our mission is to lead the way in the field of materials science & engineering through education, research, and service on a global scale. We aim to educate a diverse workforce with the skills necessary to solve complex engineering challenges, drive innovative materials research, and make meaningful ethical contributions as leaders in science, technology, the environment, and society.

Goals

1. To provide excellent, diverse students with knowledge and engineering skills in a quality learning environment that will enable them to become flexible, effective lifelong learners and leaders in materials-related industries, government agencies, and academia.
2. To have a leading undergraduate program in materials science and engineering, one that integrates a strong scientific base with engineering experience.

Objectives

Within 3-5 years after graduating our students will be able to:

1. Use their understanding of the structure, properties, performance, and processing of materials to solve complex engineering problems
2. Adapt to the rapidly changing scientific and technological landscape, recognize the implications of their work, and drive the development of future technologies.
3. Communicate effectively with their colleagues and the general public.
4. Contribute substantively and ethically, as leaders, to science, technology, the environment, and society.

Outcomes

All Materials Science and Engineering graduates should have:

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.

Enrollment and Graduation Data

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally you can see recent degrees granted below:

Level	2021	2022	2023
Bachelors Degrees	53	42	44
Masters Degrees	47	19	31
Doctoral Degrees	19	13	18

Accreditation

The Materials Science and Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Materials (1), Metallurgical (2), Ceramics (3) and Similarly Named Engineering Programs.

Program Outcomes

The matrix maps how each course in our curriculum addresses our program outcomes. Only the outcomes tracked are noted below.

Course	Student Outcomes (Black – High)						
	Apply math and science	Design	Communicate	Ethics	Teams	Experiments, Analyze, and Interpret Data	Lifelong Learning
MSE220							

MSE242							
MSE250							
MSE330							
MSE335							
MSE350							
MSE360							
MSE365							
MSE400							
MSE410							
MSE412							

MSE420							
MSE440							
MSE454							
MSE465							
MSE470							
MSE481							
MSE482							
MSE514							

Undergraduate Degree Program

Sample Schedule

B.S.E. in Materials Science and Engineering

The Materials Science and Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Materials (1), Metallurgical (2), Ceramics (3) and Similarly Named

Engineering Programs.

Please see the PDF version of the sample schedule. Additional information can be found on the Materials Science and Engineering Department Advising website.

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 & Engineering is offering science and engineering undergraduate students whose major is outside of Materials Science & 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) (F)
- Two MSE courses from the following "Electives" list (3 credits each, and the prerequisites for each include MATSCIE 220/250 and in many cases, MATSCIE 350):
  - MATSCIE 400 "Electronic, Magnetic and Optical Materials for Modern Device Technology" (Prerequisite: MATSCIE 242) (F)
  - MATSCIE 410 "Design and Applications of Biomaterials" (F)
  - MATSCIE 412 "Polymeric Materials" (Prerequisite: CHEM 210) (F)
  - MATSCIE 440 "Ceramic Materials" (W)
  - MATSCIE 454 "Computational Approaches in MSE" (Prerequisite: MATSCIE 330, 335, and 365) (F)
  - MATSCIE 465 "Structural and Chemical Characterization of Materials" (Prerequisites: MATSCIE 242 and MATSCIE 360) (W)
  - MATSCIE 470 "Physical Metallurgy" (F)
  - MATSCIE 514 "Composite Materials" (W)
- One more MATSCIE course, other than lab, research or special studies (3 or 4 credits)

F – Course offered Fall Term
W – Course offered Winter Term

Sequential Undergraduate/Graduate Study (SUGS)

Students should apply to the program in the first term of their senior year in order to be advised appropriately regarding planning for undergraduate and graduate course selections. No dual enrollment will be required. Other requirements include a minimum undergraduate grade point average of 3.2 for admission and subsequent enrollment into the SUGS program in Materials Science and Engineering. A maximum of 9 credits of prior-approved coursework may be double counted. Only technical electives and/or general electives may be double-counted. None of the 47 required Materials Science and Engineering credits may be used for the graduate degree. A maximum of 15 credit hours that are double counted or transferred for graduate credit are allowed. Contact the prospective department for more complete program information.

Graduate Degrees

- Master of Science in Engineering (M.S.E.) in Materials Science and Engineering
- Doctor of Philosophy (Ph.D.) in Materials Science and Engineering

Master of Science Programs

Two different types of M.S.E. degrees are offered: one with a primary focus on coursework (the Coursework M.S.E.) and one with an emphasis on research (the Research M.S.E.). Students supported with a GSRA or research fellowship must pursue a Research M.S.E. rather than a Coursework M.S.E.

Coursework M.S.E. Degree

Students seeking a coursework M.S.E. degree must complete 30 credit hours of courses, which must be approved by the student's advisor. Of the 30 credit hours, up to 8 credit hours may be satisfied by MATSCIE 690, and at least 15 credit hours of MATSCIE department courses (excluding MATSCIE 690) must be taken. Graduate courses offered towards the 30 credit hours are divided into two modules/categories.

i) Foundation Courses (minimum of 12 credit hours)

ii) Elective courses (maximum of 18 credit hours)

Students may count no more than 1 non-engineering, professionally related (e.g. business, entrepreneurship, public policy, patent law, TechCom, engineering education) course toward their coursework degree requirement, which must be approved by the Master's Chair. This course cannot be used as a cognate. At least 2 cognate courses (a minimum of 4 credit hours) must be taken. Students taking MATSCIE 690 must submit a research report commensurate with the number of MATSCIE 690 credits taken. This report must be approved by the project supervisor. It may also be used as a document for the Ph.D. oral candidacy exam.

Research M.S.E Degree

This degree emphasizes Research skills suitable for students targeting PhD study or a career as a research scientist/engineer in R&D organizations and industry. Therefore, the curriculum is structured to enable students to develop skills and knowledge in at least one of the following five (5) major areas of research specialization/concentration: **(1) Computational and Data-Driven Materials Science; (2) Energy, Electronic and Quantum Materials; (3) Polymer and Bio Materials; (4) Metallic and Structural Materials; (5) Advanced Materials Characterization.**

Students seeking a Research Master's degree must complete 30 credit hours of coursework including research credits.

Graduate courses offered towards the 30 credit hours are divided into three modules/categories.

i) Foundation courses (minimum of 6 to a maximum of 9 credit hours)

ii) Elective courses (maximum of 9 credit hours)

iii) Specialized courses and research (minimum of 15 credit hours)

MSE Research Course Plan of Study Form for Master's

Foundation courses:

i) MATSCIE 532 (Advanced Thermodynamics of Materials; 3 credit hours)

ii) MATSCIE 535 (Kinetics, Phase Transformations and Transport; 3 credit hours)

These courses are required for all students enrolled in a Research Masters track.

In addition, MSE 550 (Fundamentals of Materials Science and Engineering; 3 credit hours) is also required for students without an undergraduate degree in Materials Science and Engineering.

Elective courses:

Students may count up to 9 credit hours within this module. Up to 2 non-MSE courses (maximum of 6 credit hours) may be counted toward the 9 credits. One non-MSE course can be a non-engineering, professionally related (e.g. Business, Entrepreneurship, Public Policy, Patent Law, TechCom, Engineering Education) course. The other non-MSE course must be a graduate-level Engineering or Science course.

These non-MSE courses MUST be approved by the Master's committee.

Specialized courses and research:

Courses selection within this category will determine the specialization track (which will appear on the Master's degree transcript).

Students must count a minimum of 15 credit hours within this module.

i) All students enrolled in a Research Masters track must take at least two additional MSE courses (6 credits) in the area of the specialization (see list of courses for details).

ii) All students enrolled in a Research Masters track must also take a minimum of 9 credits (maximum of 12 credits) of MSE 690.

- Research Problems in Materials Science and Engineering toward the MSE 690 credits must be conducted with an MSE faculty mentor in their lab.
- With approval from the Master's committee, research internships in the industry may be considered if it involves a UM MSE faculty mentor.
- Students must submit a Master's thesis to an examining committee of three faculty members, two of which must be from MSE. This committee will include the research

advisor and two other faculty selected by the advisor in consultation with the student and approved by the Master's Committee Chair.

- The thesis must be defended orally before this committee and approved by a majority of the committee and the advisor.
- This thesis should contain a critical review of background information and relevant literature, a statement of objective, a results section, and a thorough scientific analysis of these results. It should have a degree of originality suitable for publication.
- In the event that the student is not satisfied with the results of his/her examination(s), an appeal for arbitration can be made in sequence to the Master's committee chair, the Dept. chair, the Rackham Graduate School or the College of Engineering Ombudsman.

Ph.D. Programs

Ph.D. in Materials Science and Engineering

Advancement to candidacy in the MATSCIE doctoral program is contingent on passing qualification courses and the oral preliminary exam. A master's degree is not a prerequisite. Students must complete an additional 9 credit hours of formal coursework, above that required for the M.S.E. degree. Incoming students holding an M.S.E. degree (or equivalent) from another institution must complete an additional 18 hours of formal coursework to fulfill the residency and cognate requirements set forth by the Rackham Graduate School. In general, M.S. degrees from institutions outside the U.S. or Canada will be evaluated on an individual basis to determine if they meet the criteria for equivalency as set forth by the Graduate Committee of the MATSCIE department. The criteria for such a decision will be based on the academic standards of the foreign institution, the academic performance of the student at the institution, and the fulfillment of course and research requirements similar to those required in the MATSCIE department. Reports, a thesis, and publications may be submitted to the Graduate Committee for consideration in reaching decisions in such cases.

The Department will furnish details of requirements upon request.

Materials Science and Engineering Courses (MATSCIE)

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 281 (ANTHRARC 281). Making Things: Three Million Years of Materials and Culture
Prerequisite: None. (3 credits)
Connections between the discovery of new materials – such as ceramics, concrete, precious stones and metals, glass, steel, plastics, and semiconductors – and social transformations worldwide. To see these connections, the course will fuse basic concepts in materials science and engineering with perspectives and methods from anthropological archaeology. **CourseProfile (ATLAS)**

MATSCIE 293. Special Topics in Materials Science and Engineering
Prerequisite: None. (1-4 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)
The laws of thermodynamics and their consequences. Applications to solid and liquid materials. Mass and energy balances. Gas reactions. Phase diagrams. Ellingham, Pourbaix and stability diagrams. **CourseProfile (ATLAS)**

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) (MACROMOL 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)**

MATSCIE 412 (CHE 412) (MACROMOL 412). Polymeric Materials
Prerequisites: MATSCIE 220 or 250 or Graduate Standing. Minimum grade of "C-" for enforced prerequisites. (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. **CourseProfile (ATLAS)**

MATSCIE 420. Mechanical Behavior of Materials
Prerequisite: MATSCIE 220 or 250, MECHENG 211. (3 credits)
Macroscopic and microscopic aspects of deformation and fracture. Plasticity, general continuum approach. Microscopic hardening mechanisms. Rate and temperature dependent deformation. Deformation and fracture mechanism maps. Fracture mechanics. Fatigue behavior. **CourseProfile (ATLAS)**

MATSCIE 440. Ceramic Materials
Prerequisite: None. Advisory Prerequisite: MATSCIE 350. (3 credits)
Chemistry, structure, processing, microstructure and property relationships and their applications in design and production of ceramic materials. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

MATSCIE 465. Structural and Chemical Characterization of Materials
Prerequisites: MATSCIE 350. Minimum grade of "C-" required for enforced prerequisite. (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. **CourseProfile (ATLAS)**

MATSCIE 470. Physical Metallurgy
Prerequisite: MATSCIE 335; MATSCIE 350 (Advised). Minimum grade of a "C-" for enforced prerequisite. (3 credits)
Phase transformation mechanisms in metallic systems. Nucleation, diffusion-controlled growth, spinodal decomposition and martensitic reactions. Binary and ternary phase diagrams. Solidification and precipitate evolution. Structural alloy systems including Al, Mg, Fe, Ni and Titanium. **CourseProfile (ATLAS)**

MATSCIE 481. Designing Sustainable Products and Processes
Enforced Prerequisite: Senior Standing. (3 credits)
Projects based on environmental sustainability. Project based teamwork. Life Cycle Analysis (LCA). Techno-Economic Analysis (TEA). Engineering economics. Environmental impact with emphasis on CO2 utilization. Identification of key technology drivers to reduce cost and environmental impact. Written and oral presentations of solutions. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

MATSCIE 482. Product Design and Manufacturing
Enforced Prerequisite: Senior Standing. (3 credits)

Design, manufacturing and validation of complex products. Sponsor-based projects. Project based teamwork. Prototyping. User centric design principles. System engineering. Project management. Written and oral presentations at design reviews. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

MATSCIE 493. Special Topics in Materials Science and Engineering
Prerequisite: MATSCIE 350. (to be arranged)
Selected topics of current interest for students entering industry. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

MATSCIE 506 (CHE 506) (MACROMOL 506). Soft Robotic Matter
Advisory Prerequisite: None. Enforced Prerequisite: Senior Standing or Graduate Standing. (3 credits)
Soft robotic matter consists of active materials that can sense, move within, and alter their working environment. Fundamentals and emerging approaches will be explored in soft active matter design, actuation, power, and fabrication across length scales, with focus on engineering their properties and structures for programmable robotic functions. **CourseProfile (ATLAS)**

MATSCIE 509 (BIOMEDE 509) (CHE 509) (MACROMOL 509). Advanced Biomaterials
Advisory Prerequisite: MATSCIE 220 or MATSCIE 250. Enforced Prerequisite: None. (3 credits)
Applications of biomaterials in implants, regenerative medicine, tissue engineering, and drug delivery systems will be covered. Principles of biomaterials incorporating contemporary research related to

rational design strategies for biomaterials, their processing and fabrication, biomimetics, immunomodulation, degradation, and in vivo responses will be included. **CourseProfile (ATLAS)**

MATSCIE 510 (CHEM 511). Materials Chemistry
Advisory Prerequisite: CHEM 302 and CHEM 461. (3 credits)
This course presents concepts in materials chemistry. The main topics covered include structure and characterization, macroscopic properties and synthesis and processing. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. Minimum grade requirement of “C-” for enforced prerequisites. (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 518. Surface and Interfacial Engineering
Prerequisite: Senior standing or graduate standing. (3 credits)
Provides an insight into the fundamental physics and chemistry of interfaces that enable the understanding and design of different functional surfaces. It will cover the fundamental principles that govern surface properties, techniques for surface modification and characterization, as well as novel applications of designer surfaces. **CourseProfile (ATLAS)**

MATSCIE 520. Advanced Mechanical Behavior
Prerequisite: Graduate Standing. (3 credits)
Advanced studies of deformation and failure in materials. Macroscopic and microscopic aspects of deformation. Elasticity and plasticity theories and problems in deformation processing. Fracture mechanics and composite toughening mechanisms. Mechanisms of creep deformation. **CourseProfile (ATLAS)**

MATSCIE 521 (MECHENG 577). 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)**

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 545. Fundamentals of Battery Design
Prerequisite: MATSCIE 220/250 or graduate standing. *(3 credits)*
Fundamentals of battery operation, electrochemistry, and materials in batteries. Practical battery design, assembly and testing concepts including new battery designs such as in all solid-state batteries. **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 systems. 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 (ME)

The Department of Mechanical Engineering at the University of Michigan reflects the broad aspects of the mechanical engineering field. As exhibited by our internationally recognized leadership from traditional fields such as manufacturing and automotive engineering to new enabling technologies of micro- and nanosystems technology, biomechanics and biomaterials, robotics, batteries, advanced energy systems, and environmentally friendly product design, our mechanical engineers are well positioned for the research, design, development, and manufacture of a diverse set of systems and products.

The Mechanical Engineering program provides students with an excellent foundation in the core technical competencies of the discipline: thermal and fluid sciences, solid mechanics and materials, and dynamics and control. Our design and manufacturing and laboratory courses further integrate these topics. In addition, an array of technical electives are offered so students may tailor their mechanical engineering education to best suit their career goals.

There are numerous programs offered to enrich education, such as dual degrees (ME degree and a second degree from another Engineering program or another school/college), Sequential Undergraduate/Graduate Studies(SUGS), the Engineering Global Leadership Program (EGL), study abroad (listed among CoE minors) and Research, Innovation, Service and Entrepreneurship (RISE) projects with ME faculty. Students interested in any of these programs should contact the Mechanical Engineering Academic Services Office.

Students who do well in their undergraduate program are encouraged to consider graduate work and may take some of their electives in preparation for graduate study.

Information and assistance regarding fellowships and assistantships for graduate study may be obtained in the Academic Services Office of the Department of Mechanical Engineering.

Course Guide

Mechanical Engineering Courses

Contact

Departmental Website:
http://me.engin.umich.edu/

Mechanical Engineering Department
2380 G.G. Brown Bldg.
2350 Hayward St.
Ann Arbor, MI 48109-2125

Academic Services Office

Email: me-aso@umich.edu

ASO Contacts Page: https://me.engin.umich.edu/academics/contact

Department Administration

Department Chair

Ellen Arruda, Tim Manganello/BorgWarner Department Chair, Mechanical Engineering; Maria Comninou, Collegiate Professor of Mechanical Engineering

2370 G.G. Brown

For more specific information on contacting people, go to our Contacts page.

Mission

To prepare graduates for diverse careers in both mechanical engineering and related fields.

Goals

To have students graduate with outstanding problem-solving skills and knowledge of mechanical engineering, that allows them to continue their education throughout their careers and to become leaders in their fields.

Program Educational Objectives

The Mechanical Engineering Program is designed to prepare students for successful careers having positive societal impact in industry, government, academia, and consulting. Within three to five years after graduation, our alumni are expected to:

- Apply their engineering knowledge, critical thinking, creativity, and problem-solving skills with integrity and inclusivity in professional engineering practice or in non-engineering fields, such as law, medicine, or business.
- Continue their intellectual development through graduate education, professional development courses, self-directed investigation, and/or on-the-job training and experience.
- Embrace leadership and collaborative roles in their careers.

Outcomes

Our graduates 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

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally you can see recent degrees granted below:

Level	2021	2022	2023
Bachelors Degrees	317	275	239
Masters Degrees	110	128	144
Doctoral Degrees	35	58	42

Accreditation

The Mechanical Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Mechanical and Similarly Named Engineering Programs.

Program Outcomes

The matrix maps how each course in our curriculum addresses our program outcomes. Only the outcomes tracked are noted below.

Course	Student Outcomes (Black – High)						
Fall 2020	Problems	Design	Communication	Ethics	Teams	Data	New Learning
MECHENG320							
MECHENG335							
MECHENG350							
MECHENG360							
MECHENG382							
MECHENG395							

MECHENG450							
MECHENG455							
MECHENG495							

Undergraduate Degree Program

Sample Schedule

B.S.E. in Mechanical Engineering

Please see the sample schedule and additional information on the Mechanical Engineering Department Advising website.

ME Program-Specific Course Requirements

Within the ME Program, there are five categories of program-specific courses. These include ME Core Courses, Technical Electives, Specialization Elective, Advanced Math, and EECS 314/215.

ME Core Courses

The ME Core Courses consist of five categories: Design and Manufacturing, Mechanics and Materials, Dynamics and Controls, Thermal Sciences, and Laboratories and Technical Communication. In total, there are 45 credits of required ME Core courses and together these subjects represent the fundamental technical competencies every mechanical engineering student must learn. A minimum letter grade, as noted on the Mechanical Engineering Bachelor's Degree website, must be obtained in each course, and it **cannot** be taken as Pass/Fail. The list below outlines the courses from each of the core categories:

- Design and Manufacturing: ME 250, ME 350, ME 450/455 (4 credits)
- Mechanics and Materials: ME 211, ME 382
- Dynamics and Controls: ME 240, ME 360
- Thermal Sciences: ME 235, ME 320, ME 335
- Labs and Technical Communication: ME 395, ME 495

Technical Electives (TEs)

All ME students are required to complete **9 credits of** Advanced Technical Electives to deepen their knowledge within Mechanical Engineering. For ME course descriptions, visit the ME Course List. A grade of at least a "D" must be obtained in each course.

The **9** credits of advanced TEs required must be taken in the ME Department via these 2 categories:

1. **400-level Technical Elective**: One upper-level elective must be a 400-level or higher ME class (at least 3 credit hours). This may include 400-level classes off the core TE list but does not have to. Note that ME 490 or ME 491 can fulfill this requirement.
2. **Core Technical Elective**: Two ME elective classes (totaling at least 6 credit hours) having a mechanical engineering prerequisite. See the following list for Core Technical Electives.
3. *Note: The MECHENG 500- and 600-level courses can also qualify as a Core Technical Elective if they have a MECHENG prerequisite. Please check the MECHENG Course Listing to see a list of MECHENG 500- and 600-level electives. If you would like to take one of these courses, please consult with the instructor of the course, as these are graduate-level courses.*

- Solid Mechanics and Materials: ME 305, ME 311, ME 406, ME 412, ME 451, ME 456
- Design and Manufacturing: ME 452, ME 458, ME 481, ME 482, ME 483, ME 487, ME 489
- Dynamics, Systems, and Controls: ME 424, ME 440, ME 461/EECS 460*
- Thermal Sciences: ME 336, ME 420, ME 432, ME 433, ME 438, ME 476
- Other: ENGR 350**, ME 400

**Students may not take both EECS 460 and ME 461 for Technical or Specialization Elective credit.*

***ENGR 350 is offered at Technical University of Berlin during the summer only. For ENGR 350 to be counted as an ME Technical Elective, the required sophomore-level ME courses (ME 211, ME 235, ME 240, & ME 250) must be taken before ENGR 350. Otherwise, ENGR 350 counts as a General Elective.*

Specialization Elective

All ME students are required to complete **3 credits of** a Specialization Elective. A grade of at least a "D" must be obtained. A Specialization Elective is a course intended to allow students to explore deeply a dimension of intellectual endeavor of their choosing, in both technical (including engineering) and non-technical fields across the University.

1. Have a 300 level or higher enforced prerequisite
2. Be any 300 level or higher ME course outside of the required ME program courses (ME 320, ME 335, ME 350, ME 360, ME 382, ME 395, ME 450, ME 495)

Note: ENGR, ENTR, practicum, and seminar courses will not be accepted as a Specialization Elective. Students may use any 3 or 4 credit course from the approved Advanced Math list to count as a Specialization Elective. This can count after completing the 3 credit Advanced Math requirement.

Advanced Math

In addition to the CoE Core math courses, the ME department requires students to complete at least 3 credits of Advanced Math. Students must earn a "D" grade or better to receive credit for the Advanced Math requirement, and it **cannot** be taken Pass/Fail. See the Approved Advanced Math List.

Electrical Circuits

As part of the undergraduate ME degree, students must complete EECS 314 (4) – Electrical Circuits, Systems and Applications. Students must earn a "D" grade or better in EECS 314, and **cannot** take it Pass/Fail.

Students that wish to complete an Electrical Engineering Minor should enroll in EECS 215 (4) – Introduction to Electronic Circuits, which will count in place of EECS 314 and follow the same grading rules. Students who are interested in the Electrical Engineering Minor should contact the EE Department for more information.

Economics

The ME department requires each student to take at least 3 credit hours of an economic or financial course as part of their Intellectual Breadth requirements. The approved list of economic/financial courses recommended for ME students is provided in the Mechanical Engineering Undergraduate Handbook on the department website. Most courses on the supplied list can fulfill some Intellectual Breadth requirements.

General Electives (GEs)

As part of the ME BSE degree, 119 required credits come from the CoE Core, Intellectual Breadth, and ME Program Specific categories. General Elective credits are the remaining credits needed to reach the minimum 128 total credits toward the program (CTP) required for graduation, which usually amounts to 9 to 12 credits of GEs. A grade of at least a "D-" must be obtained, and **can** be taken Pass/Fail.

For transfer students that received credit by exam, or students that transferred one or more courses from another institution, your total number of credits from the other categories may not equal 119 credits. As a result, you may have to enroll in more or less than 9 general elective credits, depending on how many credits are needed to reach the 128 credits required for graduation.

For the description of what courses count as General Electives, please visit the CoE Bulletin, and scroll to the bottom of the Core Requirements section.

Sequential Undergraduate/Graduate Study (SUGS)

The ME SUGS Program makes it possible for students to pursue a five-year sequential Bachelor of Science in Engineering (BSE) and Master of Science in Engineering (MSE) by taking four years of BSE work and one year of MSE work. ME SUGS is only for ME undergraduate students enrolled at the UM Ann Arbor campus. Prior to applying to the SUGS Program, students should meet with a ME Undergraduate Advisor to discuss the application process and create a plan of study.

Applicants for the ME SUGS Program must have a 3.6 GPA or better to be considered for admission. ME SUGS students may pursue a coursework, research, or thesis track Master's degree. The ME SUGS Program allows students to double-count a maximum of 9 credits and transfer a maximum of 3 credits from their Bachelor's degree toward the 30-credit Master's degree. This leaves 18-21 credits required to complete the Master's degree, which can be accomplished in two semesters of graduate coursework. All SUGS students are required to complete two full terms as graduate students and cannot delay their enrollment. Contact me-aso@umich.edu to learn more or request a meeting.

Joint Institute – Sequential Undergraduate/Graduate Study (JI-SUGS)

This program is designed for students who receive an undergraduate ME BSE degree from the UM – Shanghai Jiao Tong University's Joint Institute and wish to pursue a Mechanical Engineering Master's degree at UM. Students that participate in the joint undergraduate program and receive two undergraduate degrees from UM and SJTU **are not eligible** for this program. Requirements for admission include: (1) a ME BSE degree from SJTU and (2) a minimum undergraduate grade point average of 3.6. The GRE is waived for JI-SUGS students, but the TOEFL is not. A maximum of 6 credits of approved coursework may be double counted from the undergraduate degree. Contact me-aso@umich.edu to learn more or request a meeting.

Graduate Degrees

- Master of Science in Engineering (M.S.E.) in Mechanical Engineering
- Doctor of Philosophy (Ph.D.) in Mechanical Engineering

M.S.E. in Mechanical Engineering

The M.S.E. program is designed for students looking to develop a personalized academic program to strengthen their knowledge of mechanical engineering fundamentals in a specific area. Research areas include automotive, biomechanics and biosystems, controls, design, dynamics and vibrations, energy, fluids, manufacturing, mechanics and materials, mechatronics, robotics, micro/nano engineering, multi-scale computation and combustion mechanics, and thermal sciences.

There are three separate M.S.E. degree program options in ME: (1) coursework only, (2) coursework with an individual research project, and (3) coursework with an M.S.E. thesis. All program options require 30 credit hours for completion, including ME, cognate, and advanced math coursework.

Details of degree requirements may be found on the Mechanical Engineering Master's Degree and SUGS website.

Ph.D. in Mechanical Engineering

The Doctor of Philosophy (Ph.D.) degree is the highest degree awarded by the Mechanical Engineering Department and is recommended for students who are interested in leadership careers in academia (e.g. as a faculty member of a university), industry, or government. The major ME program milestones all Ph.D. students complete are:

1. Research and coursework
2. Qualifying examination (RCC & RFE)
3. Advancement to candidacy
4. Dissertation proposal examination
5. Thesis dissertation (written) and defense (oral)

A research advisor and doctoral committee is formed by each student to supervise investigative work and election of graduate courses. Candidacy is achieved when the student demonstrates competence in their field of knowledge through completion of courses and passing the qualifying examination (RCC & RFE).

The doctoral degree is conferred after the student presents the result of their investigation in the form of a dissertation, demonstrating marked ability and scholarship in a field of knowledge. Details of degree requirements may be found on the Mechanical Engineering Doctoral Degree website.

Mechanical Engineering Courses (MECHENG)

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)
Vector description of force, position, velocity and acceleration in fixed and moving reference frames. Kinetics of particles, of assemblies of particles and of rigid bodies. Energy and momentum concepts. Euler's equations. Moment of inertia properties. The simple oscillator and its applications. **CourseProfile (ATLAS)**

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 thermofluid 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)
Project work where students must apply ME principles to research, innovation, service or entrepreneurship. The student submits a proposal and a poster, and presents the poster at the ME Undergraduate Symposium. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

300 Level Courses

MECHENG 305. Introduction to Finite Elements in Mechanical Engineering
Prerequisite: MECHENG 211. (3 credits)

Introduction to theory and practice of the finite element method. One-dimensional, two-dimensional and three dimensional elements are 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 is applied through computer labs and graded assignments. **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 (NAVARCH 320). Introduction to Fluid Mechanics
Prerequisite: [MATH 215 or 255 or 285; (C or better, No OP/F)] AND [MECHENG 235 or NAVARCH 235 & MECHENG 240; (C or better, No OP/F)] AND [Fewer than 2 previous elections of MECHENG 320 (incl. grades of W & I)]. Mechanical Engineering Majors must take MECHENG 235 as a part of their major requirements. (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 similitude; laminar and turbulent flow; boundary layers; lift and drag; applications to mechanical, marine, 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)
Project work where students must apply ME principles to research, innovation, service or entrepreneurship. The student submits a proposal and a poster, and presents the poster at the ME Undergraduate Symposium. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **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)
Evolution of quality methods. Fundamentals of statistics. Process behavior over time. Concept of statistical process control (SPC). Design and interpretation of control charts. Process capability study. Tolerance. Measurement system analysis. Correlation. Regression analysis. Independent t-test and paired t-test. Design and analysis of two-level factorial experiments. Fractional factorial experiments. Response model building. Taguchi methods. Case studies. **CourseProfile (ATLAS)**

MECHENG 406. Biomechanics for Engineering Students.
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)
Analytical approach to the engineering problem and performance analysis of internal combustion engines. Study of thermodynamics, combustion, heat transfer, friction and other factors affecting engine power, efficiency and emissions. Design and operating characteristics of different types of engines. Computer assignments. Engine laboratories. **CourseProfile (ATLAS)**

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 cover different mechanical engineering disciplines. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental, and/or non-profit organizations. **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). Modeling in Biosolid Mechanics
Prerequisite: [BIOMEDE 231 or MECHENG 211], and [BIOMEDE 332 or MECHENG 382] (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)
Introduction to machining operations. Cutting tools and tool wear mechanisms. Cutting forces and mechanics of machining. Machining process simulation. Surface generation. Temperatures of the tool and workplace. Machining dynamics. Non-traditional machining. **CourseProfile (ATLAS)**

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)
Project work where students must apply ME principles to research, innovation, service or entrepreneurship. The student submits a proposal and a paper, and presents at the ME Undergraduate Symposium. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **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 under the direction of a member of the department. The student will submit a final report. For undergraduates only. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **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 Soft Materials
Prerequisite: None. Advisory Prerequisite: MECHENG 511 or prior experience in continuum mechanics or Permission of Instructor. (3 credits)
Selected topics in the mechanics of soft materials, including nonlinear elasticity, nonlinear viscoelasticity, and (visco)plasticity in amorphous and crystalline polymers. Applications include elastomers, thermoplastics, thermosets, vitrimers, hydrogels, proteins, and biological networks, cells, and tissues. **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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

MECHENG 523 (AEROSP 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. Computer projects and homework. **CourseProfile (ATLAS)**

MECHENG 524. Advanced Engineering Acoustics
Prerequisite: MECHENG 424, (BIOMEDE 424). (3 credits)
Derivation of the acoustic wave equation and development of solution techniques. Transmission and reflection from solids, plates and impedance boundaries. Radiation and scattering from non-simple geometries. Green’s functions; boundary element and finite element methods. Sound in ducts and enclosures. Introduction to structural-acoustic coupling. Automotive and other applications considered. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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)**

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)**

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)**

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)**

MECHENG 541. Mechanical Vibrations
Prerequisite: MECHENG 440. (3 credits)
Time and frequency domain mathematical techniques for linear system vibrations. Equations of motion of discrete non-conservative systems. Vibration of multi-degree-of-freedom systems. Small oscillation theory. Free vibration eigenvalue problem. Undamped system response. Viscously damped systems. Vibration of continuous systems. Modes of vibration of bars, beams, membranes, plates. **CourseProfile (ATLAS)**

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 handing with tires. **CourseProfile (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)**

MECHENG 545 (ISD 546, CEE 577). Dynamics and Control of Connected Vehicles
Prerequisite: None. Advised Prerequisite: MECHENG 360. (3 credits)

Ordinary differential equations and delay differential equations are used for modeling connected vehicle systems, which consist of human-driven vehicles and automated vehicles. Controllers are designed to improve stability, safety, energy efficiency, and traffic flow. Students will use experimental data to design controllers and evaluate those via numerical simulations. **CourseProfile (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 549 (CEE 576). Mechanisms Design
Advisory Prerequisite: CEE 373 or equivalent, MECHENG 360 or CEE 572 or equivalent, MECHENG 564/CEE 571 or equivalent. (3 credits)
Analysis of discrete- and continuous-time linear stochastic processes with primary application to engineering dynamics. Ito calculus and mean-square analysis. Continuous-time Poisson counters and Wiener processes. Stochastic response of nonlinear systems, and the Fokker-Planck Equation. Stationary analysis. Approximate techniques for nonlinear stochastic response. **CourseProfile (ATLAS)**

MECHENG 551 (MFG 560). Mechanisms Design
Prerequisite: MECHENG 350. (3 credits)
Basic concepts. Type synthesis — creative design of mechanisms; graph theory. Precision-point Burmester theory for dimensional synthesis of linkages. Applications. Cam and follower system synthesis. Joint force analysis and dynamic analysis formulations. Analytical synthesis of programmable and compliant mechanisms. Use of software for synthesis and analysis. Design projects. **CourseProfile (ATLAS)**

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)
Sampling and data reconstruction. Z-transforms and state variable descriptions of discrete-time systems. Modeling and identification. Analysis and design using root locus, frequency response and state space techniques. Linear quadratic optimal control and state estimation. Quantization and other nonlinearities. **CourseProfile (ATLAS)**

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)
Linear spaces and linear operators. Bases, subspaces, eigenvalues and eigenvectors, canonical forms. Linear differential and difference equations. Mathematical representations: state equations, transfer functions, impulse response, matrix fraction and polynomial descriptions. System-theoretic concepts: causality, controllability, observability, realizations, canonical decomposition, stability. **CourseProfile (ATLAS)**

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 (MATSCIE 521). 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) (ISD 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)
Application of lasers in materials processing and manufacturing. Laser principles and optics. Fundamental concepts of laser/material interaction. Laser welding, cutting, surface modification, forming

and rapid prototyping. Modeling of processes, microstructure and mechanical properties of processed materials. Transport phenomena. Process monitoring. **CourseProfile (ATLAS)**

MECHENG 587 (MFG 587). Global Manufacturing
Prerequisite: one 400-level MFG or DES or BUS class. (3 credits)
Globalization and manufacturing paradigms. Product-process-business integration. Product invention strategy. Customized, personalized and reconfigurable products. Mass production and lean production. Mathematical analysis of mass customization. Traditional manufacturing systems. Reconfigurable manufacturing systems. Reconfigurable machines. System configuration analysis. Responsive business models. Enterprise globalization strategies. The global integrated enterprise. **CourseProfile (ATLAS)**

MECHENG 588 (IOE 588) (MFG 588). Assembly Modeling for Design and Manufacturing
Prerequisites: MECHENG 481 and MECHENG 401 or equivalent. (3 credits)
Assembly on product and process. Assembly representation. Assembly sequence. Datum flow chain. Geometric Dimensioning and Tolerancing. Tolerance analysis. Tolerance synthesis. Robust design. Fixturing. Joint design and joining methods. Stream of variation. Auto body assembly case studies. **CourseProfile (ATLAS)**

MECHENG 589. Sustainable Design of Technology Systems.
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 any of the areas of mechanical engineering. The student will submit a report at the close of the term. Projects are overseen and graded by faculty and may also involve mentoring by representatives from external organizations. **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 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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

MECHENG 641. Advanced Vibrations of Structures
Prerequisite: MECHENG 541. (3 credits)
Energy formulation for nonconservative gyroscopic systems. Spectral methods for free and forced vibrations. Eigenvalue and boundary value problems. Non self-adjoint systems. Variational methods of approximation: Bubnov-Galerkin. Perturbation theory for the eigenvalue problem. Dynamics of rotating systems. Dynamics of constrained dynamical systems. **CourseProfile (ATLAS)**

MECHENG 645. Wave Propagation in Elastic Solids
Prerequisite: MECHENG 541. (3 credits)
Elastodynamic equations, isotropic and anisotropic materials; vector/scalar potentials, reflection and transmission at interfaces, mode conversion, surface waves, Rayleigh-Lamb equation. Green's tensor; variational, Galerkin and Hamilton's equations. Kirchhoff-Love and Reissner-Mindlin kinematic hypotheses for beam, plate and shell theories. Fourier and Laplace transform, modal and state-vector solution techniques. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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: None; mandatory satisfactory/unsatisfactory. (3 credits)
Student must complete a dissertation and defend their thesis in front of a committee of at least 2 faculty members. Projects are overseen/graded by faculty and may involve mentoring by representatives from external organizations. **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)**

700 Level Courses

900 Level Courses

MECHENG 990. Dissertation/Pre-Candidate
Advised Prerequisite: Election for dissertation work by doctoral student not yet admitted as a Candidate. (1-8 credits); (1-4 credits)
Dissertation precandidate work is overseen/graded by faculty and may involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

MECHENG 995. Dissertation/Candidate
Prerequisite: Graduate School authorization for admission as a doctoral candidate. (8 credits); (4 credits)
Dissertation candidate work is overseen/graded by faculty and may involve mentoring by representatives from external organizations. **CourseProfile (ATLAS)**

Naval Architecture & Marine Engineering

Naval Architecture and Marine Engineering (NAME)

More than 70 percent of our planet is covered by water. Engineering for the marine environment covers the design and production of all types of systems to operate successfully in this often harsh and demanding environment. In addition to traditional naval architecture and marine engineering, instruction is offered in offshore engineering, coastal engineering and marine environmental engineering. Recent graduates are active in design and research related to offshore oil and gas exploration and production platforms. Others are involved in overcoming waterborne pollution transport in the Great Lakes and oceans, coastal erosion predictions, and design of traditional ships, submersibles, high-speed vessels and recreational craft.

Since the design of modern marine systems encompasses many engineering fields, graduates of this department are called upon to handle diverse professional responsibilities; therefore, the program includes study in the fundamentals of the physical sciences and mathematics as well as a broad range of engineering aspects that constitute design for the marine environment. To provide the appropriate educational breadth, students are required to complete at least 16 credits of Intellectual Breadth (IB) requirements from an approved list of courses. It is recognized that the undergraduate program cannot, in the time available, treat all important aspects of engineering for the marine environment that may be desired by the student; therefore, graduate work is encouraged.

Ship and offshore platform analysis and design require knowledge of hull geometry, vessel arrangements, hydrostatic stability, structures, resistance, propulsion, maneuvering and seakeeping. Other areas of concern are the economic aspects of design and operation, production, model testing, propeller and control theory, vibration problems and piping and electrical system analysis and design.

The undergraduate degree program is arranged to give the student a broad engineering mechanics education by requiring basic courses in the areas of structural mechanics, hydrodynamics, marine power systems and marine dynamics. These courses cover engineering fundamentals and their application to the design and construction of marine vehicles and systems. Courses in marine structures deal with the design and analysis of marine vehicles and platforms including static strength, fatigue, dynamic response, safety and production. Resistance, maneuvering and seakeeping characteristics of bodies in the marine environment are the subject matter for courses in marine hydrodynamics. Marine power systems involve all the mechanical systems on a marine vehicle with particular emphasis on the selection and arrangement of the main propulsion system. In marine dynamics, the student studies the vibrations of marine structures and engines and the rigid body responses of the vessel to wind and waves. Through the use of technical and free electives, students may decide to focus their education in areas such as:

- Marine Structures
- Ship Production and Management
- Sailing Yachts
- High Speed Craft
- Marine Power Systems

An integration of the material covered in earlier courses takes place in the two-semester, final design sequence. In the first course of this sequence, the student works on a class design project using state-of-the-art, computer-aided design tools. In the second semester the students form design teams and work on projects of their choosing. Recent final design projects included a mega yacht, an offshore wind farm repair vessel, a cruise ship rescue vessel, an offshore well intervention vessel, a neo-Panamax containership, a naval vessel for high-energy weapons and an offshore racing trimaran.

The department works closely with the marine industry and is able to assist graduates in obtaining positions in the field. The department is in constant touch with the country’s marine design offices, shipyards, ship operators, government agencies and other organizations concerned with naval architecture and marine engineering. A summer internship program allows students to work in the industry.

Students who meet the academic requirements of both departments may earn an additional B.S.E. degree in another engineering program, or in combined programs with other engineering departments. The combined programs allow substantial substitution of courses required in one regular program for those required in the other, and typically can be completed in two extra terms.

Course Guide

Naval Architecture and Marine Engineering Courses

Contact

Departmental Website:
https://name.engin.umich.edu/

Naval Architecture and Marine Engineering Department
221 Naval Architecture and Marine Engineering
2600 Draper Drive
Ann Arbor, MI 48109-2145

Email: **Advising-at-NAME@umich.edu**
Phone: (734) 936-9224
Fax: (734) 936-8820

Department Administration

Department Chair
David Dowling, Professor of Naval Architecture and Marine Engineering, Professor of Mechanical Engineering
212 Naval Architecture & Marine Engineering Building

For more specific information on contacting people — go to our contacts page.

Mission

The mission of the Naval Architecture and Marine Engineering (NAME) Department is to be a world leader in the education of engineers in the application of engineering principles for the marine environment by:

- providing the leading bachelor's program in naval architecture and marine engineering, with emphasis on the conceptual design, engineering, manufacture, and life cycle management of marine vehicles, structures, and complex systems.
- providing the leading graduate education and research program in engineering for the marine environment, one which spans a broad range of inquiry.
- providing leadership and service to the state, national, and international marine community.

Goals

In addition, the NAME program also has the following goals:

- to recruit, educate, and support exceptional, diverse students and engage them in lifelong learning and achievement while preparing them for a sustained career of

engineering leadership in the marine-related industries, government service, and academia
- to maintain and enhance the leading undergraduate program in the world in naval architecture and marine engineering, one which provides a rigorous and effective preparation for a lifelong career of engineering leadership and service

Educational Objectives

The educational objectives of the NAME program are to produce graduates who in 3-5 years' time are:

- designing and manufacturing vehicles and structures that operate in the marine environment
- working effectively in teams
- practicing professionally in the marine industries, enrolling in graduate study, and engaging in life-long learning

Student Outcomes

The student outcomes of the NAME program are:

- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (ABET 3.1)
- 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 (ABET 3.2)
- an ability to communicate effectively with a range of audiences (ABET 3.3)
- 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 (ABET 3.4)
- 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 (ABET 3.5)
- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (ABET 3.6)
- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies (ABET 3.7)

View NAME's student outcomes to course mapping.

Program Objectives

The curriculum criteria of the NAME program are to provide students with:

- an ability to apply probability and statistical methods to naval architecture and marine engineering problems [Program: i]

- an ability to apply basic knowledge in fluid mechanics, dynamics, structural mechanics, material properties, hydrostatics, stochastic mechanics, and energy/propulsion systems in the context of marine vehicles, and/or ocean structures [Program: ii]
- familiarity and experience with instrumentation appropriate to naval architecture and marine engineering including experiment design, data collection, data analysis, and formal laboratory report writing [Program: iii]

Enrollment and Graduation Data

The University Registrar publishes the number of students enrolled annually in this program, and the number of degrees granted each term by this program. Additionally you can see recent degrees granted below:

Level	2021	2022	2023
Bachelors Degrees	23	25	29
Masters Degrees	31	24	27
Doctoral Degrees	4	12	6

Accreditation

The Naval Architecture and Marine Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Naval Architecture, Marine Engineering, Ocean Engineering, and Similarly Named Engineering Programs.

Undergraduate Degree Program

The undergraduate degree program is arranged to give the student a broad engineering mechanics education by requiring basic courses in the areas of structural mechanics, hydrodynamics, marine power systems, and marine dynamics. These courses cover engineering fundamentals and their application to the design and construction of marine vehicles and systems.

- Courses in marine structures deal with the design and analysis of marine vehicles and platforms including static strength, fatigue, dynamic response, safety, and production.
- Resistance, maneuvering and seakeeping characteristics of bodies in the marine environment are the subject matter for courses in marine hydrodynamics.
- Marine power systems involve all the mechanical systems on a marine vehicle with particular emphasis on the selection and arrangement of the main propulsion system.
- In marine dynamics, the student studies the vibrations of marine structures and engines and the rigid body responses of the vessel to the wind and waves.

Sample Schedule

Please visit the NAME website to view the most current information on the major in NAME. B.S.E. in Naval Architecture and Marine Engineering

Please see the PDF version of the **sample schedule**.

Focus of Study

In the fourth year, students are required to select two technical electives from an approved list. These electives allow students to focus their education in specific areas. Example focus areas and possible courses are as follows:

- Marine Structures: NA 410 and NA 440
- High-Speed Craft Design: NA 401 and NA 431 or NA 440
- Marine Power Systems: NA 431 and NA 401 or NA 410
- Marine Manufacturing: NA 410 and NA 562
- Sailing Yachts: NA 403 and NA 410, NA 431, or NA 440

These and other combinations of free and technical electives should be selected in consultation with the undergraduate program advisor.

Students are strongly encouraged to review the possible options prior to their senior year.

Sequential Undergraduate/Graduate Study (SUGS)

BSE/MSE in Naval Architecture and Marine Engineering

This program permits outstanding naval architecture and marine engineering students to receive the B.S.E. and M.S.E. degrees. The student benefits from the continuity of study and the inefficiencies of transferring from an undergraduate to a graduate program are eliminated. The program allows students with a 3.2 or better GPA, to apply early in the first semester of their senior year (once 85 credit hours have been completed), for a sequential undergraduate/graduate program, which allows them to double count up to nine credits and transfer up to six credits of technical or free electives. In consultation with their advisor, students select technical electives that will be relevant to the master's program of study. Students are admitted using the normal department graduate admission process, with the admission standards required for the expected successful completion of the program. Please contact the Naval Architecture and Marine Engineering Department for more complete program information.

Graduate Degrees

- Master of Science (M.S.) in Naval Architecture and Marine Engineering
- Master of Science in Engineering (M.S.E.) in Naval Architecture and Marine Engineering
- Master of Science in Engineering (M.S.E.) in Naval Architecture and Marine Engineering **Sub-Plan**: Autonomous Systems
- Joint Master of Science in Engineering (M.S.E.)/Master of Business Administration (M.B.A.) in Naval Architecture and Marine Engineering
- Doctor of Philosophy (Ph.D.) in Naval Architecture and Marine Engineering

Master’s Programs

M.S. and M.S.E. in Naval Architecture and Marine Engineering

Applicants for the M.S.E. or M.S. degrees normally hold a bachelor of science degree in naval architecture and marine engineering. However, the graduate program has been structured so that students with a bachelor’s degree in other engineering disciplines that require knowledge of basic mechanics such as mechanical engineering, applied mechanics, aerospace or civil engineering may also start directly on their master’s program. Students without an undergraduate degree in naval architecture and marine engineering but with a bachelor’s degree in other engineering disciplines will be required to take NA 470 (Foundation of Ship Design).

M.S.E. Sub-Plan: Autonomous Systems

The M.S.E. is a flexible program that allows students to take classes in different concentration areas. One of these areas is Autonomy. Over the last twenty years, the investment in marine autonomous systems has exploded. Just in underwater systems, more than 500 company startups now exist worldwide servicing the marine industry. The fields of offshore engineering, marine renewable energy, and Naval industries have emerging needs and opportunities for integrating autonomous systems into their operation. The NAME graduate program formalized the availability of classes in the area of autonomy by creating the Sub-Plan: Autonomous Systems.

Joint M.S.E./M.B.A. in Naval Architecture and Marine Engineering

The Department of Naval Architecture and Marine Engineering and the Ross School of Business offer a joint degree program for qualified persons to pursue concurrent work in business administration, and naval architecture and marine engineering studies leading to the M.B.A. and M.S.E. degrees. The program is arranged so that all requirements are completed within three years of enrollment. The degrees are awarded simultaneously. This combined degree program is not open to students who have earned either the M.B.A. or M.S.E. (NAME) degrees. Students already registered in the first year of either program may apply.

The program can begin with studies in either school. However, because of the sequential nature of the core courses in the M.B.A. program, most students will find it advantageous to start with year one in the business school. During the remainder of the program, courses might be taken in both schools. Students who wish to begin in NAME should consult a counselor in the business school to formulate an appropriate plan of study. Interested students must file separate applications and be admitted to both schools. Students admitted to this joint program must satisfy the following degree requirements:

Requirement 1) The MBA 57 credit hour degree program includes:

- 45 business administration credits, made up of:

- Roughly 30 credit hour MBA core (no credit awarded for business administration core courses successfully waived, credit must be earned with business electives)
- Roughly 15 elective hours in business administration
- MBA communication requirement

- Up to 12 credit hours of transferable electives from the Department of Naval Architecture and Marine Engineering

Requirement 2) The NAME 30 credit hour degree program includes:

- 18 total NAME credits minimum, made up of
  - 15 credits of which must be at the 500-level or above, the remaining
  - 3 credits can be 400-level or above
- Required Course – MATH for Naval Architects (NA 500, section 028, 3 credits)
- One (1) cognate course (level 400 and up) – engineering or another math course outside NAME
- Any remaining credits will be of approved coursework (not all students will need this if they already have earned 30 credits by fulfilling the first three requirements)

Ph.D. Programs

Doctor of Philosophy (Ph.D.) in Naval Architecture and Marine Engineering

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad fields 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 conduct an independent investigation in a subdivision of the selected field and must present the results of the investigation in the form of a dissertation.

A student becomes a pre-candidate for the doctorate when admitted to the Horace H. Rackham School of Graduate Studies and accepted into a field of specialization. Candidacy is achieved when the student demonstrates competence in their broad field of knowledge through the completion of coursework, passing comprehensive exams, and successful presentation of a Ph.D. prospectus.

There is no general course requirement for the doctorate. However, during the course of a student's graduate study, three math classes and 50 total classroom credit hours are expected as a minimum (with an approved M.S. degree earned before admission to the Ph.D. program, the total classroom credit hours could be reduced to 20). The comprehensive exam consists of a Part I qualifying requirement. To complete the Qualifying requirement, students need to take at least three 500 level or higher NAME classes and receive a grade of "A-" or better in each one of the classes. Students will need to fulfill the PART I requirement before they are able to present their prospectus presentation (PART II) describing the proposed Ph.D. dissertation. A special doctoral committee is appointed for each applicant to supervise the work of the student both in the election of courses and in the preparation of the dissertation.

A pamphlet describing the general procedure leading to the doctorate is available from the Rackham Graduate School upon request.

Naval Architecture and Marine Engineering Courses (NAME)

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

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 rudder 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, goodness of fit, regression, correlation, random processes, spectral concepts and Fourier Transformations. **CourseProfile (ATLAS)**

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 (MECHENG 320). Introduction to Fluid Mechanics
Prerequisite: [MATH 215 or 255 or 285; (C or better, No OP/F)] AND [MECHENG 235 or NAVARCH 235 & MECHENG 240; (C or better, No OP/F)] AND [Fewer than 2 previous elections of MECHENG 320 (incl. grades of W & I)]. Mechanical Engineering Majors must take MECHENG 235 as a part of their major requirements. (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 similitude; laminar and turbulent flow; boundary layers; lift and drag; applications to mechanical, marine, biological, environmental, and micro-fluidic systems. **CourseProfile (ATLAS)**

NAVARCH 321. Marine Hydrodynamics
Prerequisite: None. Advisory Prerequisite: NAVARCH 320 or MECHENG 320 or equivalent. (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: free surface flow, wave loads, seakeeping and transport of pollutants. **CourseProfile (ATLAS)**

NAVARCH 331. Marine Power and Energy I
Advisory Prerequisite: 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 Prerequisite: NAVARCH 331, NAVARCH 235 or ME 235, co-requisite: NAVARCH 321. (4 credits)
Marine diesel engines, steam turbines, gas turbines, combined plants. Fuels, emissions. Mechanical power transmission, reduction gears. Electrical power generation, transmission and distribution. Propeller selection and engine-propeller matching. System reliability, design of mechanical, integrated electric and hybrid propulsion systems. Boat and ship auxiliary systems. Marine engineering systems design project. **CourseProfile (ATLAS)**

NAVARCH 340. Marine Dynamics I
Prerequisite: MECHENG 240. (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 Prerequisite: 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)
Hydrodynamics of small high-speed craft including planing hulls, air cushion vehicles, surface effect ships and catamarans. Theoretical and empirical methods for resistance propulsion and attitude prediction. Nonlinear dynamics and stability of high-speed marine vehicles. Effect of hull form on resistance and dynamic performance. Structural design considerations including bottom plating strength and frame loading. Discussion of various types of framing. Material choices. **CourseProfile (ATLAS)**

NAVARCH 403. Sailing Craft Design Principles
Prerequisite: preceded or accompanied by NAVARCH 321. (3 credits)
Forces and moments acting on a sailing yacht. Speed polar diagrams. Two- and three-dimensional airfoil theory. Application to keel and rudder design. Yacht model testing. Delft Standard Series for prediction of hydrodynamic performance. Aerodynamics of yacht sails. Sail force coefficients. Velocity Prediction Program. Rigging design and analysis. Yacht racing rules. **CourseProfile (ATLAS)**

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)
Linear elastic plates. Membrane and bending theory of axisymmetric and non-axisymmetric shells. Variational formulation of governing equations boundary conditions. Finite element techniques for plate and shell problems. **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. **CourseProfile (ATLAS)**

NAVARCH 431. Marine Engineering II
Prerequisite: NAVARCH 310, NAVARCH 331, NAVARCH 332, NAVARCH 340. (3 credits)
Integrated treatment of the statics and dynamics of marine power transmission systems. Shafting design and alignment. Bearing selection and lubrication. Propeller excitation, added mass, and damping. Vibration modeling, analysis and evaluations of shafting systems: torsional, longitudinal and lateral vibrations. **CourseProfile (ATLAS)**

NAVARCH 440. Marine Dynamics II
Prerequisite: NAVARCH 321, NAVARCH 340. (4 credits)
Dynamic analysis in a fluid environment. Rayleigh's principle for continuous systems. Equations of motion for ship rigid body dynamics. Wave excitation. Response Amplitude Operator (RAO). Random processes and probability. Motion in irregular seas. Introduction to time series analysis. **CourseProfile (ATLAS)**

NAVARCH 451. Introduction to Offshore Engineering
Prerequisite: None. Advised Prerequisite: Senior standing or higher. (3 credits)
Design concepts in offshore engineering for drilling/production of oil/gas. Wave force calculation methods. Correction of linear wave theory. Forces on cylinders. Vortex induced vibrations (VIV), galloping. Suppression of VIV. Enhancement of VIV and galloping for hydrokinetic energy harnessing. Mooring dynamics. Riser mechanics. Lab experiments for VIV, galloping and mooring. **CourseProfile (ATLAS)**

NAVARCH 461 (MFG 462). Marine Structures Construction
Prerequisite: None. Advised Prerequisite: 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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

NAVARCH 471. Advanced Ship Design
Advised Prerequisite: NA 470, 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. **CourseProfile (ATLAS)**

NAVARCH 475. Capstone Design Project
Prerequisite: NAVARCH 470. Minimum grade requirement of C- for enforced prerequisite. (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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

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, hydro-elasticity, 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, Eigenvectyors. 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)
Basic equations of three dimensional elasticity. Derivation of relevant variational principles. Finite element approximation. Convergence requirements. Isoparametric elements in two and three dimensions. Implementational considerations. Locking phenomena. Problems involving non-linear material behavior. **CourseProfile (ATLAS)**

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 stern flaps, lifting bodies and bulbous bows. **CourseProfile (ATLAS)**

NAVARCH 540. Marine Dynamics II
Prerequisite: NAVARCH 340 (4 credits)
Fundamental analysis of marine dynamical systems. Normal mode analysis. Matrix representation of frequency domain seakeeping equations. Properties of linear gravity waves. Wave forces on marine structures. Linear and non-linear time domain seakeeping and maneuvering simulations. Nonlinear stability and bifurcation theory applied to mooring and capsizing. Shock mitigation. **CourseProfile (ATLAS)**

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 **CourseProfile (ATLAS)**

NAVARCH 551. Offshore Engineering I
Prerequisite: Graduate student standing or permission of instructor. (3 credits)
Offshore engineering structures. Introduction to hydrodynamic loads on offshore platforms. Detailed study of forces on slender bodies – risers, pipelines, cables. Morison's equation. Flow induced motions, vortex induced vibrations, galloping. Two-cylinder flows. Mathematical modeling, experiments, data processing. Marine hydrokinetic energy harnessing. **CourseProfile (ATLAS)**

NAVARCH 552. Offshore Engineering II
Advised Prerequisite: NAVARCH 551. (3 credits)
Design and analysis requirements of offshore engineering structures. Hydrodynamic loads on offshore platforms. Wave theories applied in offshore engineering. Marine riser mechanics: dynamics and structural stability. Mooring dynamics: nonlinear stability and design. **CourseProfile (ATLAS)**

NAVARCH 562 (MFG 563). Marine Systems Production Business Strategy and Operations Management
Advised Prerequisite: 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. **CourseProfile (ATLAS)**

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. **CourseProfile (ATLAS)**

NAVARCH 568 (EECS 568 & ROB 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. **CourseProfile (ATLAS)**

NAVARCH 569 (ROB 572). Marine Robotics
Advisory Prerequisite: Computational Linear Algebra (ROB 101) or Linear Algebra (MATH 214, MATH 217, MATH 417, or MATH 419) or graduate standing; proficiency in MATLAB. (3 credits)
Overview of marine robotic systems, including autonomous surface vehicles, remotely operated vehicles, and autonomous underwater vehicles. Topics include vehicle design, kinematic and dynamic modeling, control, sensing, and navigation. Examples draw from real robotic missions across a range of applications from inspection of critical subsea infrastructure to exploration of ocean worlds. **CourseProfile (ATLAS)**

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)
Brief review of probability and statistics. Mathematical methods of reliability analysis for systems with or without repairs. Reliability, availability, maintenance, replacement, and repair decisions. Safety and risk analysis. Risk assessment methods and case Studies. FMEA, fault tree and event tree analysis. Marine, Automotive, Manufacturing, Health Care and other applications. **CourseProfile (ATLAS)**

NAVARCH 583. Adaptive Control
Prerequisite: Graduate standing or permission of instructor. Not Offered On Regular Basis (3 credits)
Models of systems with unknown or time-varying parameters. Theory and algorithm for online parameter identification. Adaptive observers. Direct and indirect adaptive control. Model reference adaptive control. Robustness and convergence of adaptive systems. Design and analysis of nonlinear adaptive control. Application and implementation of adaptive systems. **CourseProfile (ATLAS)**

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 dynamic (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)**

700 Level Courses

NAVARCH 792. Professional Degree Thesis
(2-8 credits); (1-4 credits)
CourseProfile (ATLAS)

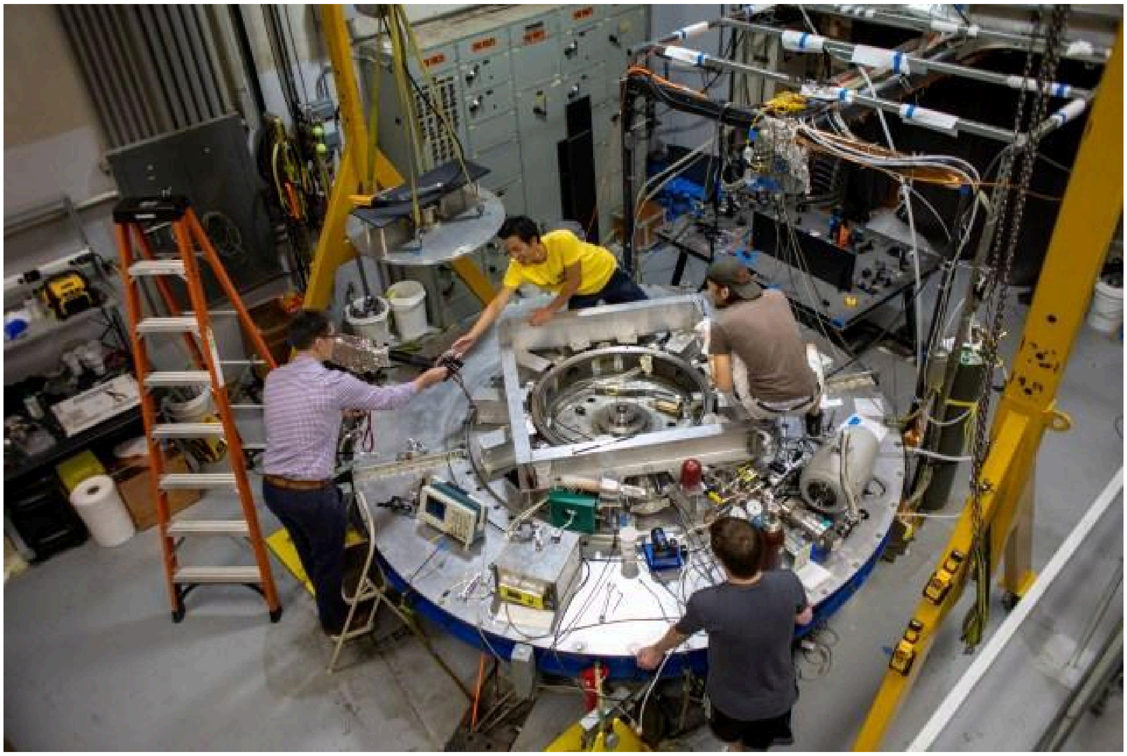
900 Level Courses

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)**

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)**

Nuclear Engineering & Radiological Sciences

Nuclear Engineering and Radiological Sciences (NERS)



Nuclear engineers contribute to the world in four major areas: Clean Zero-carbon Energy Production, Nuclear Security and Homeland Defense, Environment and Health, and Scientific Discovery. The NERS undergraduate program lays the foundation to allow graduates to contribute across these important areas. The NERS undergraduate program lays a firm foundation in both mathematics and basic sciences. As a result, students spend most of the first four semesters developing a broad background in physics, math, chemistry, computing and engineering principles before delving into nuclear engineering courses in their junior and senior years. They develop special expertise in atomic and nuclear physics, nuclear processes and the interactions between matter and radiation. Students learn to apply this knowledge to identify and solve engineering problems and conduct engineering experiments. This includes developing systems, processes and components for nuclear or radiological applications, with a close eye on radiation safety and environmental protection. In addition to nuclear engineering and radiological concepts, students use modern tools and techniques and work in multidisciplinary teams that reflect real-world engineering projects. They also engage with the environmental, social, political and ethical aspects of the field.

The undergraduate program in nuclear engineering and radiological sciences leads to the Bachelor of Science in Engineering (B.S.E.) in N.E.R.S.

Course Guide

Nuclear Engineering and Radiological Sciences Courses

Contact

Departmental Website: https://ners.engin.umich.edu/

Nuclear Engineering and Radiological Sciences Department
1906 Cooley Memorial Laboratory
2355 Bonisteel Blvd.
Ann Arbor, MI 48109-2104

Email: mlwhit@umich.edu
Phone: 734-936-3130
Fax: (734) 763-4540

Department Administration

Department Chair
Todd Allen, Glenn F. and Gladys H. Knoll Chair and Professor
3001 Michigan Mem Phoenix Project

For more specific information on contacting people, go to our contacts page.

Mission

To be the global academic leader in the innovation and evolution of nuclear engineering, uses of radiation, and plasma science.

Goals

The program provides students with:

- skills and tools necessary for industrial, medical, governmental and environmental applications of nuclear processes and radiation.
- insights and skills that will prepare them to be leaders in research and the practice of nuclear engineering and radiological sciences within 5 to 10 years of graduation.

Objectives

Within 5-10 years after graduating our students will be able to:

- Use their understanding of nuclear, radiological, and plasma technology to perform analyses and measurements related to radiation and radiation interactions with matter, nuclear power systems, and health physics design and analyses, in industry, government agencies, or academic environments.

- Adapt to the rapidly changing scientific and technological landscape, recognize the implications of their work, drive the development of future technologies, and engage in life-long learning and the continual improvement of their skills and knowledge.
- Communicate effectively with their colleagues and students, and positively influence policy makers and the general public.
- Contribute substantively as leaders in science, technology, the environment, and society.

Outcomes

Graduates of the program will have:

- 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

The University Registrar publishes ***the number of students enrolled annually in this program*** *and* ***the number of degrees granted each term by this program****. Additionally you can see recent degrees granted below:*

Level	2021	2022	2023
Bachelors Degrees	23	19	17
Masters Degrees	32	17	15
Doctoral Degrees	20	19	15

Accreditation

The Nuclear Engineering (B.S.E.) program is accredited by the Engineering Accreditation Commission of ABET, under the General Criteria and the Nuclear, Radiological, and Similarly Named Engineering Programs Program Criteria.

Program Outcomes

The matrix maps how each course in our curriculum addresses our program outcomes. Only the outcomes tracked are noted below. Please review the NERS Accreditation website for further information.

Course	Student Outcomes (Black – High)						
	Apply math and science	Design	Communicate	Ethics	Teams	Experiments, Analyze, and Interpret Data	Lifelong Learning
NERS250			■	■			
NERS311	■						
NERS312	■						
NERS315			■		■	■	
NERS320							■
NERS344							■

NERS421							
NERS425							
NERS441							
NERS444							
NERS471							
NERS484							
NERS491							
NERS492							
NERS535							
NERS575							

NERS586			[redacted]			[redacted]	

Undergraduate Degree Program

Sample Schedule

B.S.E. in Nuclear Engineering and Radiological Sciences

Please see the PDF version of the sample schedule. Additional information can be found on the NERS Department Advising website.

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 office to learn more about the SUGS application process and procedures. SUGS admissions requirements will vary.

For further information, please review the NERS Degree Options website.

Available programs include:

- B.S.E. in Nuclear Engineering and Radiological Sciences/M.S. in Nuclear Engineering and Radiological Sciences
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.S. in Biomedical Engineering
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.Eng. in Automotive Engineering
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.Eng. in Energy Systems Engineering
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.Eng. in Global Automotive and Manufacturing Engineering
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.Eng. in Manufacturing
- B.S.E. in Nuclear Engineering and Radiological Sciences/M.Eng. in Systems Engineering + Design

M.S. and M.S.E. Programs

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

- **Undergraduate Preparation:** Entrance requirements are NERS 311, 312, and 320 (or their equivalents) and may NOT be applied towards the 30 hours for the Master's Degree.
- **Bachelor of Science (BS):** Apply for the Master of Science (M.S.)
- **Bachelor of Science in Engineering (BSE):** Apply for the Master of Science in Engineering (M.S.E.)

Please review the "Checklist for Master's Degree Requirements" available in the department office and online.

Nuclear Engineering and Radiological Sciences, M.S.E.

Students entering the program must have a bachelor's degree from an accredited engineering program.

Nuclear Science, M.S.

The Nuclear Science program is available to those with bachelor's degrees from recognized programs in physics, chemistry, or mathematics who wish to work in the field of nuclear engineering and radiological sciences.

Master's Graduation Requirements

The Master's Degree in Nuclear Engineering and Radiological Sciences requires 30 hours of coursework at the graduate level, including 20 hours from NERS (of which four courses must be at the 500 level or above). Rackham requires a minimum of four credit hours of cognate graduate-level coursework. NERS requires that the cognate courses be related to the student's degree program and should be chosen with the advice of the student's graduate advisor. A student must also take at least one 400 level or higher laboratory course for the M.S. degree while a graduate student. The average grade in NERS courses must be a B (a grade point of 3.0/4.0) or better, and the average grade for all courses must also be a B or higher. Undergraduates who earned the following degrees should apply for the corresponding diplomas.

Master's Project: (Optional)

The student, with approval of the student's graduate advisor, may substitute a master's project report for two to six credit hours of graduate coursework (NERS 599). In addition to a written final report, the student will be required to make a seminar presentation on the master's project.

Minimum number of credits required: 30 credit hours.

Ph.D. Programs

Nuclear Engineering and Radiological Sciences, Ph.D. Nuclear Science, Ph.D.

The doctoral degree is conferred in recognition of marked ability and scholarship in some relatively broad fields 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 Rackham and the advisor. 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. The selected fields (options) are:

- Fission Systems and Radiation Transport
- Materials and Radiation Effects
- Plasma and Nuclear Fusion
- Radiation Measurements and Imaging

Ph.D. Candidacy and Graduation Requirements

- Laboratory course requirement
- Breadth course requirements
- NERS candidacy requirements
- Thesis prospectus
- Dissertation and dissertation defense

Laboratory Course Requirement

All Ph.D. students must take NERS 515, Nuclear Measurements Laboratory, and obtain a grade of B (3.0/4.0) or better. Students who have taken NERS 315 as an undergraduate must instead take one of NERS 425, NERS 535, NERS 575, NERS 586, NERS 590 (Transmission Electron Microscopy Lab), MSE 562 or AEROSP 521. The student's advisor and Ph.D. graduate program chair must approve in writing any variances and substitutions.

Breadth Course Requirements

All Ph.D. students must take and obtain a grade of B (3.0/4.0) or better in 6 credit hours of NERS courses selected from outside the student's option, as defined by the following lists of courses. Courses not listed do not satisfy this requirement; the student's advisor and graduate chair must approve any variances in writing. The purpose of this requirement is to ensure the breadth of nuclear engineering and radiological science education of our Ph.D. students and to ensure that the student is exposed to the quantitative analytical methods used in other specialties in the field. A laboratory course used to satisfy this breadth requirement cannot be used to satisfy the laboratory requirement (above). Breadth courses are not required for candidacy; however, they are required for final degree approval.

Breadth Requirement Courses and Option Classification:

Fission Systems and Radiation Transport: NERS 441, 442, 444, 462, 543, 544*, 546, 547, 551, 554*, 561, 590**, 644

Materials: NERS 521, 522, 524, 531, 622

Measurements: NERS 481, 484, 518, 535, 580, 582, 583, 586, 587

Plasmas and Fusion: NERS 471, 472 571, 572, 573, 574, 575, 576, 577, 578

*Students in the Measurements Option cannot elect these courses as breadth courses

**590 Computational Transport Methods

**590 Solvers for Nuclear Applications

NERS and Rackham Candidacy Requirements

- Time to Candidacy – A student must achieve candidacy within two (2) years after the first enrollment in the NERS Ph.D. program.
- Coursework In Residence – A pre-candidate must complete at least 18 credit hours of graded (including the grade of S – Satisfactory) graduate coursework registered as a Rackham student while in residence on the Ann Arbor campus.
    - Courses elected as visit (audit) do not meet this requirement, nor do any doctoral courses (those designated as 990, etc.).
- Courses elected as visit (audit) do not meet this requirement, nor do any doctoral courses (those designated as 990, etc.).
- Cognate Requirement – Before advancing to candidacy, students must complete 4 credit hours of cognate coursework with a grade of B or better according to the NERS graduation requirements. Additional Rackham requirements can be found on the Rackham Graduate School Academic Policies website.
- All courses in Responsible Conduct of Research and Scholarship (RCRS) for Ph.D. students must be completed. Please review the Responsible Conduct of Research and Scholarship website for further details.

Advancement to Candidacy

The entire NERS faculty will decide a student's advancement to candidacy based on a broad assessment of the student's performance on a written examination, the student's academic and research record, and the recommendation of the student's advisor.

The written examination is a six-hour test in a specific option: 1) Fission Systems and Radiation Transport; 2) Plasmas and Nuclear Fusion; 3) Materials and Radiation Effects; 4) Radiation Measurements and Imaging; or 5) an alternative area approved in advance by the NERS Executive Committee. The exam will cover topics at the graduate level. Students are encouraged to discuss with their research advisor specific topics covered and relevant courses. The written exam is prepared by the examination committee in each option and is given twice a year, in January and May.

To take the written exam, a student must be a doctoral pre-candidate in good standing with the graduate school, have identified a thesis advisor, and have a minimum graduate GPA of 3.3 (B+) at the time of the exam. Exceptions will be considered by petition to the departmental graduate committee. Also, a student must receive the written approval of their advisor and the NERS Graduate Chair.

The written exam will be graded anonymously, and scores will be communicated to the student within two weeks of the exam. The student will be considered by the option faculty for advancement to candidacy within a month of the written exam, taking into account the score on the written exam, the student's academic and research record, and the input of the student's advisor. A recommendation on advancement to candidacy will be prepared by the option faculty for the full NERS faculty, who will decide each case. If the faculty decision is not to advance the student to candidacy, the student will be informed of the reasons for the decision and the specific recommendations of the faculty. A student may be considered for candidacy a second time, but attempts beyond the second will require approval of the department faculty.

Note on advancement to candidacy: before the student advances to candidacy, the department will audit the student's Ph.D. checklist to ensure that all candidacy requirements have been met. The breadth courses are not required for candidacy, but they must be taken before completion of the doctoral degree.

Dissertation Prospectus

A thesis prospectus exam is required for completion of the Ph.D. degree. It is recommended that this exam is taken within 12 months of achieving candidacy status, and after the candidate has formed a dissertation committee.

The exam will consist of a presentation by the candidate on their proposed research program, lasting about 30 minutes, followed by questioning. After questions covering the presentation material, questions of a more fundamental but related nature may be introduced. These questions may cover material found in standard undergraduate or introductory graduate NERS courses. This question period is nominally expected to last 60 minutes.

This examining committee will consist of at least three members of the student's dissertation committee (the full committee will be invited), and one randomly selected NERS faculty member from outside the candidate's dissertation committee. The chair of the examining committee will be the student's dissertation committee chair. Following the questioning the examining committee will discuss the proposed research and prospectus, and vote on passing or failing the student; their decision will be communicated to the student as soon afterward as practicable, generally along with suggestions for the direction of the research, and to the NERS faculty as a whole at the next faculty meeting.

This exam may be attempted twice; the second attempt must occur within 12 months of the first. Additional attempts beyond the second will require approval of the NERS faculty.

The thesis prospectus will be scheduled at the advisor's request. The student should then submit their name, option, research topic, and an abstract to the departmental graduate coordinator, along with some dates that both the advisor and student find convenient. The graduate coordinator will then set the committee, schedule the exam, and reserve the room for the exam.

Dissertation and Dissertation Defense

Ph.D. students must complete a written dissertation describing an original, substantive, and scholarly contribution to their field of study. A dissertation committee, chaired by the student's research advisor(s), will read this dissertation and its abstract and judge their adequacy. The committee may require changes to the dissertation. Each student must also present and successfully defend their dissertation work at a public meeting.

Nuclear Engineering and Radiological Sciences Courses (NERS)

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
Advisory Prerequisite: preceded or accompanied by Math 216. (4 credits)
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 of interest such as radon, radioactive waste, and nuclear proliferation.

NERS 250. Fundamentals of Nuclear Engineering and Radiological Sciences
Prerequisite: Preceded or accompanied by Math 216 and Physics 240. No OP/F. (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)
Advisory prerequisite: NERS 311.

Nuclear properties. Radioactive decay. Alpha-, beta- and gamma- decays of nuclei. Nuclear fission and fusion. Radiation interactions and reaction cross-sections.

NERS 315. Nuclear Instrumentation Laboratory
Prerequisites: EECS 215 or EECS 314; preceded or accompanied by NERS 312. Minimum grade of C, No OP/F. (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
Prerequisite: Math 216 or 286/396. Minimum grade of C, No OP/F. (4 credits)
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 reactor physics, radiation transport, and reliability analysis.

NERS 344. Fluid Mechanics for Nuclear Engineers
Prerequisite: NERS 311 and MECHENG 235. Minimum Grade of C, No OP/F. (3 credits)
Mass, momentum, and energy balance in lumped-parameter and differential forms. Hydrostatics. Laminar and turbulent flow in pipes. Application of fluid mechanics to nuclear components and systems.

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 and NERS 320, (No OP/F) or graduate standing. Minimum grade requirement of C for enforced prerequisites. (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. Fundamentals of Heat and Mass Transfer
Prerequisite: NERS 344 (minimum grade of C); or graduate standing; or permission of instructor. (3 credits)

The objective of the course is to study the physical mechanisms underlying heat transfer modes, and the fundamental principles and laws of heat transfer. The course includes heat conduction, convective heat transfer, and heat transfer by radiation. A broad range of real-world applications is used to develop problem-solving skills.

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). Team selection, background literature review, identification/ familiarization with computational tools, writing reports, making presentations, writing a final report, and giving a final oral presentation. Experiments/Projects are overseen/graded by faculty and also involve mentoring by representatives from external organizations.

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. Present results in oral and written progress reports including a final presentation to the NERS community. Experiments/Projects are overseen/graded by faculty and also involve mentoring by representatives from external organizations.

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 Schroedinger equation and neutron-wave equations, neutron absorption, neutron scattering, details of neutron-nuclear reactions, cross sections, the Breit-Wigner formula, neutron diffraction, nuclear fission, transuranic elements, the deuteron problem, masers and lasers.

NERS 512. Interaction of Radiation and Matter
Prerequisite: NERS 511. (3 credits)
Classical and quantum-mechanical analysis of the processes by which radiation interacts with matter. Review of nuclear structure and properties. Nuclear models. Nuclei as sources of radiation. Interaction of electromagnetic radiation with matter. Interaction of charged particles with matter. Radiative collisions and theory of Bremsstrahlung. Interaction of neutrons with matter. Interaction mechanisms and cross sections are developed.

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_n and B methods, collision probabilities and Monte Carlo methods.

NERS 544. Monte Carlo Methods
Prerequisite: Graduate standing in Engineering, Mathematics or Sciences. (3 credits)
Monte Carlo methods are applicable to a broad range of scientific disciplines. Topics include probability and statistics, generation of random variates, discrete and continuous Markov chains, random processes, Markov Chain Monte Carlo, simulated annealing, estimation techniques, variance reduction, perturbation methods, Green's functions, and diffusion processes. Includes applications to 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)
Derivation and solution of point reactor kinetic equations. Concept of reactivity, inhour equations and reactor transfer function. Linear stability analysis of reactors. Reactivity feedback and nonlinear kinetics. Space-dependent reactor kinetics and xenon oscillations. Introduction to reactor noise analysis.

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 561. 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 562. 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)
An introduction to plasma simulation techniques, including fluid and Vlasov descriptions. Stability analysis. Finite difference and volume methods. The particle-in-cell method. Boundary conditions. Field solvers. Students will develop an understanding in the relationship between the hierarchy of kinetic models describing plasmas and their numerical equivalents. A series of short projects will demonstrate numerical modeling of plasma phenomena.

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)
Principles of electrostatic and electrodynamic charged particle accelerators, magnetic and electrostatic focusing, transient analysis of pulsed accelerators. Generation of intense electron and ion beams. Dynamics, stability, and beam transport in vacuum, neutral and ionized gases. Intense beams as drivers of coherent radiation generation. Novel accelerations using plasma and dielectric materials.

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 315/NERS 515 or equivalent. No OP/F. Advisory Prerequisite: NERS 484. (4 credits)
Instrumentation and applied measurements of interest for radiation safety, nuclear engineering, environmental sciences, and medical physics. Calibrations, surveys, quality control, dosimeters, radon gas, beta and gamma ray spectroscopy, background radiation, applied electronics, and other selected practical considerations. Oral and written technical communications.

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 672 (SPACE 545). High Energy Density Physics
*Prerequisite: None. Advisory Prerequisite: MATH 450, PHYSICS 405 & PHYSICS 40*6. *(3 credits)*
Fundamental tools and discoveries of high-energy density physics, where pressures are above a million atmospheres. Fundamental physical models, equations of state, hydrodynamics including shocks and instabilities, radiation transport, radiation hydrodynamics, experimental technique, inertial fusion, experimental astrophysics and relativistic systems.

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 (APPPHYS 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.

NERS 675 (ECE 510). Plasma Chemistry and Plasma Surface Interactions
Prerequisite: ECE 517, permission of instructor, or graduate standing. (3 credits)
Focuses on the plasma chemistry and plasma-surface interactions occurring in low temperature plasmas as used in, for example, materials processing, chemical conversion, biotechnology, environmental

remediation, and photon sources. Emphasis is on the atomic and molecular processes that produce chemically reactive species by electron and ion-molecule collisions, neutral-neutral reactions; and reactions with inorganic, organic and liquid surfaces. Plasma-surface interactions will be addressed that result in deposition, etching and sputtering. Radiation transport producing photoionization and photodissociation, and trapping will be discussed.

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.

NERS 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 (ROB)

U-M Robotics has been formed for innovation, building on the foundation of U-M Engineering and furthering the spirit of "Robotics with Respect." Michigan Robotics aims to meet undergraduate and graduate intellectual needs by inspiring students from their first day on campus and cultivating equitable opportunities for a diverse world. Our society has a growing and unmet demand for people skilled in robotics. Our objectives are to equip students with the foundational skills and knowledge they need to meet these challenges, affect positive systemic change, and prepare future generations for a highly dynamic innovation ecosystem.

In building the discipline of robotics, our principles organize around the definition of embodied intelligence provided by the National Science Foundation–essentially the idea that robots must sense, reason, act, and work with people to improve quality of life and productivity equitably across society. The study of robotics requires knowledge of how a robotic system sees its surroundings, how and what it can move around, how doing so will affect its surroundings, and how its actions impact the humans with whom it interacts.

While specific research questions in robotics can become much more technical, at the top level, they fall within the broad categories of how robots sense, reason, and act–on their own, or while working with or around people. The requirements and learning objectives for our undergraduate and graduate programs are organized around these principles of embodied intelligence. We are confident this learning framework will help students thrive as roboticists and enable them to continuously grow throughout their careers.

Michigan Robotics currently offers an undergraduate major, launched in Fall 2022, and Master's and Ph.D. degrees, which have been flourishing since their creation in Fall 2014.

The program combines a rigorous set of core classes, giving students the needed technical foundation, with a wide set of electives, allowing students the flexibility to specialize in different areas within robotics. Our near-term goals include expanding the program to offer a Robotics minor and SUGS program.

The M.S. and Ph.D. programs share a common set of course requirements. Ph.D. students must additionally complete a set of qualifying exams to become Ph.D. candidates, and then complete a thesis.

The academic mission and programs of Michigan Robotics are instantiated into the following core Robotics technical areas that build up embodied intelligence:

- Sensing of the environment, external agents such as other robots or humans, and internal body information to infer and perceive the state of the world
- Reasoning with estimated models of the world to make decisions to accomplish tasks, satisfy goals, and learn from experience and interaction
- Acting upon its body and environment to produce motion or other outputs that enable the robot to achieve desired effects on the physical world and interact with people
- Understanding human and social dynamics, both quantitatively and qualitatively, for robots to effectively work with people and evaluate their impact on society

Each of these areas may be considered threads of emphasis for coursework and research study.

Course Guide

Robotics Courses

Contact

Website:
http://robotics.umich.edu/

General Email: robotics-contact@umich.edu

Undergraduate & Graduate Programs: robotics-sso@umich.edu

Faculty: http://robotics.umich.edu/faculty

Social: Twitter | Instagram | YouTube

Mission

Michigan Robotics continually strives to realize a collaborative and inclusive community of scholars that uplifts the discipline of robotics through advancing and teaching its organizing principles of embodied intelligence – the idea that robots must sense, reason, act, and work with people to improve quality of life and productivity equitably across society.

Goals

The department aims to foster technical aptitude in robotics hardware, robotics software, and how robots relate to people, their environment, and their greater impact, all while growing skills in collaboration and communication that are necessary for students to become successful roboticists in industry, academe, and society. Roboticists from Michigan will become leaders in technical expertise and integrity in a field with transformational potential for societal change.

Objectives

Michigan Robotics will graduate students who are highly competent in the following areas:

- Foundational Learning Objectives:
    - Computational fluency to express ideas through coding –"coding is believing"
    - Design, Maker, and Shop competency for realizing systems that can function in the physical world
    - Linear algebra to structure, process, and manipulate data at scale
    - Human and social dynamics to work in teams and develop solutions for people
    - Technical communication and project management to understand and meet the needs of stakeholders in a professional and conscientious manner
- Intermediate Robotics Concepts: Sound understanding in at least 3 of the following core areas of robotics:
    - Localization and mapping for autonomous navigation under uncertainty
    - Reasoning, kinematics, and simulation for robots performing autonomous mobility and dexterous manipulation tasks
    - Mechanical design and dynamics for fabrication and sensorimotor control of physical robot systems
    - Electrical sensors and signals for the design of robot circuitry and embedded systems
    - Human-robot interaction for measuring and quantifying robot efficacy
- Advances and applications in Robotics:
    - Explore and extend cutting-edge knowledge across the sensing, reasoning, acting, and human-centered dimensions of robotics

Outcomes

The following objectives describe what Robotics graduates are expected to achieve within several years of graduation:

- The graduates of Michigan Robotics will have the necessary intellectual tools and technical skills to take on careers of leadership in the development of new robotics technologies spanning the breadth of sensing, reasoning, acting, and working with people

- Graduates will have a solid foundation in robotics and achieve success in graduate education and a broad range of career opportunities
- Our graduates will become dynamic and inclusive team leaders, respectful collaborators, and have the critical thinking skills to successfully innovate and address open-ended problems
- Michigan Robotics graduates will become effective communicators of technical and professional information in written, oral, visual, and graphical form
- Our graduates will distinguish themselves by both their high awareness and positive practice of moral, ethical, legal, and professional obligations, including how robotics integrates with all aspects of society

Enrollment and Graduation Data

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

Sample Schedule

B.S.E. in Robotics

Please see the PDF version of the **sample schedule**. Additional information can be found on the Robotics Department website.

Designing your Degree

The Robotics BSE is designed to allow students a high degree of flexibility in creating their undergraduate experience. Students can select different combinations of core classes and electives in order to focus on different elements or topics within robotics. While we do not offer official concentrations, we have provided several examples of how students can select classes that will enable them to focus on different areas. The Undergraduate Program Guide contains four eight-semester (four-year) sample schedules to help students envision how requirements may fit together over their time at Michigan. Each plan is only a sample of what is possible. These sample schedules are intended to represent several common interest areas but are not the only areas on which students can focus. It is not necessary to follow the sample schedules exactly, but your degree progress must respect the prerequisite chains.

These sample schedules provide four different pathways for a Robotics Major:

- Computing-focused robot autonomy
- Hardware-focused robot mechanisms
- Empiricism-focused human-robot interaction, and
- Breadth-focused well-rounded robotics

These different pathways arise from the choice of courses taken among the intermediate (300-level) Robotics courses. Robotics majors must complete at least 3 out of 5 of these courses, with the flexibility to take all five. This structure of the intermediate level of the degree allows students to customize for either breadth or depth in robotics, taking inspiration from the threaded approach to curriculum design for computing. Students can begin to specialize at the intermediate level while gaining sufficient overlap with the core of the discipline. More specifically, Robotics majors will have touch points into at least two of the three major groupings of core robotics topics.

Each sample schedule emphasizes different dimensions of robotics. A student striving to be a well-rounded roboticist can take all five intermediate-level courses, where two can serve as upper-level electives. A student looking to specialize can complement their learning at the intermediate level with upper-level elective courses. Both breadth and depth pathways through the intermediate level provide a suitable foundation for further exploration in upper-level courses, as well as continued learning into other core areas of robotics.

Graduate Degrees

- Master of Science (M.S.) in Robotics
- Doctor of Philosophy (Ph.D.) in Robotics

M.S. in Robotics

The Robotics Master's (M.S.) Degree program requires completion of 30 credits of letter-graded coursework including 3 to 6 credits of directed study.

The Michigan Robotics graduate program consists of three main technical areas, which converge as students produce functioning robots:

- Sensing of the environment, external agents, and internal body information to determine state information
- Reasoning with that information to make decisions for guidance, control, and localization
- Acting upon the body and environment to produce motion or other outputs that enable the robot to locomote or interact with the environment

MS students must take courses from all three of these areas as part of their degree program with the goal of assisting them to become well-rounded and technically proficient roboticists.

For more details on the MS degree requirements, please see our Graduate Program Manual, located on our Current Student Resources page.

Ph.D. in Robotics

The Robotics Ph.D. degree program requires completion of at least 36 credits of letter-graded coursework, with courses drawn from across the areas of Sensing, Reasoning, and Acting. All Ph.D. students are admitted into a specific research lab led by a Robotics faculty member, under whom they will conduct their Ph.D. studies and research.

Ph.D. students complete several common milestones throughout their degree, including:

1. Research and coursework
2. Comprehensive Qualifying Examination (CQE Exam)
3. Advancement to candidacy
4. Dissertation proposal examination
5. Thesis dissertation (written) and defense (oral)

For more details on the Ph.D. degree requirements, please see our Grad Program Manual, located on our Current Student Resources page.

Robotics Courses (ROB)

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)
Linear algebra and computation as a means for reasoning about data and making discoveries about the world. Topics: The Julia programming language. Systems of linear equations. Vectors, matrices, inverses. Regression. Matrix factorization. Spatial coordinates. Cameras, LiDARS, accelerometers, single-axis gyroscopes, encoders. Optimization and robot perception. What is an ODE. **CourseProfile (ATLAS)**

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)**

200 Level Courses

ROB 203. Robotics Mechanisms
Advisory Prerequisite: ROB 101. Enforced Prerequisite: No credit in ENGR 100, topic "Robotics Mechanisms (topic ID 29)". (2 credits)
Hands-on design, build, and operations of robotic systems. Students develop maker-shop skills (3D printing, laser cutting, milling, etc.), gain experience in embedded programming and controls, system design and integration. **CourseProfile (ATLAS)**

ROB 204. Introduction to Human-Robot Systems
Prerequisite: (ROB 102 or ENGR 101 or EECS 183 or ENGR 151 or EECS 180); and ENGR 100; and preceded or accompanied by: (ROB 101 or MATH 214 or MATH 217 or MATH 417 or MATH 419). Minimum grade requirement of "C-" for enforced prerequisite. (4 credits)
Foundations in human-robot systems. Covers identifying and describing how human capabilities and behaviors inform robotic design. Survey of theories, methods, and findings from relevant domains (e.g., cognitive/physical ergonomics, psychology, human-centered design), with attention to how these concepts influence robotic systems and design within development teams. **CourseProfile (ATLAS)**

ROB 290. Directed Study
Prerequisites: None. (1-6 credits)
Individual study of specialized aspects of robotics. Undergraduate students only. **CourseProfile (ATLAS)**

ROB 298. Special Topics in Robotics
Prerequisites: None. (1-8 credits)
Topics of current interest in Robotics. **CourseProfile (ATLAS)**

300 Level Courses

ROB 310. Robot Sensors and Signals
Prerequisite: ROB 204 and (EECS 215 or BME 211). Minimum grade requirement of "C-" for enforced prerequisite. Advisory Prerequisite: ROB 101 (Computational Linear Algebra) and ROB 103 (Robotic Mechanisms) (4 credits)
Covers practical analog and digital electronics for robotics. Students will: prototype, test, and debug various analog and digital circuits; interface a microcontroller to external circuits; learn to design and prototype circuit boards; interpret data recorded from physical circuits. An exploration of circuits and embedded systems that supports integrated robotic design. **CourseProfile (ATLAS)**

ROB 311. How to Build Robots and Make Them Move
Enforced Prerequisite: ROB 204. Minimum grade requirement of "C-" for enforced prerequisite. Advisory Prerequisite: (EECS 215 or PHYSICS 240 or PHYSICS 260 or MECHENG 240 or BIOMEDE 231) and ROB 310. (4 credits)
Introduces the fundamentals of mechanical design, control, fabrication, actuation, instrumentation, and computer interfaces required to realize robotic systems. Students will learn to analyze/simulate rigid body kinematics, kinetics, and dynamics, as well as assess the impedance properties of their designs. 'Hands-on' skills will be emphasized in addition to theoretical concepts. **CourseProfile (ATLAS)**

ROB 320. Robot Operating Systems
Prerequisite: ROB 204 and EECS 280. Minimum grade requirement of "C-" for enforced prerequisite. Credit Exclusions: Only 1 course may earn credit from ROB 320, ROB 380, ROB 511, and EECS 367. (4 credits)
General computational paradigm for robot operating systems that model, simulate, and control mobile manipulation robots. Composition of full-stack software systems for forward and inverse kinematics, planar path planning, high-dimensional motion planning, maximal coordinate robot simulation, and front-end visualization that work through interprocess communication. **CourseProfile (ATLAS)**

ROB 330. Localization, Mapping, and Navigation
Enforced Prerequisite: ROB 204 and EECS 280. Minimum grade requirement of "C-" for enforced prerequisite. Advisory Prerequisite: (IOE 265 or EECS 301) and (MECHENG 240 or MECHENG 360) and (MATH 215 or MATH 216). (4 credits)
Development of full-stack autonomous navigation and mapping for mobile robots. Topics include dead reckoning from odometry, sensor modeling of LIDAR and cameras, visual odometry, path planning, and simultaneous localization and mapping (SLAM). **CourseProfile (ATLAS)**

ROB 340. Human-Robot Interaction
Prerequisite: ROB 204. Minimum grade requirement of "C-" for enforced prerequisite. Advisory Prerequisite: ROB 311 (4 credits)
Covers psychophysics, modeling a human operator within a control loop, and measuring human performance in the context of robotic systems. These topics support robotic systems in unstructured and unknown environments with a human supporting decision making, mitigating risks and extending capabilities of the human-robot team. **CourseProfile (ATLAS)**

ROB 380 (EECS 367). Introduction to Autonomous Robotics
Prerequisite: EECS 281 and (MATH 214 or 217 or 296 or 417 or 419 or ROB 101); (C or better; no OP/F). Enrollment in one minor elective allowed for Computer Science Minors. Minimum grade requirement of "C" for enforced prerequisite. Credit Exclusions: Only 1 course may earn credit from ROB 320, ROB 380, ROB 511, and EECS 367. (4 credits)
A computational introduction to the modeling and control of autonomous robots and mobile manipulators. Programming projects and lectures cover 3D coordinate systems, axis-angle rotation, forward and inverse kinematics, physical simulation and numerical integration, motion control, path planning, high-dimensional motion planning, and robot software systems. Emphasizes portable programming of general robots. **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 requirement 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 450. Robotics Capstone
Prerequisite: Junior standing or senior standing and [TCHNCLCM 350, (C or better)] and [ONE of ROB 310, 311, 320, 330, or 340], (C or better)]. Minimum grade requirement of "C" for enforced prerequisites. (4 credits)
Primary goal is to challenge students to synthesize the knowledge acquired through their Robotics undergraduate courses at U-M using a systematic and iterative design and analysis process and applying it to solving a real open-ended Robotics problem. **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 requirement of "C" 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)**

ROB 490. Directed Study
Prerequisite: None. (1-6 credits)
Individual study of specialized aspects of robotics. Undergraduate students only. **CourseProfile (ATLAS)**

ROB 498. Special Topics in Robotics
Prerequisite: None. (1-8 credits)
Topics of current interest in robotics. **CourseProfile (ATLAS)**

500 Level Courses

ROB 501. Mathematics for Robotics
Prerequisite: Graduate standing or permission of instructor. Advisory Prerequisite: 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. Mobile Manipulation Systems
Advisory Prerequisite: Linear Algebra (Math 214, 217, 417, 419 or equivalent) and Programming (EECS 280, EECS 402, ROB 502 or equivalent). Prerequisite: None. Credit exclusions: Only 1 course may earn credit from ROB 320, ROB 380, ROB 511, and EECS 367. (3 credits)
Introduction to computational models, algorithms, and software systems for full-stack autonomous robot control that generalizes across a wide variety of mobile manipulation platforms. Topics include robot description conventions, path and motion planning, reactive control, forward and inverse kinematics, dynamical simulation, numerical integration, and robot middleware design. Extensive 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 560. BioInspired Robotic Design
Advisory Prerequisite: ROB 550. (4 credits)
Examines original scientific research to extract general principles that can be applied to robotics, such as: template and anchor models, walking, running, swimming, flying, sensing, and navigation. Students build functional prototypes and learn about the bioinspired design process through case studies that highlight health, the environment, and safety. **CourseProfile (ATLAS)**

ROB 572 (NAVARCH 569). Marine Robotics
Advisory Prerequisite: Computational Linear Algebra (ROB 101) or Linear Algebra (MATH 214, MATH 217, MATH 417, or MATH 419) or graduate standing; proficiency in MATLAB. (3 credits)
Overview of marine robotic systems, including autonomous surface vehicles, remotely operated vehicles, and autonomous underwater vehicles. Topics include vehicle design, kinematic and dynamic modeling, control, sensing, and navigation. Examples draw from real robotic missions across a range of applications from inspection of critical subsea infrastructure to exploration of ocean worlds. **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. Projects are overseen and graded by faculty and may also involve mentoring by representatives from industrial, governmental and/or non-profit organizations. **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: 1 previous election of ROB 590 (min 3 credits); AND Co-requisite: 1 additional election of ROB 590 (min 3 credits) which may be elected concurrently with ROB 690. Minimum grade requirement of "C" for enforced prerequisite. (1.5-3 credits)
Faculty-supervised research that culminates in a submitted and graded document styled as an original research manuscript. Builds on earlier research completed in six credits of ROB 590 and is letter graded. Projects are overseen/graded by faculty and may also involve mentoring by representatives from external organizations. **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. **CourseProfile (ATLAS)**

Engineering Division, Technical Communications, & UARTS Courses

Engineering Division Courses (ENGR)

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. Only 2 credits granted for ENGR 101 to those who have completed or are enrolled in ENGR 161; 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. Only 2 credits granted for ENGR 151 to those who have completed or are enrolled in ENGR 161. 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. **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) These credits do not earn CTP (Credit Towards Program).
Practical work experience related to the student's field of study in consultation with an academic advisor. **CourseProfile (ATLAS)**

200 Level Courses

ENGR 230. Honors Seminar I
Prerequisite: None. (1 credit)
This course provides the foundation for participation in the Honors Program. Students explore potential Honors capstone focus areas, reflect on individual academic growth and create a plan for development in several engineering core competency areas. Students work in small groups while participating in reflective and integrative learning exercise. Students engage in open dialogue on topics relevant to the engineering discipline. **CourseProfile (ATLAS)**

ENGR 255. Introductory Multidisciplinary Engineering Project
Prerequisite: None. (1-4 credits)
Intro course in which students acquire, develop, and refine skills for success in the modern engineering design process using faculty or faculty/industry 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) These credits do not earn CTP (Credit Towards Program).
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 330. Honors Seminar II
Prerequisite: None. (1 credit)
This course develops interpersonal and intrapersonal qualities that are essential tools for success as an engineer. Students further their understanding of strengths, consider values in the context of ethical decisions, deepen their understanding of social identity and priviledge and develop a clear personal vision and leadership philosophy. **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 engineering design process using faculty or faculty/industry 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, 286 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)**

400 Level Courses

ENGR 400. Engineering Cooperative Education
Prerequisite: Permission of program director. (no credit) These credits do not earn CTP (Credit Towards Program).
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 430. Honors Seminar III
Prerequisite: None. (1 credit)
This course supports integrative learning for students in the final year of the Honors Program. Students integrate learning from previous educational experiences to develop lifelong learning skills and prepare to contribute to the fields of science and engineering. Students provide mentorship to lower-division students on the creation of a personal development plan. **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. (1-4 credits)
Advanced course in which students acquire, develop, and refine skills for success in the modern engineering design process using faculty or faculty/industry 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
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)**

ENGR 499. Designing Your Engineering Future
Prerequisite: None. Advised Prerequisite: Students must have at least one experiential (i.e., active, concrete, contextual) encounter. (2 credits for full-term, 1 credit for half-term)
Students leverage past UM experiences to communicate their development of various professional competencies such as teamwork, leadership, ethics, entrepreneurial mindset, and creativity. Through discussions with peers and industry mentors, students will reflect on their experiences and create a set of guiding principles and a professional statement for their future. **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 570 (NERS 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.

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)
Graduate course in which students acquire, develop, and refine skills for success in the engineering design process using faculty or faculty/industry 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)**

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
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.

Technical Communications Courses (TCHNCLCM)

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

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)**

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)**

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)**

TCHNCLCM 350. Technical Communication for Robotics
Prerequisite: ROB 204 AND (ENGR 100 or ROB 103 or ENGL 124 or ENGL 125 or UA 150). Minimum grade of "C-" required for Enforced Prerequisite. Advised Prerequisite: 3 out of the following 5 courses: ROB 310, ROB 311, ROB 320, ROB 330, ROB 340. (3 credits)
Teaches students the communication skills needed to support the lifecycle of an engineering project in Robotics, including: communication to understand requirements, articulating those requirements, writing a proposal, communicating with one's team, sharing project updates, and presenting final project work. Includes career documents and best practices for visual communication. **CourseProfile (ATLAS)**

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)**

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)**

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: TCHNCLCM 300 OR TCHNCLCM 380 OR (BCOM 250 AND 350) OR ROB 204; Minimum grade of "C-" required for Enforced Prerequisite. BCOM 250 AND 350 accepted for Dual Business and Computer Science students. TCHNCLCM 380 accepted for Dual IOE and Computer Science students. ROBOTICS 204 accepted for Dual Robotics and Computer Science students. (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 (UARTS)

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. Writing and Interdisciplinary Collaborative Design
Prerequisite: None. (4 credits)
UARTS 150: Writing and Interdisciplinary Collaborative Design – 4-credit project-based/writing course for first-year students in Living ArtsEngine (engineering students take ENGIN100.210). Instructors from five different disciplines support exploration through a collaborative video game project – a multimodal essay combining architecture, art, design, engineering, music, and writing. Fulfills FYWR and Engineering 100.

UARTS 175. Collaborative Creative Project
Prerequisite: UARTS 150 or instructor permission. (1 credit)
Teams of Living ArtsEngine students will plan, implement, execute, iterate, and deliver solutions and/or physical prototypes to open-ended interdisciplinary design challenges. Students will present their creative ideas to others and apply feedback they receive to improve their work. A portfolio-style documentation process will be used to log each team's progress.

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. (1-5 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 275. Leading Collaborative Creative Projects
Prerequisite: None. (1 credit)
Through working with teams of Living ArtsEngine students engaged in project-based activities, peer mentors will study the intellectual underpinnings of interdisciplinary systems and methods of collaboration and design processes, acquire and practice the tools and methods of project management, and develop leadership skills in the management of interdisciplinary creative teams.

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. (1-5 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. (1-5 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. (1-5 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.