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Application Procedure

Institutional Admissions Requirements

The general requirements for admission to graduate study at the university are listed below.

1. The applicant must show official evidence of having earned a baccalaureate degree or its U.S. equivalent from an accredited college or university. If an international transcript does not adequately demonstrate that an applicant has the equivalent of an American bachelor’s or master’s degree, the Office of Graduate Admissions will require such verification by an independent service such as the Center for Educational Documentation (http://www.cedevaluations.com/), Boston, MA (617-338-7171).

2. The degree must have been earned with a satisfactory scholastic average to demonstrate that the applicant has had adequate preparation for the field in which graduate studies are to be undertaken.

3. Certain graduate programs require graduate entrance examinations. The applicant must have obtained a satisfactory score on the appropriate entrance examination if required for admission by the program or department to which admission is sought. The official score report must be submitted; a photocopy of the examinee’s report is unacceptable.

4. The Commonwealth of Massachusetts requires that all full-time graduate students (9 or more credits) must be immunized against measles, mumps, rubella, tetanus, and diphtheria. In addition, all students in programs in the health professions, regardless of age or enrollment status, must show proof of immunization. Students will not be permitted to register for courses at the University unless proof of immunization has been sent directly to the Director of Health Services, University of Massachusetts Lowell, Lowell, MA 01854 978-934-4991.

Departmental Requirements

The rules, regulations, and policies delineated by the University constitute only the minimum requirements for admission, retention, and graduation. Each department may have additional requirements mandated by the unique nature of its programs. It is the responsibility of the graduate student to be aware of the minimum requirements of the University and, in addition, to fulfill the special requirements of the particular program in which he or she is enrolled.

Application Procedure for Graduate Admission

Applicants can apply using the online application.

Master's & Doctoral Application

- Application Deadline
- Types of Admission
- Graduate Certificate Application Procedure
- Non Degree Status
- Graduate Readmission/Deferral Policy

Master's & Doctoral Application Information

A non-waivable and non-refundable application fee must be received before the application is processed. Each applicant must file the following documents:

1. A completed application form.
2. Official transcripts of all undergraduate and graduate records.
3. Letters of recommendation written by individuals qualified to judge the ability of the applicant to carry on graduate work and research as requested by the department. Refer to the department page to learn about the number of required recommendations.
4. Official scholastic test scores specified for various degree programs at the University (see individual departmental requirements). An applicant who has earned a graduate degree from an accredited university may petition the department graduate coordinator to waive the scholastic test requirements (e.g. GRE).

5. The official score report for an institutionally approved language test for students from countries where English is not the national language. The thresholds for English tests are set by the department. Institutionally approved English tests: TOEFL, TOEFL IBT Home Edition, IELTS, Duolingo, PTE Academic, and ASC English School Level 6. All test scores must be official and sent directly by the testing agency.

Application Deadline

The University of Massachusetts Lowell Graduate Admissions Office has a "rolling admissions" policy. However, some programs have early, fixed application deadlines. Consequently, the applicant is strongly urged to contact the department of interest to determine the last date on which applications may be received. In general, early applications will ensure that all materials are processed on time and that a student who wishes to apply for a teaching assistantship will be given due consideration. Many programs will fill available openings several months before the beginning of the semester. A student who has been accepted into a graduate program must attend within a year of acceptance or, at the discretion of the department, be required to submit a new application. Application files for individuals who do not matriculate will be retained for only two years from the date of application.

Types of Admission

A student may be admitted to graduate study at the University of Massachusetts Lowell under one of the two classifications listed below.

1. Matriculated status: A student who has met all requirements for admission to a degree program and who has been recommended by the department in which he or she proposes to study as a degree candidate.

2. Matriculated with conditions: A student who has not fully met the requirements stipulated by the program may be admitted as a prospective candidate for a degree with specified conditions to be met in the future. Such a student must have as an initial objective the satisfactory completion of all requirements for full matriculation.

Graduate Certificate Candidate Application Information

Graduate certificate programs are designed for students holding a baccalaureate degree in a field related to the certificate program. A student who wishes to apply to a certificate program must complete the Graduate Certificate Application, submit the appropriate application fee, and submit an official transcript indicating the conferral of a bachelor’s degree. The graduate record exam (GRE) and letters of recommendation are not required.

A student in a certificate program who wishes to enroll in a master’s or doctoral program is ineligible to receive credit towards a degree until he or she files a formal application and is then admitted as a matriculated student.

The maximum number of graduate credits a student may complete while enrolled in a graduate certificate is 12 credits.

Non-Degree Status

An individual without advanced degree objectives may take courses in certain programs with non-degree status. A student who wishes to take courses as a non-degree student must submit an official transcript indicating the conferral of a bachelor’s degree. A student in non-degree status is ineligible to receive credit towards a degree until he or she files a formal application and is then admitted as a matriculated student.

The maximum number of graduate credits a student may complete with non-degree status is 12 credits.

NOTE: International students are not eligible for non-degree status.

Graduate Readmission/Deferral Policy

1. A matriculated student who formally withdraws in good standing from the university may request readmission within two years by completing only the cover page of the graduate application.

2. A newly accepted student dropped from a
graduate program for failure to register may be re-admitted by submitting a new application cover page and fee within two years of acceptance date.

3. A matriculated student who fails to maintain continuous enrollment and has not formally withdrawn may be readmitted by submitting a new application cover page and fee within two years of being dropped from the program.

4. A student may request a deferment of enrollment up to one year beyond the date when he or she was scheduled to begin his or her graduate program. If the one-year time period is exceeded, the student must submit a new application and fee. Deferral must be requested before the start of the semester for which the student is accepted.

Financial Assistance & Assistantships

FINANCIAL ASSISTANCE

- Applying for Financial Aid
- Other Types of Assistance

The Solution Center
(https://www.uml.edu/thesolutioncenter/financial-aid/default.aspx)
University Crossing Lobby
220 Pawtucket Street, Suite 131
Lowell, MA 01854
Telephone: 978-934-2000
Office Hours: Monday - Friday: 8:30 a.m. to 5 p.m.

Applying Financial Aid

The University requires students to file a Free Application for Federal Student Aid (FAFSA). Students may apply for the FAFSA online at www.FAFSA.ed.gov (http://www.FAFSA.ed.gov). It is recommended that students save time by requesting personal identification numbers called Federal Student Aid PINs before the student applies for aid. The PIN can be used to electronically sign the FAFSA, electronically sign certain loan contracts, and access online information about federal student aid the student has received. The PIN must be requested online at www.studentaid.ed.gov (https://www.studentaid.ed.gov/sa/fafsa/filling-out/fsaid).

Copies of students and spouses federal income tax, W2 forms and other forms may be requested by the Financial Aid Office to verify information provided on the FAFSA. Many forms requested are available on The Solution Center website. All information requested by the Financial Aid Office is required to complete the application process and is held in strictest confidence.

Eligibility Requirements

To receive financial aid from the various student aid programs, a student must:

- Have demonstrated financial need to qualify for need-based aid programs. Need is defined as the cost of attendance minus the expected family contribution derived from filing the FAFSA. Students may also be eligible for non-need based aid programs, such as the Federal Direct Unsubsidized Loan program and meritorious awards.
- Be a U.S. citizen or eligible non-citizen.
- Have a valid Social Security Number.
- Make satisfactory academic progress.
- Have a high school diploma or a General Education Development (GED) certificate, pass a test approved by the U.S. Department of Education, meet other standards the state of Massachusetts establishes that are approved by the U.S. Department of Education, or complete a high school education in a home school setting that is treated as a home school or private school under state law.
- Be a matriculated student enrolled in a degree granting or approved certificate program. Students enrolled in non-degree programs are not eligible for financial aid.
- Be enrolled at least half-time each semester. (Minimum of six credits for graduate students).
- Cannot be in default or in over payment on a federal student loan.
- Register with the Selective Service, if required (www.sss.gov (http://www.sss.gov))

Determining Financial Need:

Demonstrated financial need is the difference between the cost of attendance and the expected family contribution. The cost of attendance (COA) includes direct expenses such as tuition and fees, and also includes indirect such as room, board, books and
Transportation. The expected family contribution (EFC) is determined by the federal needs analysis formula and is calculated by completing a Free Application for Federal Student Aid (FAFSA).

**Types of Financial Aid:**

**William D. Ford Federal Direct Subsidized/Unsubsidized Loan Program:** The primary source of financial aid recommended for graduate students is the William D. Ford Federal Direct Student Loan Program. This program allows the student to borrow up to $20,500 per year at a low interest rate in subsidized and/or unsubsidized loans. Eligibility for a subsidized or unsubsidized direct loan is determined from the information provided on the FAFSA. A student may receive a subsidized loan and an unsubsidized loan for the same enrollment period. A subsidized loan is awarded on the basis of financial need. A student will not be charged any interest before repayment begins or during authorized periods of deferment. An unsubsidized loan is not awarded on the basis of need. A student will be charged interest from the time the loan is disbursed until it is paid in full. If a student allows the interest to accumulate, it will be capitalized that is, the interest will be added to the principal amount of the loan and additional interest will be based upon the higher amount. For more information about graduation student aid contact visit the Solution Center at [www.uml.edu/thesolutioncenter/financial-aid/Receiving-Aid/Types-Aid/graduate/loans.aspx](https://www.uml.edu/thesolutioncenter/financial-aid/Receiving-Aid/Types-Aid/graduate/loans.aspx).

**William D. Ford Federal Direct PLUS Loan Program:**

A non-need based federal loan offers up to the cost of attendance minus financial aid per academic year to qualified graduate students and parents/stepparents of undergraduate dependent students. Interest rate is fixed and repayment begins 45-60 days after the second disbursement. Refer to the Direct Loan website ([https://studentaid.gov/help-center/answers/article/federal-direct-loan-program](https://studentaid.gov/help-center/answers/article/federal-direct-loan-program)) for current interest rates. A FAFSA is not required to apply for the PLUS loan; however, students are encouraged to file a FAFSA so that they can receive the maximum aid available. Parents may download an application online from The Solution Center ([https://www.uml.edu/thesolutioncenter/financial-aid/Receiving-Aid/Types-Aid/graduate/loans.aspx](https://www.uml.edu/thesolutioncenter/financial-aid/Receiving-Aid/Types-Aid/graduate/loans.aspx)). Applications should be returned to the financial aid for processing. This is a loan that needs to be repaid by the parent/stepparent.

**Other Types of Assistance:**

**Federal Professional Nurse Traineeship Grant Program:** Federally funded grant available to graduate nursing students. Award amounts vary and are dependent upon funding. Please contact the School of Nursing for more information.

**Federal Teach Grant:** Federally funded grant available to qualifying graduate education majors enrolled in coursework or plan to complete coursework toward a career in teaching in a high need subject area. Contact the Graduate School of Education for more information.

**Deans Fellowships:** $2,000 awards granted to eligible, newly admitted full-time, in-state Masters candidates not receiving a teaching or research assistantship.

**Provosts Fellowships:** $4,000 awards granted to eligible, newly admitted full-time, out-of-state and international Masters candidates not receiving a teaching or research assistantship.

**ASSISTANTSHIPS**

**Teaching and Research Assistantships**

A limited number of teaching and research assistantships are available for matriculated, full-time (minimum of 9 credits/semester) graduate students. All assistantships are subject to the agreement between UMass Lowell and UAW/Graduate Employees Organization. Teaching assistantships are assigned by the student’s department; therefore, queries regarding teaching assistantships should be directed to the departmental graduate coordinator ([https://www.uml.edu/Graduate-Student-Services/Coordinators.aspx](https://www.uml.edu/Graduate-Student-Services/Coordinators.aspx)) or chairperson (see [www.uml.edu/Grad/Coordinators.aspx](https://www.uml.edu/Grad/Coordinators.aspx)). Research assistantships are available through special arrangements with individual research advisers. Individuals interested in research assistantships should contact departmental faculty members concerning the availability of this form of financial aid.

**Qualifying for an Assistantship**

To ensure that assistantships are awarded to the most qualified individuals, the University has established the following requirements:

1. 1. No teaching/research assistantship may be awarded to a graduate student with incompletes, F’s, or U’s on his or her transcript.

2. 2. No teaching/research assistantship may be awarded to a graduate student who fails to maintain good academic standing ([https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf](https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)) (a grade point average under 3.0 on the official transcript). See the Academic Standing information at [www.uml.edu/catalog/graduate/policies/Academic_Stan ding.htm](https://www.uml.edu/catalog/graduate/policies/Academic_Stan ding.htm) (a grade point average under 3.0 on the official transcript).

3. 3. No University-funded teaching/research assistantship
may awarded to a master’s degree candidate if he/she has completed the total number of credits required for his/her program.

4. Level III teaching/research assistantships may only be awarded to graduate students who have reached doctoral candidacy (i.e. completed all course work, oral/written and language examinations) and are enrolled in dissertation research.

Teaching and Research Assistants are awarded either a semester or a yearly contract. The current negotiated agreement between The University of Massachusetts Lowell Board of Trustees and the Graduate Employee Organization is posted on the Human Resources website. Current stipend levels may be found there as well.

Graduate Student Assistantships

A limited number of student assistantships may be available in the departments. Students in this category are paid an hourly rate and are obligated to pay their own tuition and fees. All queries concerning assistantships should be directed to the graduate coordinator (https://www.uml.edu/Graduate-Student-Services/coordinators.aspx) in the student’s department.

Doctoral Programs Offered

Listed by Degree Earned

- Doctor of Education
- Doctor of Engineering
- Doctor of Nursing Practice
- Doctor of Philosophy
- Doctor of Physical Therapy
- Doctor of Science

Doctor of Education

- Leadership in Schooling (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Mathematics & Science Education (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

Doctor of Philosophy in Engineering (Ph.D.)

- Chemical Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Civil Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Computer Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Electrical Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Energy Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Mechanical Engineering
- Mechanical Engineering/Chemical Engineering
- Mechanical Engineering/Civil and Environmental Engineering
- Mechanical Engineering/Energy Engineering
- Mechanical Engineering/Industrial Engineering
- Mechanical Engineering/Manufacturing Engineering
- Mechanical Engineering/Manufacturing Engineering
- Plastics Engineering

Doctor of Nursing Practice (DNP)

- Nursing

Doctor of Philosophy (Ph.D.)

- Applied Psychology and Preventative Science
- Applied Biology (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
Biomedical Science; Developmental & Evolutionary Biology; Quantitative Biology & Biophysics; and Cellular & Molecular Biology

- Biomedical Engineering & Biotechnology
- Business Administration

Doctor of Physical Therapy (DPT)
- Physical Therapy

Doctor of Science
- Public Health

Master’s Programs Offered

Master of Arts
- Community Social Psychology
- Criminal Justice
- History
- Peace & Conflict Resolution
- Security Studies

Master of Business Administration
- Master of Education
- Master of Music
- Master of Public Administration
- Master of Public Health
- Master of Science
- Master of Science in Engineering
- Education Specialist

Master of Public Health

Master of Science
- Applied Mechanics
- Engineering
- Atmospheric Sciences
- Radiological Sciences
- Polymer Science
- Polymer Science/Plastics Engineering
Master of Business Administration (MBA)
- General Business
- Accounting
- Business Analytics
- Entrepreneurship
- Finance (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Healthcare
- Information Technology (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- International Business
- Managerial Leadership
- Marketing

Master of Education (M.Ed.)
- Curriculum & Instruction
- Educational Administration
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)PrincipalNon-licensureHigher Education
- Reading & Language
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)Teacher of Reading Non-licensure

Master of Music (MM)
- Music EducationCommunity Music
- Sound Recording Technology

Master of Public Administration (MPA)
- Human Service Management
- Public Humanities and the Arts
- Justice Administration

Master of Public Health (MPH)
Public Health (https://www.uml.edu/Health-Sciences/Public-Health/Programs-of-Study/masters/MPH.aspx)
- Dietetics
- Epidemiology
- Healthcare Management
- Nutrition
- Social and Behavioral Sciences

Master of Science (MS)
- Accounting
- Applied Biomedical Sciences
- Autism Studies
- Biological Sciences
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)BioinformaticsBiotechnologyEducation, Communication and Outreach Option (This program does NOT lead to teaching licensure)
- Biomedical Engineering & BiotechnologyBiomedical & Biotechnology (PSM)
- Business Analytics
- ChemistryChemistry & Polymer Science
  (PSM)Pharmaceutical Biochemistry (PSM)
- Computer ScienceSoftware Entrepreneurship - Not Accepting new applicationsEntrepreneurship (PSM) - Not Accepting new applications
- Co-op Option in Engineering
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Engineering Management
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Entrepreneurship
- Environmental Studies
  (https://www.uml.edu/resources/catalog-
Atmospheric Sciences

- **Finance**
- **Health Information Management**
- **Information Technology**
- **Marine Sciences & Technology**
- **Mathematics**
- **Nursing**
- **Pharmaceutical Science**
- **Physics**
- **Public Health**
- **Radiological Science & Protection**
- **Security Studies**

Education Specialist (EdS)

- **Administration, Planning & Policy**
- **Curriculum & Instruction**
- **Reading & Language**

Graduate Certificates Offered

- **Chemical Engineering**
- **Civil**
- **Computer Engineering**
- **Electrical Engineering**
- **Energy Engineering**
- **Mechanical Engineering**
- **Plastics Engineering**
- **Additive Manufacturing (AM) in Radio Frequency (RF) & Microwave (MW) Applications**
- **Applied Statistics**

**Master of Science in Engineering (M.S.E.)**

- **Chemical Engineering**
- **Civil**
• Behavioral Intervention in Autism for Board Certified Behavior Analyst
• Behavioral Management in Autism (BCaBA)
• Biomedical Engineering and Biotechnology
• Biotechnology & Bioprocessing
• Business Analytics
• Chemistry
• Clinical Pathology
• Commercial Development for Plastic Engineers
• Communications Engineering
• Composites and Materials
• Criminal Justice Leadership & Policy Development
• Cyber Security
• Design and Manufacturing
• Diversity in the Workplace
• Domestic Violence Prevention
• Energy Conversion
• Environmental Atmospheric Science
• Environmental Biotechnology
• Environmental GeoScience
• Ergonomics & Biomechanics
• Evaluation and Assessment
• Family Studies
• Field Programmable Gate Array
• Field Programmable Gate Array Lab-Enhanced (corporate program)
• Financial Management
• Forensic Criminology
• Foundations of Business
• Health Informatics
• Health Management
• Human Computer Interaction (We are not accepting applications at this time).
• Integrated Engineering Systems (interdisciplinary)
• Innovation and Entrepreneurship
• Materials Sciences & Engineering
• Medical Imaging and Instrumentations
• Medical Plastics Design & Manufacturing
• Microelectromechanical Systems/Nanoelectromechanical Systems (interdisciplinary)
• Microwave and Wireless Engineering
• Modeling, Simulation, and Control of Systems and Processes
• Molecular & Cellular Biotechnology
Bachelor's to Master's Programs

Earn Two Degrees in as Little as Five Years

- Eligibility
- Course Credits
- How to Transition
- Francis College of Engineering Expanded Bachelor's to Master's Policy

NOTE: A course with a Pass/No Credit election cannot be applied to the university's Bachelor's to Master's Program.

In order to encourage outstanding UMass Lowell undergraduate degree students to continue their studies towards an advanced degree, qualified students may transition to the Bachelor's to Master's Degree Option. (Bachelor's to Master’s programs include the Fast Track to Teaching and Plus 1 programs.)

This option carries distinct benefits. No graduate application is required for UMass Lowell's Bachelor's to Master's programs. In addition, many departments offer course credit benefits. (For detailed information regarding specific course credit benefits, please see the Graduate Coordinator in the respective masters degree granting department.)

The transcripts of the students who declare their intention to transition to master's programs will be reviewed by the graduate coordinator to ensure the GPA and prerequisite requirements are met. Students should also provide one letter of recommendation to support their transition to the master's program. Refer to the Bachelor's to Master's page for more information.

Eligibility

Any UMass Lowell undergraduate junior or senior with a grade point average of 3.0 or better may apply to a Masters
degree program at UMass Lowell under the Accelerated Bachelors to Masters Degree Option. However, to be accepted into this option the following minimum conditions must be met (individual departments may have more stringent requirements):

1. The student must have a cumulative grade point average of 3.0 or above at the time the baccalaureate degree is conferred in order to maintain eligibility for this option.
2. The student must apply for and receive his/her baccalaureate degree before matriculating into the graduate program.
3. Once accepted, a student is expected to begin his/her graduate studies in the semester immediately following conferral of the baccalaureate degree unless the student submits a written request for deferral. A student is allowed to defer for a maximum of one year from the date of acceptance. For example, if accepted for the Spring 2020 semester, an individual can defer to either the Fall 2020 or Spring 2021 semesters. A student defers acceptance by submitting a written request to the Office of Graduate Admissions (mailto:Graduate_Admissions@uml.edu). All deferral requests must specify which semester the student wishes to enroll. Students who are confirmed to transition to the Bachelors to Masters Degree Option who opts not to enroll in at least one course within the graduate department to which they have been accepted in the semester immediately following conferral of the bachelors degree and who does not submit a deferral request forfeits his/her rights to benefits under this program. Should the student decide to begin his/her studies at a later time he/she will be required to the graduate program and submit all required admission materials.

Course Credits

The graduate degree granting department may allow course credit benefits; however, the following requirements apply:

1. Any graduate courses taken by a baccalaureate degree student that are credited towards the Masters degree must have been obtained with a grade of B or better.

2. A graduate level course used to fulfill both an undergraduate degree requirement and a undergraduate minor requirement is also eligible to be used in the Master’s, but only up to the maximum number allowed for the specific Master’s degree.

3. Only courses of 5000 level or higher may count toward the Masters degree.

4. Transfer credit is not accepted for graduate certificates. The Bachelor’s to Master’s program benefits do not include credits toward a graduate certificate.

5. As defined by the graduate degree granting department, a maximum of 12 graduate credits (5000 level or above) may be used for the masters degree as follows:
   - Up to 12 credits may be transferred provided these graduate credits were taken in excess of the university minimum of 120 baccalaureate degree credits, or;
   - for programs requiring fewer than 33 credits, a maximum of up to six credits of graduate (5000 level or higher) courses may be used by a student in the Accelerated Bachelor’s to Master’s Degree Option for both the graduate and undergraduate degrees; or,
   - for program requiring 33-35 credits, at the discretion of the affected department, a maximum of up to nine credits of graduate (5000 level or higher) courses may be used by a student in the Accelerated Bachelor’s to Master’s Degree Option for both the graduate and undergraduate degrees; or,
   - for programs requiring 36 or more credits, at the discretion of the affected department, a maximum of up to twelve credits of graduate (5000 level or higher) courses may be used by a student in the Accelerated Bachelor’s to Masters Degree Option for both the graduate and undergraduate degrees.

6. Students must petition to have specific courses (5000 level or above) taken during their undergraduate career apply towards their graduate degree via an Academic Petition.

7. A course with a Pass/No Credit election cannot be
How to Transition to Bachelor’s to Master’s Programs

Undergraduate students are requested to apply to transition by submitting the application for transition found on the Undergraduate Bachelor’s to Master’s page (https://www.uml.edu/Academics/undergraduate-programs/bachelors-masters.aspx). Students normally apply to transition in the second semester of their third year as an undergraduate (up until the last day of classes in their final semester before graduation).

Francis College of Engineering Expanded Bachelor’s to Master’s Policy

The Francis College of Engineering participates in the UMass Lowell Bachelors to Masters Program and expands this benefit to applicants from other ABET-accredited engineering programs. All applicants from ABET-accredited institutions who meet the UMass Lowell BS/MS admissions criteria may transfer (double count) eligible graduate-level credits taken for the completion of their undergraduate degree program at their home institution to their UMass Lowell (UML) masters degree program. The maximum number of credits to be transferred will be the same as are allowed by UMass Lowell Francis students who graduate from the College of Engineering. Additionally, all Bachelors to Masters rules and regulations, including minimum grade requirements, must be met.

Eligibility

Applicants for this expanded program must have a minimum undergraduate cumulative GPA of 3.0 in appropriate engineering majors from other ABET-accredited institutions. As with current admissions policy in Engineering, the GRE may be waived for applicants meeting these criteria (minimum GPA from ABET-accredited engineering program).

Double Counting

Consistent with the current transfer policy, only graduate courses with grades of B or better may transfer. Also consistent with current policy, each department decides whether a course from another institution may or may not fulfill a departmental program requirement.
Course Credit

Maximum Semester Credit Limit
Graduate Credit for Undergraduate Courses
Undergraduate Credit for Graduate Courses

Maximum Semester Credit Limit

The usual course load for full-time graduate students is 9 credits/semester. Depending upon the program requirements and abilities of the student, individuals may carry more than 9 credits each semester. However, the absolute maximum number of total credits (combined undergraduate and graduate) for which a graduate student will be allowed to register is 18 credits/semester. The maximum number of thesis or dissertation credits for which a student may enroll in any semester is nine credits.

UMass Lowell instruction is scheduled during standard 15-week fall and spring semester terms. During the summer/winter terms varying shorter length special programs are available and may be considered as the equivalent to full-time status for the specific time period within a session. This is for enrollment purposes only.

The credit-hour policy, a statement of what students will learn is necessary if credit is based on a demonstration by the student of learning equivalent to that established as the expected product of a period of study corresponding to a time-based credit-hour assignment. The credit-hour standard for the course, and the way that the credit-hour standard is achieved, are communicated to students as part of the course syllabus or equivalent documentation.

Please note: Financial aid, veterans benefits or other types of aid define 9 credits for full-time study during the fall/spring terms. The grid below displays how the credit hour is met with shorter time sessions over the summer/winter.

<table>
<thead>
<tr>
<th># of weeks</th>
<th># of credit hour(s)</th>
<th># Calculated Credit Hour Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 credit</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>2 credits</td>
<td>90</td>
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<td>5 credits</td>
<td>225</td>
</tr>
<tr>
<td>6</td>
<td>6 credits</td>
<td>270</td>
</tr>
</tbody>
</table>

Navitas Summer Pathway Program

The University of Massachusetts Lowell (UMass Lowell) offers a 10-week summer session to its Pre Undergraduate and Pre Masters international students. These students are admitted into a Bachelors or Masters program with the condition of a preparatory semester(s) which could encompass the summer session. The Pre Undergraduate and Pre Masters summer session consists of intensive academics of 18-22 clock hours per week in English, Mathematics and Cultural Support.

Graduate Credit for Undergraduate Courses

UMass Lowell courses at the 400 level are designed for seniors but under certain circumstances may be taken by graduate students for graduate credit. A maximum of 6 credits of 400 level courses may be used for credit toward the graduate degree with the permission of the degree granting department. Three hundred level courses and below are never counted toward a graduate degree. If a graduate student takes certain undergraduate courses to make up for background deficiencies or to satisfy language requirements, the course credit hours are not used as part of the graduate degree program but will appear on the graduate transcript.

Undergraduate Credit for Graduate Courses

A qualified junior or senior may take a course at the 500 level for undergraduate credit in accordance with the policy and procedures of the department or college in which the course is offered. The grade received in any such course is used in calculating the undergraduate's cumulative grade point average. Counting of graduate credits for both the bachelors and masters degrees is subject to departmental requirements.

At no time may grades computed in an undergraduate GPA be used toward a graduate GPA.
Francis College of Engineering

The education of engineers in state-of-the-art areas of advanced technology and the UMass Lowell’s commitment to national and regional economic development are the major premises upon which the graduate programs in the College of Engineering are based. These programs are intended to produce engineers whose education not only develops expertise in the design, development and production of products, but also an understanding of the management involved in the creation of new products, companies and service organizations. Thus, the graduate programs in engineering are intended to educate engineers capable of keeping abreast with the rapidly changing technology that characterizes the high technology economy of the Northeast and for research careers in academia, industry and government. These graduate programs lead to degrees of Master of Science in Engineering, Master of Science, and Doctor of Philosophy. The College is led by James A. Sherwood, Ph.D., Interim Dean of the Francis College of Engineering (https://www.uml.edu/Engineering/default.aspx). The graduate programs for the College are overseen by Joey Mead, Associate Dean of Graduate Studies (https://www.uml.edu/Research/shap3d/faculty-staff/mead-joeiy.aspx).

You will need Adobe Acrobat Reader (https://get.adobe.com/reader/) to view any pdf files. It can be downloaded for free from the Adobe website (https://get.adobe.com/reader/).

On this page you will find:

- Graduate Programs Offered
- Common Admission Requirements
- Common Doctoral Degree Requirements
- Dissertation Proposal
- Other Doctoral Programs
- Links to department catalog section
- Engineering College-Wide Courses (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Faculty in the College of Engineering (https://www.uml.edu/Engineering/faculty.aspx)

Graduate Programs Offered

The Master of Science in Engineering (M.S. Eng.) degree awarded in the following fields:

- Chemical Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Civil Engineering - Options: Environmental, Geotechnical, GeoEnvironmental, Structural, Transportation (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Computer Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Co-op Option in Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Electrical Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Mechanical Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Plastics Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

The Master of Science (M.S.) degree awarded in the following fields:

- Engineering Management (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Environmental Studies

Francis College of Engineering Expanded Bachelor’s to Master’s Policy

The Doctor of Philosophy (Ph.D.) degree awarded through the College of Engineering in the following options:

- Chemical Engineering (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
The intent of the Doctor of Philosophy (Ph.D.) program is to prepare engineers for leadership and research positions in industry, academia and government. The doctoral program includes advanced graduate course work in engineering and allied subjects and research culminating in a doctoral dissertation.

A total of 63 credit hours of graduate level courses are required for the Ph.D. degree. These credits are composed of the following components:

- The Ph.D. degree must involve a traditional research-based dissertation, plus: A minimum of 30 approved credit hours of graduate-level engineering including associated science and math courses. A minimum of 21 credit hours of doctoral dissertation. The balance of the remaining 12 credits can be a mix of graduate-level engineering including associated science and math course and dissertation credits at the discretion of the department, faculty advisor and dissertation committee.

In addition to this 63 semester hours of approved graduate courses and dissertation:

- The student must have a minimum grade point average of 3.25 to graduate.
- The student is required to take and pass the doctoral qualifying examination.

Options are offered in the following areas:

- Civil and Environmental Engineering
- Computer Engineering
- Electrical Engineering
- Mechanical Engineering
- Plastics Engineering
- Industrial Engineering
- Civil and Environmental Engineering
- Chemical Engineering (with options in renewable or nuclear engineering)
- Energy Engineering (jointly administered by Mechanical Engineering and Chemical Engineering)

Rules and requirements vary slightly with the administering department.

**Common Admission Requirements**

Admission to the program will be based on review by Graduate Admissions and by the Admissions Committee of each administering Department. Applicants are required to submit the following items to Graduate Admissions:

- Graduate Record Examination (GRE) scores
- TOEFL (Test of English as a Foreign Language), IELTS, or Duolingo exam scores are required for international students
- Two letters of recommendation.
- Statement of Purpose
- Application fee
- Application form
- Official transcripts.

Doctoral programs in the College of Engineering may also require a BS or MS in Engineering or a closely related field. Depending on the option selected, students may be required to make up prerequisites which they lack in comparison to the equivalent Engineering curriculum at the University of Massachusetts Lowell.

**Transfer Credits**

1. A student with a masters degree in Engineering or a closely related field may apply to have coursework for the master’s degree up to a total of 24 credits.
2. A student with graduate-level work completed at a credited US or Canadian university may apply for transfer...
of up to 24 semester credits in acceptable graduate engineering courses (with grade of B or better) towards the doctoral program, upon approval by the Department Graduate Coordinator.

3. In cases where a student has an M.B.A., or has completed the Business Administration Minor for Engineering students, in addition to a B.S. in engineering or a closely related field, portions of the management component of the Doctor of Engineering program may be waived upon review by the administering department.

Note: Students may be required to make up prerequisites which they lack in comparison to the equivalent Engineering curriculum at the University of Massachusetts Lowell.

Common Doctoral Degree Requirements

In addition to 63 semester hours of approved graduate credits and thesis:

1. The student must have a minimum grade point average of 3.25 to graduate.
2. Students are required to take and pass a doctoral qualifying examination before they are officially classified as a doctoral candidate.

Doctoral Qualifying Examination

1. The doctoral qualifying examination is administered on a declared schedule, usually twice each year. The timing and format of the doctoral qualifying examination may vary by department.
2. The student is permitted two attempts at passing the doctoral qualifying examination.
3. If this first attempt at the doctoral qualifying examination is unsatisfactory, a second and final attempt at passing the exam must occur at the next offering of the qualifying exam. Failure to schedule or to participate in the qualifying exam process as outlined will be considered a failed attempt.
4. Students failing the doctoral exam twice will automatically be dismissed from the doctoral program.
5. Students who do not take the examination at the prescribed time may lose all their financial support, if any, and may be dismissed from the doctoral program.

6. The decision of each administering Department regarding whether a student has passed the qualifying exam is final.

Doctoral Dissertation Proposal

Each student is required to submit and defend a dissertation proposal before a Department Doctoral Committee. This committee shall be comprised of the departmental faculty advisor and at least two other faculty members. This committee may or may be the same as the dissertation research committee for the student. Upon approval by this Department Doctoral Committee, the doctoral graduate coordinator for the department will notify the Vice Provost for Graduate Education and the Associate Dean for Graduate Studies in the College of Engineering that the student is now formally a candidate for the Doctor of Engineering/Doctor of Philosophy degree. Admission to candidacy status does not guarantee awarding of the doctoral degree.

Dissertation

After a student has chosen an area of research and a research advisor, a Dissertation Committee is selected by the student and his or her research advisor in accordance with the policy of the department. The Dissertation Committee shall consist of at least three members, one of whom is the research supervisor and at least two of whom shall be from the student’s major department. An outside expert from industry or another university may be a member of the committee, but that individual must possess academic credentials which would qualify him or her to serve as a member of the University of Massachusetts Lowell faculty. The responsibilities of the Dissertation Committee shall be to:

1. Approve the research topic;
2. Supervise the progress of the dissertation;
3. Read, evaluate, and approve or disapprove of the written dissertation;
4. Hear, evaluate and approve or disapprove of the oral defense of the dissertation;
5. Report the completion of all dissertation requirements to the department and the Registrar’s Office.

• The Thesis Guide (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

Other Doctoral Programs
The Doctor of Philosophy in Physics (Ph.D.) degree awarded through the Kennedy College of Sciences in the following fields:

- Applied Mechanics
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Energy Engineering
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Radiological Sciences
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

The Doctor of Philosophy in Chemistry (Ph.D.) degree awarded through the Kennedy College of Sciences in the following fields:

- Biochemistry
- Environmental Studies
- Polymer Science/Plastics Eng. Option

Links to Department Sections in This Graduate Academic Catalog:

- Chemical Engineering
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Civil &Environmental Engineering
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Electrical &Computer Engineering
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Energy Engineering
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Mechanical Engineering
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
- Plastics Engineering
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
Doctor of Philosophy in Engineering, Biomedical Engineering

Program Description

Admission Requirements
Applicants to the BME doctoral option are required to have a degree at the level of Bachelor or Master’s in engineering or basic/applied/health sciences with a strong emphasis on mathematics (Calculus I and II), chemistry (Organic Chemistry), and the physical sciences (Physics I, and Physics II), with some exposure to the life sciences (physiology, cell biology, or molecular biology). Students who do not meet all requirements may be admitted into the program pending the successful completion of requisite courses.

Applicants must submit official transcripts of all undergraduate and graduate records. Three letters of recommendation written by individuals qualified to judge the ability of the applicant to conduct graduate work and research are required. GRE and TOEFL (if applicable) are required.

Financial Support
Doctoral students will be supported from a variety of sources. It is expected that the bulk of the funding will be from externally funded research grants. As is current practice in the College of Engineering, these will be combined Teaching Assistant/Research Assistant positions for the first two years. In general, continued support after the first two years will be as a Research Assistant. It is anticipated that a number of doctoral students will be supported by fellowships or traineeships in the future.

Course Requirements
As with other options in the Ph.D. in Engineering, the Biomedical Engineering doctoral option will require the satisfactory completion of a total of 63 credit hours, with a minimum of 30 course credits and 21 research credits. The remaining 12 credits can be a mix of research and course credits. Students will have to maintain a minimum GPA of 3.25 to graduate.

1. Biomedical Core Courses (15 credits) - To fulfill this requirement, all students must complete the following four courses: Bioinstrumentation (3), Fundamentals of Biomaterials (3), Biomechanics (3), and Quantitative Physiology (3). In addition, an Advanced Mathematics (3) course will be required. This math core course will be chosen in conjunction with the dissertation research advisor. All students must demonstrate proficiency by passing with a minimum CGPA of 3.25 in the core courses.

2. Track Courses (12 credits) - The purpose of the track courses is to provide depth of knowledge in a specific area of Biomedical Engineering and to pose a solid foundation for students to excel in their specific research topic. It is recommended that students first identify a field of interest in collaboration with their research advisor, and then select track courses that align with the research topic of choice. Initial tracks for the program will mimic the tracks in the undergrad BME program (Medical Devices, Biomechanics, or Cellular &Tissue Engineering). Additional track courses can be chosen in collaboration with the research advisor.

3. Elective Courses (3 credits minimum) - The remaining three required course credits can be selected in conjunction with the research advisor to add breadth to the program. This course can be an appropriate engineering, math, or science course.

4. Graduate Seminar Course (0 credit) - A key component of the Ph.D. option will be to provide comprehensive professional skills training from start to finish. This training will be accomplished through courses as well as other requirements of the program. Importantly, the program will be designed to ensure that student progress is actively monitored such that students will move through the program in a timely manner (3 to 5 years). This rate of progress will be accomplished by including a Graduate Seminar Course (0 credit) in each year of their program. One of the requirements of this seminar will be a work-in-progress presentation of their research to date. As the student progresses through the program, this presentation may include a review of the literature, methods development for their proposal, and preliminary findings of their research.

5. Dissertation Research (21 credits) - A minimum of 21 credit hours of Dissertation Research will be required.

6. Additional Credits (12 credits) - An additional 12 credits that can be a mix of research and course credits to bring the total for the degree up to 63 credits.

- Doctor of Philosophy in Biomedical Engineering Degree Pathway (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

Qualifying Exam
The Dissertation Research Proposal will also serve as the qualifying exam. Each Ph.D. student is required to present their research proposal to their Graduate Committee and to describe initial results obtained to date together with plans to complete the research. A full-time student will have to write and orally defend their Dissertation Research Proposal by the end of their second year. Core knowledge and ability to think critically and in an interdisciplinary fashion will be evaluated during the defense of the Dissertation Research Proposal. Students who fail to pass this examination on the first attempt will be given one opportunity to re-take the exam. Students who fail the exam a second time will be recommended to complete an appropriate master’s degree and exit the doctoral program.

Optional Industrial Internship
As an optional component to the program, select students will...
have the opportunity to apply for an Industrial Internship with an industrial partner after passing their Dissertation Research Proposal. These internships will expose students to non-academic environments and will also help foster the development of new University-Corporate collaborations.

Dissertation Defense
A thesis for the doctoral degree must represent distinct scholarship and must be an original contribution to knowledge. It must show familiarity with the state-of-the-art of the field and must demonstrate the ability to plan and carry out the proposed research, to organize results, and to defend the approach and conclusions in a scholarly manner.

BME Graduate Committee
The proposed doctoral option will be overseen by a standing BME Graduate Committee comprised of faculty members from the Biomedical Engineering Department. This committee will be chaired by the Associate Chair for Biomedical Engineering. The committee will:
1. evaluate program curriculum and policies,
2. monitor the dissertation research proposal exam,
3. approve thesis defense committees, and
4. assist in mediating issues that may arise between students and faculty.

Master's Program in Biomedical Engineering & Biotechnology
The Boston, Dartmouth, and Lowell campuses of the University of Massachusetts offer joint Master of Science in Biomedical Engineering and Biotechnology.

Co-op Option in Engineering

Admission Requirements
Applicants from many different science/engineering undergraduate programs are invited to apply. Because the degree brings together biomedical engineering with biotechnology, it is designed equally for students with life sciences or engineering/physical science backgrounds. One's specific background will be of less interest in determining qualification for entrance than will be one's personal and career goals, demonstrated academic ability, research potential and commitment to an interdisciplinary, team-work approach.

Applicants will be accepted from individuals holding appropriate bachelor’s degrees or master’s degrees (or the US baccalaureate equivalents from a foreign institution). Applicants should have a background in life science, physical science or engineering. All applicants must have taken a full year (two semester or three quarter sequence) of calculus and the successful applicants will normally have had undergraduate coursework in statistics/experimental design and in life science/biomedical science.

Applicants must submit the following and are expected to meet the standards indicated:

1. Generally students with an overall undergraduate or graduate grade point average of 3.0 or higher will be considered for admission. Applicants must present official undergraduate and graduate transcripts from all schools attended.
2. Applicants accepted into the program should present a minimum Graduate Record Exam (GRE) combined verbal (142) and quantitative (152) score of 294. The AACC will also pay particular attention to the applicant’s score on the GRE analytical writing section of the general examination because of the emphasis placed on strong writing skills in this program. Only official GRE scores form Educational Testing Service will be considered acceptable.
3. Applicants must have a minimum of two semesters of calculus and strong quantitative skills.
4. International applicants should present a minimum Test
of English as a Foreign Language (TOEFL) score of 79
(internet version), 213 (computer version) or 550 (paper
version). Only official TOEFL scores from Educational
Testing Service will be considered acceptable.
5. Two letters of recommendation, from individuals familiar
with the applicants academic ability will be required.
6. Applicants will also be required to submit a Statement of
Purpose (personal essay) that should indicate their
qualifications for and motivation to undertake this
program as well as their personal and career goals.
Specifically, the statement should indicate the applicant’s
background, research credentials and career plans as they
relate to the multidisciplinary nature of the program.
7. Applicants shall also to submit a personal resume.
Individual circumstances can be taken into account and
extraordinary qualifications in some areas can be used to
outweigh weaknesses in others.
Along with an admissions decision comes consideration of the
appropriate program of courses for the applicant. The
interdisciplinary nature of our program gives special
importance to the advising relationship in forming a specific
academic program to meet each student’s specific goals.
Applicants may be offered admission with a number of courses
identified as conditional requirements that they will need to
take to fill in for gaps in preparation or knowledge. Each
admitted student is assigned to a faculty advisor, who will
guide them in course selection.

Transfer of Credits
For students who have previously completed graduate course
work, the admission committee may approve the transfer of up
to 12 credits of graduate credits for courses from an accredited
United States or Canadian college or university that received a
grade of B (not B-) or better if those courses were not already
used in the degree requirements of another earned degree. The
graduate school will govern the maximum number of credits
that may be transferred into the program. The transfer credit
may replace core or specialization course requirements. The
project/directed studies credits will be accepted for transfer
from institutions within the UMass system.
Students may also have core courses waived without transfer of
course credit. Students would still be responsible for the full
credits required of the master’s degree (minimum of 31 credits),
but would not have to take the waived course.

Academic Program
The curriculum is organized around common experiences,
including common core courses, elective/specialization courses
and an optional research project. The program makes some use
distance learning/on-line/faculty exchange for delivery of
courses. The program encourages a multidisciplinary team
approach during a variety of courses.

General Program Requirements
The program of courses includes a core requirement
(Requirement 1) and elective / specialization course
requirements (Requirement 2).
The Master of Science requires completion or transfer of at
least 31 total credits. Students must meet the specific
requirements of their "home campus" for such matters as grade
averages, documentation of completion of requirements and
registration for program continuation if needed. No courses
receiving a grade below C (2.0) can receive credit. Grades
earned below C are still calculated in the student’s grade point
average.
Students are limited in the number of Directed or Independent
Study courses credits, maximum 6 credits, that they can apply
toward their program. All courses must be conducted at the
graduate level.
Students must pursue and complete a program of study
approved by their assigned advisor. The interdisciplinary
nature of this program makes close contact between each
student and his or her advisor important.

Core Course Requirements - Requirement 1 (minimum 19
credits)
The core courses provide a common foundation for all
students, either from life science or physical science/engineering
backgrounds. Core requirements consist of three compulsory
courses and four additional courses selected from four
categories of approved courses. All course selections must be
approved by the advisor.

Students shall complete the following three core courses:

BMBT.5000
(https://www.uml.edu/catalog/courses/BMBT/5000)
Introduction to Biomedical Engineering and Biotechnology (3 cr)
BMBT.5200
(https://www.uml.edu/catalog/courses/BMBT/5200) Bioethics
(1 cr)
Elective Specialization Course from the list below (3 cr) or
Research Project (3 cr)

For the Research Project, students should conduct research in a
faculty lab or in industry and register for an Independent
Study/Advanced Project under the Research Advisor’s
department. If the Research Advisor can’t set up a number in
their department, the student should register for BMBT.7200
(https://www.uml.edu/catalog/courses/BMBT/7200)
Independent Study with a section established for the Research Advisor.

Students shall take one course from each of the following four core categories. Students should consult the advisor for the most appropriate selection from the approved courses in each of the categories. With adequate justification, students may submit a Academic Petition to substitute a course for one of the courses listed below in these respective categories.

**MATH (3 cr.)***

- BMEN.5380 [Computational Biomechanics](https://www.uml.edu/catalog/courses/BMEN/5380)
- CHEN.5390 [Math Methods for Engineers](https://www.uml.edu/catalog/courses/CHEN/5390)
- CHEN.5480 [Engineering Process Analytics](https://www.uml.edu/catalog/courses/CHEN/5480)
- MATH.5300 [Applied Math I](https://www.uml.edu/catalog/courses/MATH/5300)
- MATH.5760 [Statistical Programming Using SAS](https://www.uml.edu/catalog/courses/MATH/5760)

**PHYSIOLOGY (3-4 cr.)***

- BIOL.5490L [Biology Of Muscle Lab (1 cr)](https://www.uml.edu/catalog/courses/BIOL/5490L)
- BIOL.5620 [Cardiovascular Physiology Lecture (3 cr)](https://www.uml.edu/catalog/courses/BIOL/5620)
- BIOL.5630 [Cardiovascular Physiology Lab (1 cr)](https://www.uml.edu/catalog/courses/BIOL/5630)
- BIOL.5800 [Development Biology (3 cr)](https://www.uml.edu/catalog/courses/BIOL/5800)
- BIOL.5810L [Development Biology Lab (1 cr)](https://www.uml.edu/catalog/courses/BIOL/5810L)
- BIOL.5900 [Human Neurobiology (3 cr)](https://www.uml.edu/catalog/courses/BIOL/5900)

**LABORATORY (3-5 cr.)***

- BIOL.5190/5210L [Biochemistry Techniques (5 cr)](https://www.uml.edu/catalog/courses/BIOL)
- BIOL.5290 [Recombinant Protein Production Techniques (4 cr)](https://www.uml.edu/catalog/courses/BIOL/5290)
- BIOL.5320/5340L [Genomics and Cell Culture (4 cr)](https://www.uml.edu/catalog/courses/BIOL)
- BIOL.5760 [Monte Carlo Simulation of Radiation Transport (3 cr)](https://www.uml.edu/catalog/courses/BIOL/5760)
- CHEN.5860 [Radiation Biology (3 cr)](https://www.uml.edu/catalog/courses/CHEN/5860)
- EECE.5600 [Biomedical Instrumentation (3 cr)](https://www.uml.edu/catalog/courses/EECE/5600)
- MLSC.6100/6101L [Clinical Toxicology and Lab (4 cr)](https://www.uml.edu/catalog/courses/MLSC)
- NUTR.5650 [Lab Methods in Nutrition Assessment (3 cr)](https://www.uml.edu/catalog/courses/NUTR/5650)
- PHRM.6400/6420 [Pharmaceutical Analysis and Lab (4 cr)](https://www.uml.edu/catalog/courses/PHRM)
- RADI.5060 [Nuclear Instrumentation with Lab (3 cr)](https://www.uml.edu/catalog/courses/RADI/5060)

**ADVANCED CELL AND MOLECULAR BIOLOGY (3 cr.)***

- BIOL.5420 [Advanced Cell Biology (3 cr)](https://www.uml.edu/catalog/courses/BIOL/5420)
- BIOL.5670 [Molecular Biology (3 cr)](https://www.uml.edu/catalog/courses/BIOL/5670)
- BIOL.5820 [Cancer Biology (3 cr)](https://www.uml.edu/catalog/courses/BIOL/5820)
- BIOL.6660 [Selected Topics in Molecular and Cellular Biology (3 cr)](https://www.uml.edu/catalog/courses/BIOL/6660)
- NUTR.5720 [Nutrigenetics (3 cr)](https://www.uml.edu/catalog/courses/NUTR/5720)
- RADI.5620 [Radiation Biology (3 cr)](https://www.uml.edu/catalog/courses/RADI/5620)

*Students may take additional courses from the Core categories as Elective courses.

** Students who take this course, which included a co-requisite lab, to satisfy the Physiology Core requirement, may take a
course from the Elective list below in place of the LAB core requirement. A Graduate Academic Petition will be required.

**Elective Specialization Course Requirements - Requirement 2 (minimum 12 credits)**

All students shall complete a minimum of 12 credits of elective specialization courses. Students may take courses from one specialization area, across specialization areas and/or from the list of additional course offerings as noted below. Specialization courses will help the student attain depth in focused areas.

**Elective Specialization Courses:**

**a. Courses in MEDICAL IMAGING AND INSTRUMENTATION**
- EECE.5100 (https://www.uml.edu/catalog/courses/EECE/5100) Digital Signal Processing
- EECE.5110 (https://www.uml.edu/catalog/courses/EECE/5110) Medical Diagnostic Imaging
- EECE.5410 (https://www.uml.edu/catalog/courses/EECE/5410) Introduction to Biosensors
- EECE.5520 (https://www.uml.edu/catalog/courses/EECE/5520) Microprocessor Systems II & Embedded Systems
- EECE.6150 (https://www.uml.edu/catalog/courses/EECE/6150) Medical Image Reconstruction
- EECE.7100 (https://www.uml.edu/catalog/courses/EECE/7100) Selected Topics: Biomedical Imaging and Data Science

**b. Courses in BIOTECHNOLOGY AND BIOPROCESSING**
- CHEN.5340 (https://www.uml.edu/catalog/courses/CHEN/5340) Industrial Bioprocessing
- CHEN.5350 (https://www.uml.edu/catalog/courses/CHEN/5350) Cell and Microbe Cultivation
- CHEN.5380 (https://www.uml.edu/catalog/courses/CHEN/5380) Advanced Separations in Biotechnology
- CHEN.5450 (https://www.uml.edu/catalog/courses/CHEN/5450) Isolation and Purification of Biotech Products
- CHEN.5460 (https://www.uml.edu/catalog/courses/CHEN/5460) Biomaterial Science
- CHEN.5500 (https://www.uml.edu/catalog/courses/CHEN/5500) Biomedical Applications of Nanotechnology
- CHEN.5550 (https://www.uml.edu/catalog/courses/CHEN/5550) Biopharmaceutical Regulatory Compliance

**c. Courses in CLINICAL PATHOLOGY**
- MLSC.5120 (https://www.uml.edu/catalog/courses/MLSC/5120) Medical Bacteriology
- MLSC.5500 (https://www.uml.edu/catalog/courses/MLSC/5500) Foundations in Biomedical Research
- MLSC.5530 (https://www.uml.edu/catalog/courses/MLSC/5530) Emerging Topics in Clinical Chemistry
- MLSC.5800 (https://www.uml.edu/catalog/courses/MLSC/5800) Clinical Applications of Molecular Genetics
- MLSC.6130 (https://www.uml.edu/catalog/courses/MLSC/6130) Infections Disease
- MLSC.6150 (https://www.uml.edu/catalog/courses/MLSC/6150) Medical Mycology and Parasitology
- NUTR.5720 (https://www.uml.edu/catalog/courses/NUTR/5720) Nutrigenetics

**d. Course in MEDICAL PLASTICS DESIGN AND MANUFACTURING**
- CHEN.5550 (https://www.uml.edu/catalog/courses/CHEN/5550) Biopharmaceutical Regulatory Compliance
- PLAS.5030 (https://www.uml.edu/catalog/courses/PLAS/5030) Mechanical Behavior of Polymers
- PLAS.5180 (https://www.uml.edu/catalog/courses/PLAS/5180) Plastics Product Design
- PLAS.5530 (https://www.uml.edu/catalog/courses/PLAS/5530) Medical Device Design I
- PLAS.5540 (https://www.uml.edu/catalog/courses/PLAS/5540) Medical Device Design II
- PLAS.5750 (https://www.uml.edu/catalog/courses/PLAS/5750) Biomaterials I
- PLAS.5790 (https://www.uml.edu/catalog/courses/PLAS/5790) Problems in Biomaterials
- PLAS.6020 (https://www.uml.edu/catalog/courses/PLAS/6020) Medical Device Development Regulation
- PLAS.6750 (https://www.uml.edu/catalog/courses/PLAS/6750) Biomaterials II

**e. Courses in MOLECULAR & CELLULAR BIOTECHNOLOGY**
- BIOL.5410 (https://www.uml.edu/catalog/courses/BIOL/5410) Topics in Cell Biology
- BIOL.5600 (https://www.uml.edu/catalog/courses/BIOL/5600) Stem Cell Biology
- BIOL.5690L (https://www.uml.edu/catalog/courses/BIOL/5690L) Molecular Techniques
- CHEN.5350 (https://www.uml.edu/catalog/courses/CHEN/5350) Cell and Microbe Cultivation
- CHEN.5450 (https://www.uml.edu/catalog/courses/CHEN/5450) Isolation and Purification
f. Courses in PHARMACEUTICAL SCIENCES
PHRM.6100 (https://www.uml.edu/catalog/courses/PHRM/6100) Principles of Pharmaceutical Sciences
PHRM.6410 (https://www.uml.edu/catalog/courses/PHRM/6410) Drug Delivery
PHRM.6600 (https://www.uml.edu/catalog/courses/PHRM/6600) Pharmacokinetics and Drug Metabolism

g. Courses in ERGONOMICS AND BIOMECHANICS
BMEN.5300 (https://www.uml.edu/catalog/courses/BMEN/5300) Ergonomics and Work
BMEN.5380 (https://www.uml.edu/catalog/courses/BMEN/5380) Computational Biomechanics
BMEN.5310 (https://www.uml.edu/catalog/courses/BMEN/5310) Occupational Biomechanics
BMEN.5400 (https://www.uml.edu/catalog/courses/BMEN/5400) Occupational Safety Engineering
BMEN.6380 (https://www.uml.edu/catalog/courses/BMEN/6380) Methods in Work Analysis
PUBH.5061 (https://www.uml.edu/catalog/courses/PUBH/5061) Environmental Health

h. Additional Course Offerings

**Biological Sciences:**
BIOL.5050L (https://www.uml.edu/catalog/courses/BIOL/5050) Bioinformatics
BIOL.5090 (https://www.uml.edu/catalog/courses/BIOL/5090) Photobiology
BIOL.5720 (https://www.uml.edu/catalog/courses/BIOL/5720) Virology
BIOL.5840 (https://www.uml.edu/catalog/courses/BIOL/5840) Comparative Vertebrate Embryology
BIOL.5930 (https://www.uml.edu/catalog/courses/BIOL/5930) Immunology
BIOL.5940 (https://www.uml.edu/catalog/courses/BIOL/5940) Advanced Topics in Immunology
BIOL.5 (https://www.uml.edu/catalog/courses/BIOL/5062/5062L) Bioinformatic Tools in Sequence Analysis

**Biomedical Engineering:**
BMEN.5020 (https://www.uml.edu/catalog/courses/BMEN/5020) Biomaterial
CHEM.5700
(https://www.uml.edu/catalog/courses/CHEM/5700)Protein Chemistry
CHEM.6310
(https://www.uml.edu/catalog/courses/CHEM/6310)Principles of Medicinal Chemistry I

**Chemical Engineering:**
CHEN.5370
(https://www.uml.edu/catalog/courses/CHEN/5370)Nanomaterials Characterization I
CHEN.5410
(https://www.uml.edu/catalog/courses/CHEN/5410)Nanomaterials Characterization II

**Electrical and Computer Engineering:**
EECE.5160
(https://www.uml.edu/catalog/courses/EECE/5160)Biomedical Imaging and Data Science
EECE.5440
(https://www.uml.edu/catalog/courses/EECE/5440)Computational Data-Driven Modeling I

**Medical Lab Science:**
MLSC.5310
(https://www.uml.edu/catalog/courses/MLSC/5310)Clinical Immunohematology
MLSC.6000
(https://www.uml.edu/catalog/courses/MLSC/6000)Biomarker Discovery & Application
MLSC.6001
(https://www.uml.edu/catalog/courses/MLSC/6001)Biomarker Discovery & Application

**Nutritional Science:**
NUTR.5630
(https://www.uml.edu/catalog/courses/NUTR/5630)Vitamins & Minerals
NUTR.6010
(https://www.uml.edu/catalog/courses/NUTR/6010)Nutrition Assessment
NUTR.6040
(https://www.uml.edu/catalog/courses/NUTR/6040)Nutrition Epidemiology

**Pharmaceutical Science:**
PHRM.6120
(https://www.uml.edu/catalog/courses/PHRM/6120)Principles of Pharm Sciences Lab
PHRM.6301
(https://www.uml.edu/catalog/courses/PHRM/6301)Drug Discovery

**Plastics Engineering:**
PLAS.5320
(https://www.uml.edu/catalog/courses/PLAS/5320)Adhesives and Adhesion
PLAS.5970
(https://www.uml.edu/catalog/courses/PLAS/5970)Plastics and the Environment
PLAS.6420
(https://www.uml.edu/catalog/courses/PLAS/6420)Characterization of Polymers and Plastics

**Radiological Science/Medical Physics:**
RADI.5010L
(https://www.uml.edu/catalog/courses/RADI/5010L)Radiation Safety and Control I
RADI.5020L
(https://www.uml.edu/catalog/courses/RADI/5020L)Radiation Safety and Control II
RADI.5240
(https://www.uml.edu/catalog/courses/RADI/5240)Environmental Health Physics
RADI.5330
(https://www.uml.edu/catalog/courses/RADI/5330)External Radiation Dosimetry and Shielding
RADI.5340
(https://www.uml.edu/catalog/courses/RADI/5340)Internal Radiation Dosimetry and Bioassay
RADI.5410
(https://www.uml.edu/catalog/courses/RADI/5410)Radiochemistry
RADI.5650
(https://www.uml.edu/catalog/courses/RADI/5650)Introduction
to Radiation Therapy Physics  
RADI.5820  
(https://www.uml.edu/catalog/courses/RADI/5820)

Numerical Methods in Radiological Science  
RADI.5980  
(https://www.uml.edu/catalog/courses/RADI/5980)

Introduction to Medical Imaging  
RADI.6050  
(https://www.uml.edu/catalog/courses/RADI/6050)

Radiation Interactions and Transport  
RADI.6060  
(https://www.uml.edu/catalog/courses/RADI/6060)

Monte Carlo Simulation of Radiation Transport  
RADI.6650  
(https://www.uml.edu/catalog/courses/RADI/6650)

Advanced Radiation Therapy Physics  
RADI.6980  
(https://www.uml.edu/catalog/courses/RADI/6980)

Other:  
XXXX.XXXX Other elective as approved by BMEBT Graduate Coordinator

Earning the Master of Science Degree

Following successful completion of coursework with a minimum of 31 credits completed or transferred in that satisfy the core and elective specialization courses, the student will be awarded the Master of Science degree. Students must have at least a cumulative B average to receive the Master of Science degree.

Combined Bachelor’s and Master’s Degree Program

The program participates in the University’s effort to encourage outstanding graduate students to begin study toward an advanced degree while still undergraduates. Arrangements are possible for joint programs, that combine a bachelor’s degree in one of the other departments in the University with a master’s degree in the Biomedical Engineering and Biotechnology program. Such arrangements are made for eligible students after discussions with graduate coordinators in both departments (see eligibility requirements).

Biomedical Engineering &Biotechnology Doctoral Program

The Boston, Dartmouth, Lowell and Worcester campuses of the University of Massachusetts offer a joint Ph.D. degree program in Biomedical Engineering and Biotechnology. Students in the Ph.D. program may elect to receive the MS degree along the way to the doctorate.

- Admission Requirements

- Academic and Research Advisors
- Transfer of Credits/Advanced Standing
- Academic Program
- General Program Requirements
- Core Course Requirements (Requirement 1)
- Elective Specialization Course Requirement (Requirement 2)
- Earning the En-Route MS Degree
- Doctoral Dissertation Proposal
- Selection of the Doctoral Dissertation Committee
- Qualifying Examination
- Doctoral Credit Requirements
- Dissertation Defense
- Appendix - Elective Specialization Courses

Admission Requirements

Applicants from many different science/engineering undergraduate programs are invited to apply. Because the degree brings together biomedical engineering with biotechnology, it is designed equally for students with life sciences or engineering/physical science backgrounds. One’s specific background will be of less interest in determining qualification for entrance than will be one’s personal and career goals, demonstrated academic ability and research potential, and commitment to an interdisciplinary, team-work approach.

Applications will be accepted from individuals holding appropriate bachelors degrees or masters degrees (or the US baccalaureate equivalents from a foreign institution). Applicants should have a background in life science, physical science, or engineering. All applicants should have had undergraduate coursework in statistics/experimental design and life science/biomedical science, and meet the minimum requirements as stated below.

Applications are encouraged to contact participating faculty to discuss potential research opportunities and to describe those discussions in their Statement of Purpose (see below). A personal interview with the applicant by the campus Advising/Admissions/Curriculum Committee (AACC) may be recommended but is not required.

An application can be completed and submitted on-line. Applicants must submit the following and are expected to meet the standards indicated:

- Students with an overall undergraduate (and graduate, if applicable) grade point average of 3.0 or higher will be considered for admission. Applicants must present official
undergraduate and graduate transcripts from all schools attended.

- For acceptance into the program, applicants should present a minimum Graduate Record Exam (GRE) score of 142 in verbal and 152 in quantitative tests (294 combined). The date of the GRE exam should not precede the date of application by more than three years. The AACC will also pay particular attention to the applicants score on the GRE analytical writing section. Only official GRE scores from the Educational Testing Service will be considered acceptable.

- Applicants must have a minimum of two semesters or three quarters (equivalent of one academic year) of calculus, strong quantitative skills, and undergraduate coursework in statistics/experimental design and life science/biomedical science, as evidenced by their transcripts.

- International applicants, whose native language is not English, should present a minimum Test of English as a Foreign Language (TOEFL) score of 79 (internet version), 213 (computer version) or 550 (paper version). Only official TOEFL scores from the Educational Testing Service will be considered acceptable. Students who have completed at least two academic semesters of full time college/university in the United States may request a waiver of this requirement. For further details please see the information on international graduate admissions.

- Three letters of recommendation, from individuals familiar with the applicants academic ability and potential to conduct original research at the doctoral level, will be required.

- Applicants will also be required to submit a Statement of Purpose (personal essay). This statement is an important element in the application packet. It has two related roles:
  - Indication of an applicants qualifications and motivation for the program. Applicants should briefly describe their qualifications for and motivation to undertake this program as well as their personal and career goals. Specifically, the statement should indicate the applicants background and career plans as they relate to the multidisciplinary nature of the BMEBT doctorate, and discuss their research experience (academic, industrial) and include any publications and grants or patents;
  - Indication of how an applicant will fit into the program. Applicants should describe their specific areas of interest within Biomedical Engineering and Biotechnology, so that a fit between their interests and qualifications and the specific specialization options that the program offers can be determined. If the applicant has a specific interest in working with one or more of the program’s faculty, they should describe that specific interest and identify those faculty member(s). The Statement of Purpose should also exemplify the applicants writing skills.

- We invite applicants also to submit a personal rsum.

Admissibility will be determined by the AACC. The AACC may take into consideration individual circumstance. Extraordinary qualifications in some areas can be used to outweigh weaknesses in others. Admissibility to the Program does not guarantee funding. Final acceptance into the program depends on the applicant securing the support of a research advisor in the form of a Research Assistant (RA), or a department that has an available Teaching Assistant (TA) position relevant to the student’s background, or a combination of these two. Other sources of funding, such as scholarships and self-support, are also possible. Applicants may be offered admission contingent upon the successful completion of remedial courses to fill gaps in preparation or knowledge.

Academic and Research Advisors

It is the responsibility of the applicant to identify a faculty research advisor with the assistance of the Program. The research advisor will serve as the chair of the student’s dissertation committee. Academic advising is initially the responsibility of the AACC, and it pertains to the completion of the core courses (Requirement 1). The research advisor will also hold the responsibility of serving as academic advisor with respect to the selection of specialization courses (Requirement 2) that may be applicable to the student’s research.

Transfer of Credits/Advanced Standing

For students who have previously completed graduate course work, the AACC may approve the transfer of graduate credits for courses from an accredited college or university in the United States or Canada that received a grade of B (3.0 on a 4.0 scale) or better if those courses were not required by another earned degree. The graduate school at each campus
will govern the maximum number of credits that may be transferred into the program. The transfer credit may replace core or specialization course requirements. No project/directed studies, seminar or dissertation research credits will be accepted for transfer from institutions outside of the UMass system.

The AACC may also approve to waive courses without transfer of course credit. Students would still be responsible for the full 31 credits required for the MS and 63 credits required for the Ph.D., but would not have to take the waived course.

To earn the en-route MS degree, a student must complete or transfer in credit to meet the core requirements (19 credits) and specialization requirements (12 credits) for Requirement 1 and Requirement 2, respectively. Transfer credits are not to exceed 24 in total.

Students who join the doctoral program with an earned masters degree may receive "Advanced Standing". For these students, the number of credits required to complete the Ph.D. will be determined by the AACC, but at a minimum 12 course credits (core or specialization), doctoral seminar (taken twice, 1 credit each) and 30 dissertation research credits will be required. Students with Advanced Standing will be required to submit a Doctoral Dissertation Proposal and pass the Doctoral Qualifying Examination before progressing to the dissertation stage. As part of its academic advising roles, Advanced Standing is initiated by the AACC, but the formal request is filed by the student via completing an Academic Petition with attached supporting documentation, such as transcripts and course syllabi. The AACC can request information from the student pertaining to courses taken at the previous institution(s) and other relevant material prior to making a final decision on what courses the student will be required to take at UMass Lowell. The AACC will prepare an Advanced Standing Letter, summarizing the academic requirements, including courses the student will have to take.

**Academic Program**

The curriculum is organized around common experiences, including common core courses, elective courses and specialization options, and a research project. The program makes some use of distance learning/on-line/faculty exchange for delivery of courses and seminars, and the campuses are close enough to permit commuting between them. The program encourages a multidisciplinary team approach during a variety of courses, including the research project, and in the selection of the dissertation committee. In addition, each student then completes a focused research project leading to a doctoral dissertation. Industry representation may occur in the research project, doctoral seminar series, and via participation in the Doctoral Dissertation Committee.

**General Program Requirements**

The program of courses is based on the MS curriculum and it includes a core requirement, including a research project (Requirement 1), elective specialization requirement (Requirement 2), and two credits of doctoral seminar. As students advance, they will have to pass a qualifying examination, which is combined with the defense of the dissertation proposal, complete a dissertation project with a minimum of 30 credits of research, and pass the dissertation defense.

The Ph.D. degree requires completion or transfer of at least 63 total credits (or a minimum of 44 credits for students with advanced standing due to an existing MS degree). Students must meet the specific academic requirements of their "home campus" for such matters as grade point averages, documentation of completion of requirements, registration for program continuation if needed, and submitting the final dissertation to the library along with other documents required for graduation. No course receiving a grade below C (2.0 on a 4.0 scale) can receive credit to satisfy the minimum credit requirement. Grades earned below C are still calculated in the students grade point average.

Students are limited in the number of Directed or Independent Study course credits that they can apply toward their program. No more than 6 credits of coursework below the level of dissertation registration may be in the form of Directed or Independent Study. All courses must be conducted at the graduate level.

Students must pursue and complete a program of study approved by their academic advisor. The interdisciplinary nature of this program makes close contact between each student and his or her advisor important. Academic petitions pertaining to approval of core of elective specialization courses that are not listed in the approved course list should be routed through the academic and/or research advisors before being submitted to the AACC for review.

**Core Course Requirements (Requirement 1)**

The core courses follow the MS curriculum. They provide a common foundation for all students, either from life science or physical science/engineering backgrounds. A detailed list of courses in the MS curriculum is provided in the Appendix. Briefly, core requirements consist of three compulsory courses and four additional courses selected from four categories of approved courses.

**Students shall complete the following three core courses:**

- **BMBT.5000**
  [Introduction to Biomedical Engineering and Biotechnology](https://www.uml.edu/catalog/courses/BMBT/5000) (3 cr)
- **BMBT.5200**
  [Bioethics](https://www.uml.edu/catalog/courses/BMBT/5200) (1 cr)
- Research Project (3 cr) - Independent Study/Advanced Project / BMBT.7200
Independent Study

For the Research Project, students should register for an Independent Study or Advanced Project taken from the research advisor’s department. If the Research Advisor can’t set up a number in their department, the student should register for the BMBT.7200 Independent Study with a section established for the Research Advisor. The Research Project course should be taken toward the end of the MS course requirements to help students prepare for Qualifier Exam/Proposal Defense.

Students shall take one course from each of the following four core categories. Students are encouraged to consult their research and/or academic advisors for the most appropriate selection from the approved courses in each of these categories. Upon recommendation by their advisors, and with adequate justification expressed on the academic petition, approved courses may be substituted by other courses that substantially relate to these respective categories.

**Mathematics (3 cr)**

- **BMEN.5** (https://www.uml.edu/catalog/courses/BMEN/5810) Computational Biomechanics
- **CHEN.5390** (https://www.uml.edu/catalog/courses/CHEN/5390) Methods for Engineers
- **CHEN.5480** (https://www.uml.edu/catalog/courses/CHEN/5480) Engineering Process Analytics
- **MATH.5300** (https://www.uml.edu/catalog/courses/MATH/5300) Applied Math I
- **MATH.5** (https://www.uml.edu/catalog/courses/MATH/5550) Statistical Programming Using SAS
- **PHYS.5630** (https://www.uml.edu/catalog/courses/PHYS/5630) Computational Methods in Physics
- **PUBH.5750** (https://www.uml.edu/catalog/courses/PUBH/5750) Epidemiology and Biostatistics
- **PUBH.5770** (https://www.uml.edu/catalog/courses/PUBH/5770) Biostatistics for Health Data
- **RADI.5820** (https://www.uml.edu/catalog/courses/RADI/5820) Numerical Methods in Radiological Sciences
- **RADI.6060** (https://www.uml.edu/catalog/courses/RADI/6060) Monte Carlo Simulation of Radiation Transport

**Muscle and Lab (4 cr)**

- **BIO.L.5620/5630L** (https://www.uml.edu/catalog/courses/BIO.L/5620) Cardiovascular Physiology Lecture and Lab
- **BIO.L.5800/5810L** (https://www.uml.edu/catalog/courses/BIO.L/5800) Developmental Biology and Lab
- **BIO.L.5900** (https://www.uml.edu/catalog/courses/BIO.L/5900) Human Neurobiology (3 cr)
- **HSCI.5510** (https://www.uml.edu/catalog/courses/HSCI/5510) Clinical Pathophysiology (3 cr)
- **XXXX.XXXX** Other physiology course approved by the AACC

**Laboratory (3-5 cr)**

- **BIO.L.5190/5210L** (https://www.uml.edu/catalog/courses/BIO.L/5190) Biochemistry Techniques (5 cr)
- **BIO.L.5290** (https://www.uml.edu/catalog/courses/BIO.L/5290) Recombinant Protein Production Techniques (4 cr)
- **BIO.L.5320/5340L** (https://www.uml.edu/catalog/courses/BIO.L/5320) Genomics and Lab (4 cr)
- **BIO.L.5760** (https://www.uml.edu/catalog/courses/BIO.L/5760) Cell Culture (4 cr)
- **BIO.L.5950** (https://www.uml.edu/catalog/courses/BIO.L/5950) Immunology Lecture and Lab (2 cr)
- **CHEN.5860** (https://www.uml.edu/catalog/courses/CHEN/5860) Biotech Processing Projects Lab (3 cr)
- **EECE.5600** (https://www.uml.edu/catalog/courses/EECE/5600) Biomedical Instrumentation (3 cr)
- **MLSC.6100/6101L** (https://www.uml.edu/catalog/courses/MLSC) Clinical Toxicology and Lab (4 cr)
- **NUTR.5650** (https://www.uml.edu/catalog/courses/NUTR/5650) Lab Methods in Nutrition Assessment (3 cr)
- **PHRM.6400/6420L** (https://www.uml.edu/catalog/courses/PHRM) Pharmaceutical Analysis and Lab (4 cr)
- **RADI.5060** (https://www.uml.edu/catalog/courses/RADI/5060) Nuclear Instrumentation with Lab (3 cr)
- **XXXX.XXXX** Other lab course approved by the AACC

**Advanced Cell and Molecular Biology (3 cr)**

- **BIO.L.5420** (https://www.uml.edu/catalog/courses/BIO.L/5420) Advanced Cell Biology (3 cr)
- **BIO.L.5670** (https://www.uml.edu/catalog/courses/BIO.L/5670) Molecular Biology (3 cr)
- **BIO.L.5820** (https://www.uml.edu/catalog/courses/BIO.L/5820) Cancer Biology (3 cr)
- **BIO.L.6660** (https://www.uml.edu/catalog/courses/BIO.L/6660) Selected Topics in Molecular and Cellular Biology (3 cr)
- **NUTR.5720** (https://www.uml.edu/catalog/courses/NUTR/5720) Nutrigenetics (3 cr)
RADI.5620 (https://www.uml.edu/catalog/courses/RADI/5620)
Radiation Biology (3 cr)
XXXX.XXXX Other advanced cell and molecular biology course approved by AACC

* Students may take additional courses from the Core categories as Elective Specialization courses

** Students who take this course, which includes a co-requisite lab, to satisfy the Physiology Core requirement may take a course from the Elective Specialization list (see Appendix) in place of the Lab core requirement. An academic petition will be required.

Elective Specialization Course Requirements (Requirement 2)

All students shall complete a minimum of 12 credits of elective specialization courses. Students may take courses from one specialization area, across specialization areas and/or from the list of additional course offerings. Please consult the Appendix for a list of approved elective courses.

Specialization courses will help the student attain depth in focused areas. Academic/research advisors involved in each specialization will see to an appropriate combination of depth and breadth in the students selection of these courses. They may announce some structure to the course selections allowed within the area. With the approval of their advisor, students will select a minimum of 12 credits of course work from within one of the specializations or from any combination of specializations, including the additional course offerings, as listed in the Appendix. Any graduate course approved by the AACC may be used to satisfy this requirement.

Earning the En-Route MS Degree

Following successful presentation of the research project and with a minimum of 31 credits completed or transferred in required and approved courses, the student will be awarded the Master of Science degree as a credential along the way toward the doctorate. Students must have at least a cumulative B average to receive the en-route MS degree and advance to the Doctoral Qualifying Examination. (Students not working up to that level are subject to review for dismissal from the program. Specific standards are set for graduate students on each "home campus" for continuation in graduate programs.) Doctoral students who enter the program with advanced standing will not earn the en-route MS degree.

Doctoral Dissertation Proposal

The Dissertation Proposal is written under the direct supervision of the research advisor. It must be completed before the Doctoral Qualifier Examination is scheduled. The Dissertation Proposal will follow the format established for NIH proposals, including the page limits, and will include a review of the literature on the students chosen topic, present original hypotheses, design experiments to test the hypotheses, document the appropriate methodology that will be used, project anticipated results, and indicate how such results might be interpreted. The proposal must show application to current biomedical/biotechnological problems.

Selection of the Doctoral Dissertation Committee

Students will select their Doctoral Dissertation Committee while they develop their Dissertation Proposal. The Committee must have at least three full-time faculty members from UMass Lowell, with the research advisor serving as the Chair. Participation of faculty outside the research group or outside the host research department is encouraged, and so is selection of one additional member of the Dissertation Committee from relevant and appropriate industry. Only one emeritus faculty is allowed.

Each students committee is approved by the campus AACC, which will also approve any changes to a previously approved committee.

Qualifying Examination

The Qualifying Examination is combined with the Dissertation Proposal Defense. The two parts in combination are referred to as the Doctoral Qualifying Examination.

The Doctoral Qualifying Examination must be taken within one year after completion of the MS Biomedical Engineering and Biotechnology requirements or within two years for students with advanced standing. It will consist of an oral presentation of the written dissertation proposal to an audience of peers and the Doctoral Dissertation Committee, followed by examination by the Committee.

At least two weeks prior to the date of the presentation of the dissertation proposal, an announcement must be submitted to the program graduate coordinator to be posted on UML Announcements. At the same time, the written copy of the proposal must be provided to the Dissertation Committee members.

The dissertation proposals presentation is open to the public. The presentation will outline the motivation for the research, give a summary of the related past work in the area and present the scope of the proposed dissertation research. The presentation should be no longer than 45 minutes. The presentation should clearly articulate the proposed contribution of the student to the knowledge base and how it differs from or complements past work. The examinee will be expected to answer questions from the audience to demonstrate his/her understanding of the proposed research, as well as his/her proficiency in the general research field related to the dissertation proposal.

Following the presentation, the Dissertation Committees examination will primarily focus on the subject of the proposal, but it may also include areas that may come up during the discussion, as appropriate.
After successfully defending the dissertation proposal and passing the concomitant examination, the student attains the designation doctoral candidate. If the student fails any part of the Doctoral Qualifier Examination, the Doctoral Dissertation Committee may recommend retaking it within one or two semesters, depending on the circumstances. Failure to pass the second Doctoral Qualifier Examination results in dismissal from the Ph.D. program.

**Doctoral Credit Requirements**

1. **Doctoral Seminar - 2 credits minimum (credits for a seminar depends on host department)**
   
   Doctoral students should present research in progress in an appropriately selected doctoral seminar. The selection of the most appropriate seminar will be based on the suggestion of the students research advisor. The seminar will emphasize not only research, but also communication and writing. Students will write summaries of each presentation and submit it to the AACC/graduate coordinator as a progress report. Course is graded pass-fail or satisfactory-unsatisfactory (depending on grading system in use for each department).

2. **Dissertation Research (variable credit each semester, 30 credits minimum)**
   
   Doctoral students will register for a minimum of 30 credits of doctoral research with their faculty advisor (dissertation chair). They will use these credits during preparation and defense of the dissertation proposal/qualifying examination, carrying out their dissertation research and preparation and defense of the doctoral dissertation.

   BMBT.7590
   (https://www.uml.edu/catalog/courses/BMBT/7590)
   Dissertation Research (1-9 credits)

**Dissertation Defense**

The Dissertation should be of publishable quality in an appropriate peer-reviewed journal. Ideally, one or more journal papers are published or at least submitted for publication to a journal or conference before the dissertation defense. Students should submit proof of submittal, acceptance, or the published paper.

At least two weeks prior to the date of the dissertation defense, an announcement must be submitted to the program graduate coordinator to be posted in UML Announcements.

The doctoral candidate will defend his/her written dissertation before the Doctoral Dissertation Committee, the University, and the outside community. The specific format of the defense is usually decided by the committee chair, but a typical format consists of the Ph.D. candidate first presenting an overview of the thesis research, then answering specific questions asked by the committee members. Questions may test anything from knowledge of the existing literature, to scrutiny of the material and methods or experimental design, to the assumptions in the research, to the interpretation of the results, to recommendations for future work. It is common for the committee to ask that certain minor revisions be made to the written dissertation before final submission. Successful defense of the dissertation and submission of the finished work to the library will result in the awarding of the Ph.D. in Biomedical Engineering and Biotechnology. Dissertations must be filed with Dissertation Abstracts International.

**Appendix - Elective Specialization Courses**

**a. Courses in MEDICAL IMAGING AND INSTRUMENTATION**

EECE.5100 (https://www.uml.edu/catalog/courses/EECE/5100) Digital Signal Processing

EECE.5110 (https://www.uml.edu/catalog/courses/EECE/5110) Medical Diagnostic Imaging

EECE.5410 (https://www.uml.edu/catalog/courses/EECE/5410) Introduction to Biosensors

EECE.5520 (https://www.uml.edu/catalog/courses/EECE/5520) Microprocessor Systems II & Embedded Systems

EECE.6150 (https://www.uml.edu/catalog/courses/EECE/6150) Medical Image Reconstruction

EECE.7100 (https://www.uml.edu/catalog/courses/EECE/7100) Selected Topics: Biomedical Imaging and Data Science

**b. Courses in BIOTECHNOLOGY AND BIOPROCESSING**

CHEN.5340 (https://www.uml.edu/catalog/courses/CHEN/5340) Industrial Bioprocessing

CHEN.5350 (https://www.uml.edu/catalog/courses/CHEN/5350) Cell and Microbe Cultivation

CHEN.5380 (https://www.uml.edu/catalog/courses/CHEN/5380) Advanced Separations in Biotechnology

CHEN.5450 (https://www.uml.edu/catalog/courses/CHEN/5450) Isolation and Purification of Biotech Products

CHEN.5460 (https://www.uml.edu/catalog/courses/CHEN/5460) Biomaterial Science

CHEN.5500 (https://www.uml.edu/catalog/courses/CHEN/5500) Biomedical Applications of Nanotechnology

CHEN.5530 (https://www.uml.edu/catalog/courses/CHEN/5530) Biopharmaceutical Regulatory Compliance

**c. Courses in CLINICAL PATHOLOGY**

MLSC.5120 (https://www.uml.edu/catalog/courses/MLSC/5120) Medical Bacteriology

MLSC.5500 (https://www.uml.edu/catalog/courses/MLSC/5500) Foundations in Biomedical Research

MLSC.5530 (https://www.uml.edu/catalog/courses/MLSC/5530) Emerging Topics in Clinical Chemistry
g. Courses in ERGONOMICS AND BIOMECHANICS

BMEN.5300
(https://www.uml.edu/catalog/courses/BMEN/5300) Ergonomics and Work
BMEN.5310
(https://www.uml.edu/catalog/courses/BMEN/5310) Occupational Biomechanics
BMEN.5380
(https://www.uml.edu/catalog/courses/BMEN/5380) Computational Biomechanics
BMEN.5400
(https://www.uml.edu/catalog/courses/BMEN/5400) Occupational Safety Engineering
BMEN.6380
(https://www.uml.edu/catalog/courses/BMEN/6380) Methods in Work Analysis
PUBH.5061
(https://www.uml.edu/catalog/courses/PUBH/5061) Environmental Health
PUBH.5510

h. Additional Course Offerings

Biological Sciences:
BIOL.5050L
(https://www.uml.edu/catalog/courses/BIOL/5050L) Bioinformatics
BIOL.5090
(https://www.uml.edu/catalog/courses/BIOL/5090) Photobiology
BIOL.5720
(https://www.uml.edu/catalog/courses/BIOL/5720) Virology
BIOL.5840
(https://www.uml.edu/catalog/courses/BIOL/5840) Comparative Vertebrate Embryology
BIOL.5930
(https://www.uml.edu/catalog/courses/BIOL/5930) Immunology
BIOL.5940
(https://www.uml.edu/catalog/courses/BIOL/5940) Advanced Topics in Immunology
BIOL.
(https://www.uml.edu/catalog/courses/BIOL/5950)5062/5062L Bioinformatic Tools in Sequence Analysis

Biomedical Engineering:
BMEN.5020
(https://www.uml.edu/catalog/courses/BMEN/5020) Biomedical Engineering
BMEN.5030
(https://www.uml.edu/catalog/courses/BMEN/5030) Medical Device Design
BMEN.5035
(https://www.uml.edu/catalog/courses/BMEN/5035) Advanced Medical Device Development
BMEN.5040
(https://www.uml.edu/catalog/courses/BMEN/5040) Medical Device Development
BMEN.5110
(https://www.uml.edu/catalog/courses/BMEN/5110) Tissue
Engineering
BMEN.5115
(https://www.uml.edu/catalog/courses/BMEN/5115) Advanced Tissue Engineering
BMEN.5130
(https://www.uml.edu/catalog/courses/BMEN/5130) Neural Engineering
BMEN.5305
(https://www.uml.edu/catalog/courses/BMEN/5305) Biomechanics
BMEN.5325
(https://www.uml.edu/catalog/courses/BMEN/5325) Biofluid Mechanics
BMEN.5350
(https://www.uml.edu/catalog/courses/BMEN/5350) Respiratory Dynamics Devices
BMEN.5380
(https://www.uml.edu/catalog/courses/BMEN/5380) Computational Biomechanics
BMEN.5390
(https://www.uml.edu/catalog/courses/BMEN/5390) Computer Aided Engineering Design and Analysis
BMEN.5410
(https://www.uml.edu/catalog/courses/BMEN/5410) Biomedical Optics
BMEN.5610
(https://www.uml.edu/catalog/courses/BMEN/5610) Drug Delivery

Chemical Engineering:
CHEN.5370
(https://www.uml.edu/catalog/courses/CHEN/5370) Nanomaterials Characterization I
CHEN.5410
(https://www.uml.edu/catalog/courses/CHEN/5410) Nanomaterials Characterization II

Chemistry:
CHEM.5130
(https://www.uml.edu/catalog/courses/CHEM/5130) Spectroscopy
CHEM.5500
(https://www.uml.edu/catalog/courses/CHEM/5500) Biochemistry I
CHEM.5510
(https://www.uml.edu/catalog/courses/CHEM/5510) Biochemistry II
CHEM.5550L
(https://www.uml.edu/catalog/courses/CHEM/5550) Lab in Modern Biochemistry and Biophysics
CHEM.5600
(https://www.uml.edu/catalog/courses/CHEM/5600) Advanced Physical Biochemistry
CHEM.5620
(https://www.uml.edu/catalog/courses/CHEM/5620) Biopharmaceutical Development
CHEM.5700
(https://www.uml.edu/catalog/courses/CHEM/5700) Protein Chemistry
CHEM.6310
(https://www.uml.edu/catalog/courses/CHEM/6310) Principles of Medicinal Chemistry I

Electrical and Computer Engineering:
EECE.5160
(https://www.uml.edu/catalog/courses/EECE/5160) Biomedical Imaging and Data Sci
EECE.5440
(https://www.uml.edu/catalog/courses/EECE/5440) Comp. Data-Driven Modeling I
EECE.5470
(https://www.uml.edu/catalog/courses/EECE/5470) Comp. Data-Driven Modeling II
EECE.5560
(https://www.uml.edu/catalog/courses/EECE/5560) Robotics
EECE.5590
(https://www.uml.edu/catalog/courses/EECE/5590) Intro to Nanoelectronics
EECE.5680
(https://www.uml.edu/catalog/courses/EECE/5680) Electro Optic Systems
EECE.5810
(https://www.uml.edu/catalog/courses/EECE/5810) Comp Vision &Dig Image Proc
EECE.5950
(https://www.uml.edu/catalog/courses/EECE/5950) Solid State Electronics
EECE.6690
(https://www.uml.edu/catalog/courses/EECE/6690) Opto Electronic Devices

Mechanical Engineering:
MECH.5710
(https://www.uml.edu/catalog/courses/MECH/5710) Quality Engineering
MECH.5750
(https://www.uml.edu/catalog/courses/MECH/5750) Industrial Design of Experiments
MECH.5760
(https://www.uml.edu/catalog/courses/MECH/5760) Engineering Project Management
MECH.5960

Medical Lab Science:
MLSC.5310
(https://www.uml.edu/catalog/courses/MLSC/5310) Clinical Immunohematology
MLSC.6000
(https://www.uml.edu/catalog/courses/MLSC/6000) Biomarker Discovery &App
MLSC.6001
(https://www.uml.edu/catalog/courses/MLSC/6001) Biomarker Discovery &App Lab

Nutritional Science:
NUTR.5630
(https://www.uml.edu/catalog/courses/NUTR/5630) Vitamins &Minerals
NUTR.6010
(https://www.uml.edu/catalog/courses/NUTR/6010) Nutrition Assessment
NUTR.6040
Nutrition Epidemiology

**Pharmaceutical Science:**
PHRM.6120
(https://www.uml.edu/catalog/courses/PHRM/6120) Principles of Pharm Sciences Lab
PHRM.6501
(https://www.uml.edu/catalog/courses/PHRM/6501) Drug Discovery

**Plastics Engineering:**
PLAS.5320 (https://www.uml.edu/catalog/courses/PLAS/5320) Adhesives and Adhesion
PLAS.5970 (https://www.uml.edu/catalog/courses/PLAS/5970) Plastics and the Environment
PLAS.6420 (https://www.uml.edu/catalog/courses/PLAS/6420) Characterization of Polymers and Plastics

**Radiological Science/Medical Physics:**
RADL.5010L (https://www.uml.edu/catalog/courses/RADL/5010) Radiation Safety and Control I
RADL.5020L (https://www.uml.edu/catalog/courses/RADL/5020) Radiation Safety and Control II
RADL.5240 (https://www.uml.edu/catalog/courses/RADL/5240) Environmental Health Physics
RADL.5330 (https://www.uml.edu/catalog/courses/RADL/5330) External Radiation Dosimetry and Shielding
RADL.5340 (https://www.uml.edu/catalog/courses/RADL/5340) Internal Radiation Dosimetry and Bioassay
RADL.5410 (https://www.uml.edu/catalog/courses/RADL/5410) Radiochemistry
RADL.5650 (https://www.uml.edu/catalog/courses/RADL/5650) Introduction to Radiation Therapy Physics
RADL.5820 (https://www.uml.edu/catalog/courses/RADL/5820) Numerical Methods in Radiological Science
RADL.5980 (https://www.uml.edu/catalog/courses/RADL/5980) Introduction to Medical Imaging
RADL.6050 (https://www.uml.edu/catalog/courses/RADL/6050) Radiation Interactions and Transport
RADL.6650 (https://www.uml.edu/catalog/courses/RADL/6650) Advanced Radiation Therapy Physics
RADL.6980 (https://www.uml.edu/catalog/courses/RADL/6980) Advanced Medical Imaging

**Other:**
XXXX.XXXX Other elective as approved by BMEBT
Graduate Coordinator
BMBT.5000 Introduction to Biomedical Engineering & Biotechnology (Formerly IB 500) - Credits: 3

This introductory course envelopes a breadth of different topics and fundamental concepts in biomedical engineering and biotechnology (BMEBT) that will allow students to explore and identify areas that may be of interest to them. Topics covered in the course may include, but are not limited to, the following: engineering and ethics, anatomy and physiology, biomechanics, biomaterials, tissue engineering, bioinstrumentation, biomedical sensors, biosignal processing, radiation treatment and medical imaging. Speakers from industry may also be invited to present topics of contemporary importance.

BMBT.5120 Medical Image Processing (Formerly IB 512) - Credits: 3

This course will focus on post-acquisition manipulation and analysis used clinically and in research. Techniques for processing N-dimensional images acquired using several different medical image modalities will be studied including basic image visualization, filtering, segmentation and registration. The emphasis will be on engineering methods and techniques rather than a rigorous mathematical investigation of algorithms and theory. Programming will not be required, but homework and projects will require use of an open-source software tool, ImageJ, to perform image processing tasks. [NOTE: Many students in prior semesters have expressed a preference for using MATLAB from Mathworks for image processing. All assignments can be completed using either ImageJ OR MATLAB].

BMBT.5130 Biomedical Analytics & Informatics (Formerly IB 513) - Credits: 3

The focus of this course will be on the analysis of large biomedical data sets using the R Programming Language, an open-source programming language with several development platforms freely available for Windows, Mac, and Linux. The central topics will cover basic data analytics methods applying the widely used data analysis tool, R. This course will not focus on any specific biotechnology area. Many of the analytical skills obtained can be applied across a number of biomedical applications. The syllabus also covers an overview of major biomedical “Big Data” areas. Students may implement their final course project using a dataset in any biomedical application area of their choosing, i.e. genomics, medical imaging, health policy informatics, and personal health monitoring. There is no programming pre-requisite for this course. Students must have the willingness and capacity to learn how to apply R Programming.

BMBT.5160 Basic Principles of Nuclear Magnetic Resonance Imaging (Formerly IB 516) - Credits: 3

The goal of this course is to provide the student with a general understanding of the physical principles of magnetic resonance imaging (MRI) and the instrumentation used to create a magnetic resonance image. This goal will be sought without deep exploration of any particular physical science or mathematical discipline. Background knowledge in freshman-level science and mathematics courses is assumed. The topics to be covered in this course include: 1) theoretical and experimental aspects of MRI and their application to problems in medicine and biology, 2) physical principles underlying the generation and detection of the nuclear magnetic resonance signal, 3) MRI instrumentation, and 4) Nuclear magnetic resonance relaxation parameters and how they affect contrast in a magnetic resonance image.

BMBT.5170 Embedded System Design in Medical Systems (Formerly IB 517) - Credits: 3

This course covers the design principles of embedded systems including both the hardware and software aspects. We will introduce the design methodology and cost effectiveness of embedded systems. We will discuss the microprocessor, memory and storage subsystems. The interfacing between the computer system and medical instruments will be reviewed. Firmware, operating systems, programming tools will be considered. The course will have a lab component that includes hands-on exercises of embedded Linux (or RTEMS) in an online virtual laboratory environment.

BMBT.5200 Ethical Iss. Biomedical (Formerly IB 520) - Credits: 1

The purpose of this course is to illustrate the ethical implications of engineering, and how to reason through these implications and make the best decisions possible. This course addresses ethical issues that arise in the discipline of biomedical engineering. Unlike most bioethics courses, this course draws from the literature in biomedical ethics and from engineering ethics, to cover important emerging issues that face biomedical engineers. Topics may include, but are not limited to, ethics related to general research, public health, robotic surgery, medical device validation, gene editing, artificial organs, longevity research, prosthetics, artificial intelligence, and brain-computer interfaces.

BMBT.5250 Introduction to Translational Science (Formerly IB 525) - Credits: 3

Introduction to Translational Science will introduce students to the elements of translational research and is targeted toward individuals who have no prior experience with clinical or translational research. This course will focus on the principles and practices of translational medicine as they apply to the
development of a new drug (small molecules and/or biologics), device, or diagnostic. The course will cover the following topics: Defining translational research, pre-clinical development of novel targets and leads, clinical development, the regulatory process, the design of the first-in-human clinical trial, protecting human subjects and managing clinical data.

BMBT.5500 BMBT Laboratory Experience (Formerly IB 550) - Credits: 3
BMBT.5750 Quantitative Physiology (Formerly IB 575) - Credits: 3

This course presents physiology at the organ system level with a quantitative approach. It helps integrate the curriculum for individuals with life science and engineering undergraduate backgrounds, permitting engineers and physical scientists an appreciation of how organisms function from the organ/system perspective and gives life scientists a more rigorous quantitative approach to physiology than is usual in undergraduate courses.

BMBT.6000 Capstone Project (Formerly IB 600) - Credits: 3

Design or research project, either on campus or in industry, that synthesizes the knowledge accumulated in the BMEBT core curriculum. The course includes a brief project proposal, final report and presentation to be overseen by a UMass Lowell faculty member, as well as industry sponsor if conducting the research in industry. All research must be publishable (i.e. projects with strict IP are not allowed). Students should register in their final semester of MS required coursework.

BMBT.6010 Sem: Biomedical Engineering & Biotechnology (Formerly IB 601) - Credits: 3

The goal of the seminar is to have students develop effective writing and speaking skills required for preparation of research papers and professional presentations. The course emphasizes the importance of clear, concise writing style and delivery of presentations to both scientists and the lay public. Outside readings are designed to critically evaluate contemporary issues related to: disclosure and conflict of interest, publishing ethics, the balance of research, security, and publishing censorship, electronic science collaborations, and the social implications of science. Preparation of research grant proposals, the curriculum vitae, and poster presentations, and the submission of manuscripts for publication are also reviewed.

BMBT.6050 1-Credit Continued Capstone Project (Formerly IB 605) - Credits: 1

1-Credit Continued Capstone Project course is for students who need an extra semester to complete their capstone. Part of

reduced course load program for international students.

BMBT.7100 Directed Study (Formerly BMBT 710) - Credits: 1-3
BMBT.7120 Directed Studies (Formerly IB 712) - Credits: 2-3
BMBT.7200 Independent Study (Formerly IB 720) - Credits: 3
BMBT.7210 Independent Study (Formerly IB 721) - Credits: 1
BMBT.7220 Independent Study (Formerly IB 722) - Credits: 2
BMBT.7560 Doctoral Dissertation (Formerly IB 756) - Credits: 6
BMBT.7590 Dissertation Research (Formerly IB 759) - Credits: 1-9
BMBT.7610 Continued Graduate Research - Credits: 1
BMBT.7700 CPT - Co-op Training (Formerly IB 770) - Credits: 1

Course required to perform CPT

BMBT.7710 CPT-Co-op Training (Formerly IB 771) - Credits: 0-1

Course required to perform CPT. "Variable credit course, student chooses appropriate amount of credits when registering."

BMBT.7800 Thesis Review (Formerly IB 780) - Credits: 1

Thesis Review

BMEN.5020 Fundamentals of Biomaterials - Credits: 3

This course will provide an introduction to materials used in biomedical applications. It will provide students with an understanding of the fundamental principles and language associated with current biomaterials research and to understand the issues associated with medical applications of these materials. The goal is to enable students in the course to read the biomaterials literature with critical understanding. The course will introduce principles of materials science and cell biology underlying the design of medical implants, artificial organs, and matrices for tissue engineering and covers surface
chemistry and physics of selected biomaterials, surface characterization methodology, acute and chronic response to implanted biomaterials, and molecular and cellular interactions.

BMEN.5035 Advanced Medical Device Development - Credits: 3

This course focuses on the events that occur after the "solution concept freeze" in the medical device development process, including device designs, clinical evaluation, quality systems, manufacturing processes, regulatory and legal compliance.

BMEN.5040 Medical Device Development Regulation - Credits: 3

A comprehensive and in-depth analysis of US medical device diagnostics development and approval requirements. Detailed analysis of quality assurance issues and regulatory reforms implemented under the Food and Drug Administration. Provides a step-by-step guide though the Center for Devices and Radiological Health (CDRH) investigation device exemptions, premarket approval, 510(k) application process and product development protocol and review process.

BMEN.5110 Tissue Engineering - Credits: 3

Tissue engineering utilizes engineering materials, cells, and other biochemical factors to develop and manipulate cells, tissues, or organs which can replace and/or support biological functions. In this course, we will explore the principles underlying tissue structure-function relationships; how to rationally alter, restore, or improve cellular environments; and clinical implementations.

BMEN.5115 Advanced Tissue Engineering - Credits: 3

Tissue engineering research continues to attract the interest of researchers and the general public. Popular media outlets like the New York Times, Time, and Wired continue to engage a wide audience and foster excitement for the field as regenerative medicine inches toward becoming a clinical reality. This course will cover enabling technologies, and current applications of the tissue engineering field. The enabling technologies section will focus upon those strategies typically incorporated into tissue-engineered devices or utilized in their development, including advanced scaffolding techniques, bioreactors, and micro physiological systems. Finally, the applications section presents engineered tissues and organs that are currently under development for generative medicine applications.

BMEN.5130 Neural Engineering - Credits: 3

Neural Engineering represents the intersection between neuroscience and the technologies designed to measure and modulate the nervous system. This course will review the fundamental principles of cellular and systems neuroscience in the peripheral and central nervous systems, followed by surveys of cutting edge optical/electrical neural interfaces, in vivo/vitro synthetic model systems, prostheses, as well as ethical considerations in neuroscience/neural engineering.

BMEN.5200 Bioinstrumentation - Credits: 3

This course builds upon students’ undergraduate knowledge/experience in circuit analysis and biological signal quantification/processing. Using analog and digital filtering/processing techniques, students will analyze real data sets related to cell/tissue imaging, biomedical imaging, force transduction, and electrophysiological recordings (EMG, EKG, and MEA). As a final project, students will be required to design and propose a set of experiments using bioinstrumentation techniques covered in class, with an emphasis on failure modes and effects analysis (hardware) as well as signal processing and proposed statistical analysis.

BMEN.5210 Quantitative Physiology - Credits: 3

Quantitative Physiology will provide learning opportunities for graduate students to understand and develop competencies in a quantitative, research oriented, systems approach to physiology. Systems examined may include cellular; musculoskeletal; cardiovascular; respiratory; endocrine; gastrointestinal; and renal. Where applicable, mathematical models and engineering analyses will be used to describe system performance.

BMEN.5300 Ergonomics and Work (Formerly BMBT.5300) - Credits: 3

An overview of the scientific basis for design of the workplace to optimize physical and mental interaction of workers with machines, tools, and work methods. Topics include work measurement, anthropometry, biomechanics, work physiology, cumulative trauma disorder and information presentation and processing.

BMEN.5305 Biomechanics - Credits: 3

The course provides an overview of musculoskeletal anatomy, the mechanical properties and structural behavior of biological tissues, and biodynamics. Specific course topics will include structure and function relationships in tissues and organs; application of stress and strain analysis to biological tissues; analysis of forces in human function and movement; energy and power in human activity; introduction to modeling viscoelasticity of tissues.

BMEN.5315 Biomechanics II - Credits: 3
This course prepares students with the mathematical preliminaries and theoretical framework to analyze the mechanics of biological materials and human movement. The course will focus on methods to model biological tissues as non-linear, elastic, homogeneous, anisotropic, incompressible materials, and analyze human movement, including the impulse-momentum and work-energy principles, as well as gait analysis.

BMEN.5320 Occupational Biomechanics Laboratory
(Formerly BMBT.5320) - Credits: 3

A laboratory presentation of the biomechanical basis for understanding and predicting human motor capabilities using bioinstrumentation. Computerized data acquisition, electromyography and load cells for strength measurement are examples of the equipment used in this lab. Particular emphasis is placed on the evaluation of occupational activities.

BMEN.5325 Biofluid Mechanics - Credits: 3

This course will introduce fundamental principles and mathematical/physical models for air and blood flow in the physiological systems. Their practical applications will be discussed, with an emphasis on modeling and the potential of flow studies for clinical research applications.

BMEN.5350 Respiratory Dynamics and Devices - Credits: 3

An aerosol is an assembly of particles suspended in a gaseous medium. They are omnipresent in our workplaces and outdoor environments. They include a wide range of phenomena such as dust, fume, smoke, mist, fog, haze, clouds and smog. Certain aerosols pose significant health threats, while others improve the quality of our lives. It is necessary to understand how airborne particles behave to control against their undesirable effects and to harness their beneficial potential. This course will explore the mechanics of aerosol behavior, including their generation, transformation, and fate occupational and environmental settings.

BMEN.5380 Computational Biomechanics - Credits: 3

Computational biomechanics is a powerful engineering method to model fluid-structure interaction in biological systems. While its traditional roots are in the realm of engineering, the techniques have found wide use in the biomedical engineering domain to simulate the biomechanical response and hemodynamics of the human body and medical devices. This course will prepare students with hands-on and practical skills using computational packages and software to solve biomechanical problems.

BMEN.5390 Computer Aided Design for Biomedical Engineering - Credits: 3

This course introduces the student to the use of CAD for construction of basic shapes and multi-vie drawings. It is a project-oriented course introducing the student to graphic design using SolidWorks. Design, analysis and visualization of engineering components and systems using interactive computer programs with an emphasis on computer simulation.

BMEN.5400 Occupational Safety Engineering
(Formerly BMBT.5400) - Credits: 3

The purpose of this course is to introduce students to the principles of safety hazards in the work environment. This course is primarily designed to emphasized the safety aspects to the hazards at work. It begins with the historical development of occupational safety and health and progressively examines the fundamentals of recognition, measurement, evaluation, and control of occupational safety hazards.

BMEN.5410 Biomedical Optics - Credits: 3

This course will introduce fundamental principles of the interactions between light and biological tissue, including their applications in biology and medicine for detection, imaging, and treatment.

BMEN.5610 Drug Delivery - Credits: 3

This class describes the engineering of pharmaceutical delivery systems emphasizing design and application of materials and novel techniques to overcome challenges or barrier to effective drug delivery. Topics will include drug delivery fundamentals and transport mechanisms, drug formation for delivery, and applications.

BMEN.5810 Data Analytics & Biostatistics for BME - Credits: 3

Data analysis is a major skill that is required to solve problems as well as to design and develop biotechnology solutions and medical devices. A bioengineer must not only apply the long standard general statistical methods in order to analyze data but also master some of the unique aspects involved in the analysis of biomedical datasets. This course will require the student to become proficient in MATLAB and the Statistics and Machine Learning Toolbox in order to achieve course learning objectives. The student will also be required to demonstrate their bioanalytical proficiency through the implementation of an individual project.

BMEN.5900 Graduate Seminar in Biomedical Engineering - Credits: 0
The Graduate Seminar in Biomedical Engineering includes speaker presentations by invited external and internal faculty, as well as student presentations. The objectives of the course are to improve oral communication and visual presentation skills as well as growing exposure to cutting-edge research in the different biomedical tracks. Required for all graduate students.

BMEN.6090 Research Methods in Medical Device Design - Credits: 3

Research Methods will provide biomedical engineering graduate students with a mentored experience to learn and master a hands-on research methodology. Appropriate research methodologies are those within Medical Device Design that provide the student with critical hands-on skillsets to further support their graduate studies. Student will work approximately 3 hours a week per credit on a designated research project. Regular meetings with the research mentor will also occur. Students are required to submit final project report and final presentation to their mentor.

BMEN.6190 Research Methods in Cellular & Tissue Engineering - Credits: 3

Research Methods will provide biomedical engineering graduate students with a mentored experience to learn and master a hands-on research methodology. Appropriate research methodologies are those within Cellular and Tissue Engineering that provide the student with critical hands-on skillsets to further support their graduate studies. Student will work approximately 3 hours a week per credit on a designated research project. Regular meetings with the research mentor will also occur. Students are required to submit final project report and final presentation to their mentor.

BMEN.6320 Advanced Biomechanics (Formerly BMBT.6320) - Credits: 3

A course in advanced biomechanical modeling methods, covering three dimensional static models, optimization methods and dynamic models. Special emphasis will be placed on biomechanical models of the hand. Time will also be dedicated to reviewing current developments in the scientific literature.

BMEN.6380 Methods of Work Analysis (Formerly BMBT.6380) - Credits: 3

Criteria for selection of an approach to ergonomic job analysis depend on the combination of exposures (Micro- and Macro-level ergonomic stressors) observed to be present as well as the analytical goal. Many ergonomic analysis techniques are based on traditional industrial engineering approaches (time-motion study and work sampling), applied to the identification and evaluation of potential risks to workers' health. A variety of methods, both observational and instrumental, will be discussed; laboratory sessions will permit hands-on application of several of these for critical evaluation.

BMEN.6390 Research Models in Biomechanics - Credits: 3

Research Models will provide biomedical engineering graduate students with a mentored experience to learn and master modeling framework in biomechanics. Appropriate research models will provide the student with critical hands-on skillsets to further support their graduate studies. Student will work approximately 3 hours a week per credit on a designated research project. Regular meetings with the research mentor will also occur. Students are required to submit final project report and final presentation to their mentor.

BMEN.7590 Doctoral Dissertation Research - Credits: 1-9

Doctoral Dissertation Research Credits.
**Biomedical Engineering**

**Department of Biomedical Engineering**

The Department of Biomedical Engineering at UMass Lowell offers a:

- Doctor of Philosophy in Biomedical Engineering

The Boston, Dartmouth, and Lowell campuses of the University of Massachusetts offer a joint:

- Master of Science in Biomedical Engineering and Biotechnology
- Doctor of Philosophy in Biomedical Engineering and Biotechnology
- Graduate Certificate in Biomedical Engineering and Biotechnology (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

**Graduate Certificates**

**Graduate Certificates in Chemical Engineering**

UMass Lowell offers the following graduate certificates in chemical engineering:

- Biotechnology & Bioprocessing
- Materials Sciences & Engineering
- Modeling, Simulation, & Control of Systems and Processes

**Biotechnology & Bioprocessing?**

**Contact:**
Seongkyu Yoon, Ph.D.
phone: 978-934-4741
e-mail: seongkyu_yoon@uml.edu (mailto:seongkyu_yoon@uml.edu)

The certificate is intended for students who hold a baccalaureate degree in science, engineering, health, or related disciplines. The courses emphasize biological and engineering principles, process concepts and the application of these to process design and improvement. Courses deliberately cross disciplinary boundaries and emphasize teamwork in a multidisciplinary environment as well as a result-oriented, document-driven approach to efficient project completion.

**Required Courses:**

- BIOL.5350 (https://www.uml.edu/catalog/courses/BIOL/5350) -or- CHEN.5350 (https://www.uml.edu/catalog/courses/CHEN/5350)
  - Principles of Cell and Microbe Cultivation
- BIOL.5450 (https://www.uml.edu/catalog/courses/BIOL/5450) -or- CHEN.5450 (https://www.uml.edu/catalog/courses/CHEN/5450)
  - Isolation and Purification of Biotech Products
- BIOL.5550 (https://www.uml.edu/catalog/courses/BIOL/5550) -or- CHEN.5550 (https://www.uml.edu/catalog/courses/CHEN/5550)
  - Biopharmaceutical Regulatory Compliance
- Plus One Approved 3 credit Elective

**Materials Sciences & Engineering**

**Department of Chemical Engineering**

**Contact:**
Zhilyong Gu, Ph.D.
phone: 978-934-3540
e-mail: zhilyong_gu@uml.edu (mailto:zhilyong_gu@uml.edu)

This 12 credit certificate provides an advanced course of study in materials science and engineering that will broaden and enhance the capabilities and education of experienced professionals and technologists at the graduate level.

**Required Course:**

- CHEN.5080 (https://www.uml.edu/catalog/courses/CHEN/5080)
  - Introduction to Materials Sciences (3 credits)

**Elective Courses** (choose three):

- CHEN.5230 (https://www.uml.edu/catalog/courses/CHEN/5230)
  - Nanodevices and Electronic Materials (3 credits)
- CHEN.5240 (https://www.uml.edu/catalog/courses/CHEN/5240)
  - Self
Assembly & Nanotechnology (3 credits)
- CHEN.5290
  (https://www.uml.edu/catalog/courses/CHEN/5290)
Recent Advances in Nanotechnology and Green Chemistry (3 credits)
- CHEN.5330
  (https://www.uml.edu/catalog/courses/CHEN/5330)
Macromolecular Colloidal Science and Engineering (3 credits)
- ENGY.5370
  (https://www.uml.edu/catalog/courses/ENGY/5370)
Nanomaterials Characterization I (3 credits)
- ENGY.5410
  (https://www.uml.edu/catalog/courses/ENGY/5410)
Nanomaterials Characterization II (3 credits)

Modeling, Simulation, & Control of Systems & Processes

Department of Chemical and Nuclear Engineering

Contact:
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phone: 978-934-5204
email: valmor_dealmeida@uml.edu

The sequence of courses provides advanced training in the modeling and analysis of complex systems with some special focus on thermo-fluid processes and general control system design and analysis. The courses are mathematically intensive and many require the use of modern computer analysis tools (Matlab, Simulink, Aspen, etc.). The graduate certificate program is appropriate for students and professionals interested in gaining skills in mathematical modeling and simulation techniques, and for those individuals interested in updating their knowledge and experience with modern control methods.

This is a 12 credit certificate.

Choose Four Courses:
- ENGY.5090
  (https://www.uml.edu/catalog/courses/ENGY/5090)
System Dynamics (3 credits)
- CHEN.5220
  (https://www.uml.edu/catalog/courses/CHEN/5220)

Computer-Aided Chemical Process Design (3 credits)
- CHEN.5280
  (https://www.uml.edu/catalog/courses/CHEN/5280)
Advanced Transport Phenomena (3 credits)
- CHEN.5300
  (https://www.uml.edu/catalog/courses/CHEN/5300)
Advanced Control Strategies (3 credits)
- CHEN.5390
  (https://www.uml.edu/catalog/courses/CHEN/5390)
Math Methods for Engineers (3 credits)
- CHEN.5480
  (https://www.uml.edu/catalog/courses/CHEN/5480)
Engineering Process Analytics
- A Technical Elective with the Approval of the Coordinator (3 credits)

Apply (https://www.uml.edu/Grad/Process/certificate-app.aspx)

Degree Pathways for Biomedical Engineering

The Department of Biomedical Engineering at UMass Lowell offers a Doctor of Philosophy in Biomedical Engineering.

- Degree pathway
  (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
CHEN.5020 Principles of Chemical Engineering
(Formerly 10.502) - Credits: 3

Introduction to the field of chemical engineering and solution of problems involving units and dimensions, mass balances, flow sheets and gas relationships.

CHEN.5060 Colloidal, Interfacial and Nanomaterials Science and Engineering (Formerly 10.506) - Credits: 3

Unifying principle and the three main classes of colloids (dispersions, macromolecular solutions and micelles) are considered. Topics covered include surface tension, work and energy, effect of surface curvature, zeta potential, surface activity and diverse applications of interest to chemical engineers.

CHEN.5080 Material Science and Engineering (Formerly 10.508) - Credits: 3

An advanced overview of solid materials that are likely to be considered for engineering applications in, or be produced by the chemical process industries. They will be discussed from the viewpoints of their unit cell structures, appropriate phase diagrams, their chemical and physical attributes, and the association of these to end use applications. Discussion of metals, ceramics, polymers, and composites. For Non-UML graduates.

CHEN.5100 Advanced Separation Processes (Formerly 10.510) - Credits: 3

This course emphasizes separation processes requiring a rate analysis for adequate understanding, which includes most of the newer separation methods of industrial importance such as membrane, sorption and chromatographic separations. Unifying fundamental relations and concepts are emphasized. Graphical and numerical design procedures are covered.

CHEN.5120 Industrial Chemistry (Formerly 10.512) - Credits: 3

Survey of the major sources and uses of chemicals, industrial chemical processes, fundamental raw materials, and career paths available in the chemical industry. More intensive treatment of selected industrial processes with emphasis of green/sustainable chemical processes.

CHEN.5200 Advanced Thermodynamics (Formerly 10.520) - Credits: 3

Classical and statistical thermodynamics are applied to develop procedures for obtaining estimates of equilibrium properties required for chemical process design. An introduction to surface energy as an important parameter in the processing of colloids, especially in the nanometer size range, will also be undertaken.

CHEN.5220 Chemical Process Design (Formerly 10.522) - Credits: 3

Process synthesis, definition, and characterization. Introduction to modular process simulation packages such as ASPEN PLUS, Recycle and tear stream analysis. Stream convergence, Unit operations models, Flow sheet manipulation. Data records and physical property estimation techniques.

CHEN.5230 Nanodevices and Electronics Materials Processing (Formerly 10.523) - Credits: 3

Materials processing methods in electronics and related industries; crystal contamination control, growth, diffusion, etching, epitaxy, ion implantation, lithography, and other topics.

CHEN.5240 Self Assembly and Nanotechnology (Formerly 10.524) - Credits: 3

This course will describe two of the most fast-growing area/fields with both fundamental importance and practical relevance: self-assembly and nanotechnology. The first half of the course will discuss the theories and applications of self-assembly phenomena. The second half will focus on nanomaterials and nanotechnology.

CHEN.5250 Sustainable Chemistry and Engineering - Credits: 3

This course will provide an overview of the principles of sustainable or green chemistry and engineering. The first half of the course will review the fundamental chemical engineering principles (including chemical reactions, kinetics, catalysis, thermodynamics, separations, and equilibrium) that can be used to advance the field of green chemistry and engineering. The second half of the course will introduce several emerging green engineering topics, including waste treatment, alternative energy, and renewable materials and chemicals.

CHEN.5260 Advanced Kinetics and Reactor Design (Formerly 10.526) - Credits: 3

The course will cover advanced chemical reaction kinetics, rate laws and reactor design with an emphasis on heterogeneous and catalytic reaction systems involving interphase and mass transfer effects.
CHEN.5280 Advanced Transport Phenomena  
(Formerly 10.528) - Credits: 3

An advanced study of the mechanisms of the transport processes. Transport equations are developed from both microscopic and macroscopic viewpoints. Analogies and similarities between the transport processes are discussed. Considerable emphasis is placed upon solutions to problems.

CHEN.5290 Recent Advances in Nanotechnology and Green Chemistry  
(Formerly 10.529) - Credits: 3

This course is designed to expose students to a variety of concepts in chemistry and challenge them to think critically about experiments used to interrogate these concepts. Organic polymer chemistry with an emphasis on electronically conducting polymers will be the main area of focus. Students would first be introduced to scientific subject matter outside their realm of familiarity and be expected to identify new concepts and links to existing experimental paradigms. The course is divided into 3 parts: (i) introduction to nanothehnology and green chemistry with a focus on nanoscale electronic polymers, (ii) green chemistry and the overlap area with nanotechnology, and (iii) green engineering.

CHEN.5300 Advanced Control Strategies  
(Formerly 10.530) - Credits: 3

An introduction to computer control and to some of the common control strategies applied to the design of complex chemical process control systems.

CHEN.5320 Principles of Chemical Engineering II  
(Formerly 10.532) - Credits: 3

Continuation of Principles of Chemical Engineering including real gas relationships, humidity, energy balances, and combined mass-energy balance systems. Introduction to the first law of thermodynamics. Note: Non-majors only.

CHEN.5330 Macromolecular Colloidal Science and Engineering  
(Formerly 10.533) - Credits: 3

This course treats both synthetic and natural macromolecules (i.e., polymers, and biopolymers), Interrelating synthesis commercial manufacture, molecular, macroscopic and application properties as well as the colloidal nature of their solutions. Pertinent fundamental principles are reviewed.

CHEN.5340 Industrial Bioprocessing - Credits: 3

Students will learn principles and concepts of industrial bioprocessing. The course covers key concepts and practices of upstream, downstream and analytical bioprocessing technologies. In addition, recent FDA initiatives of Process Analytical Technology (PAT), Quality by Design, and Emerging Technologies will be covered. The course consists of 14 modules. Each module will cover subject matter provided by industry experts.

CHEN.5350 Cell and Microbe Cultivation  
(Formerly 10.535) - Credits: 3

This course presents the principles of biochemical engineering with an emphasis on the unit operation of cell cultivation for production of commercially important products, especially biopharmaceuticals. The bioreactor is viewed as a device for controlling the environment of recombinant and traditional cultures. Major topics include media design, kinetics of growth and production, expression systems, bioreactor types, cell physiology, and bioprocess economics.

CHEN.5370 Nanomaterials Characterization I  
(Formerly 10.537) - Credits: 3

This lecture course will provide an in-depth introduction to the principles, instrumentation and applications of most common nanomaterial characterization techniques. Nanomaterial imaging, physical, chemical, and optical property analyses are the main focus of this class. Topics covered will include: electron microscopy (SEM/TEM), scanned probe microscopy (AFM), elemental analysis (EDX/XPS), crystal structure analysis (XRD/SAED), thermal analysis (DSC/TGA), laser based characterization (LSCM/DLS/Raman), chromatographic methods (GC), infrared spectroscopy, UV/Vis spectroscopy and contact angle goniometry. The analytical and quantitative applications of these techniques for investigating different types of nanomaterials will also be described. Lab demonstrations will be included in lectures.

CHEN.5380 Advanced Separations in Biotechnology  
(Formerly 10.538) - Credits: 3

This course provides in depth analysis of the two methods used most often in Bioseparations, filtration and chromatography. For both techniques, basic concepts are reviewed. Membrane, depth, sterile and tangential flow filtration, as well as ion exchange, hydrophobic interaction, and hydroxyapatite chromatography are considered. The emphasis for both methods is on specific applications, scale-up, validation and cleaning.

CHEN.5390 Mathematical Methods for Engineers  
(Formerly 10/24.539) - Credits: 3

Ordinary and partial differential equations, linear algebra, matrix/vector calculus, numerical methods, introduction to
optimization methods, and other topics as time permits. Both analytical and numerical techniques are integrated to give good analytical skills coupled with practical problem solving tools. Extensive computer work with the MATLAB package is required. (Same as 24.539).

CHEN.5410 Nanomaterials Characterization II (Formerly 10.541) - Credits: 3
This hands-on laboratory course will cover the practical aspects of light, electron and scanned probe microscopy techniques discussed in Nanomaterials Characterization I (10.540). A variety of nanomaterials samples systems will be characterized using laser scanning confocal microscopy (LSCM), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and atomic force microscopy (AFM). The laboratory experiments will provide practical experience in sample preparation techniques, optimization of instrumental conditions for imaging and spectroscopy, and data analysis and interpretation. Students will work on individual term projects involving real-world samples that are of interest to them, and use the techniques they learned in the course to characterize their samples.

CHEN.5440 Formulation of Biotherapeutics (Formerly 10.544) - Credits: 3
Biotherapeutics, particularly antibodies, are currently the fastest growing pharmaceuticals. Ideally, biotherapeutics are formulated in aqueous solutions and are often a great challenge due physical and chemical stability issues. This course addresses the latest trends and challenges in biologics formulation with a focus on the important role of preformulation in understanding the biological molecule itself for greater "formulatability" and "developability". The course will feature interactive discussions on early formulation screening, thorough biophysical and analytical characterization, improving the feedback loop in the early formulation-development interface, overcoming aggregation and other heterogeneity challenges, and improving overall product profile. In addition, the course will also cover an optimization of the formulation process through rational iterative approach and in-depth case studies. As a whole, this course focuses on providing you with additional tools and knowledge to help streamline solutions to formulation and stability issues for biologics.

CHEN.5450 Isolation and Purification (Formerly 81.545) - Credits: 3
Efficient isolation and purification of biological products, especially proteins, from complex natural mixtures.

CHEN.5460 Biomaterials Science and Engineering -
Credits: 3
The goal of this course is to provide an understanding for design, synthesis, fabrication, and characterization of biomaterials for medical applications. The course will also cover biomimetic engineering strategies to generate materials that can be used for improving human health such as drug delivery, tissue engineering, and regenerative medicine. Example topics include biocompatibility, protein adsorption, degradation, swelling, mechanical properties, biomaterial-tissue interactions, vaccines, micro/nano technologies, instructive biomaterials for stem cells, medical devices and implants, performance of implants, and modulation of cell behavior and function through biomaterial strategies.

CHEN.5480 Engineering Process Analytics (Formerly 10.548) - Credits: 3
This course covers multivariate statistical data analysis and experimental design. Students will learn how to extract information by analyzing various engineering datasets, and how to generate information-rich datasets via minimum experiments. Software for data analysis and experimental design will be utilized during tutorial and practice.

CHEN.5500 Biomedical Applications of Nanotechnology (Formerly 10.550) - Credits: 3
The course will aim to give students an introduction to the applications of nanotechnology in biomedicine. The course will cover the basics of nanomaterials including synthesis and characterization, use of nanotheranostics platforms for drug delivery and imaging, nanomaterials for tissue engineering; nanobiodevices and nanotoxicology. The course is designed for graduate students in the Chemical Engineering and the Biomedical Engineering/Biotechnology programs as well as seniors in Chemical Engineering.

CHEN.5520 Directed Study: Chemical Engineering (Formerly 10.552) - Credits: 3
CHEN.5550 Biopharmaceutical Regulatory Compliance (Formerly 10.555) - Credits: 3
This course examines the regulatory framework in which "drugs", "biologics" and "cellular therapies" are evaluated in the United States, including the laws, regulations and the state of industrial practice.

CHEN.5560 Materials for Aerospace and Energy Applications (Formerly 10.556) - Credits: 3
Material requirements for emerging applications in aerospace and energy sectors will be discussed. Mechanical, thermal and
electrical and barrier properties of filled polymers and polymer nanocomposites will be studied. The effect of resin structure, filler additives, reactive diluents on the resulting properties will be reviewed. Scale-up issues will be studied using basic principles of chemical engineering.

CHEN.5860 Biotechnology Processing Projects Laboratory (Formerly 10.586) - Credits: 3
Development of manufacturing processes for the products of biotechnology are followed through a series of process unit operations. Following the synthesis, purification and formulation of a specific enzyme throughout the course, students examine interactions between process steps and evaluate the impact of each on the total production process. As a final project, students assume the role of project team leader, developing a commercial-scale production process for the enzyme.

CHEN.5930 Cooperative Education (Formerly 10.593) - Credits: 0
CHEN.6010 Seminar (Formerly 10.601) - Credits: 0
Required for all graduate students.

CHEN.6020 Graduate Seminar (Formerly 10.602) - Credits: 0
Required for all graduate students.

CHEN.6500 Nanoscale Transport Phenomena for Manufacturing Nanodevices (Formerly 10.650) - Credits: 3
An interdisciplinary course taught by faculty from the Chemical, Mechanical and Plastics Engineering Departments, who have special knowledge in nanoscale fluid mechanics and heat transfer. The course on nanoscale transport phenomena constitutes a bridge between existing fluid and heat transfer courses in multiple disciplines and emerging nanoscale science and engineering concepts to reflect the forefront of nanomanufacturing. The course is designed to incorporate recent advances in manufacturing polymer-based nanodevices. Key issues of the implementation and maintenance costs for fabrication will be addressed. Hands-on laboratory experiments will be performed to complement the lectures with the ultimate goal of designing and building a complete nanodevice at the end of the course. The course will prepare graduates for employment focused on designing and manufacturing nano/microfluidic systems, lab-on-a-chip devices, electronics devices, medical devices, and other emerging technologies.

CHEN.7200 Special Projects in Chemical Engineering (Formerly 10.720) - Credits: 3
Special projects undertaken by a student to expand his/her knowledge in specific fields related to his/her master's project.

CHEN.7330 Graduate Project - Chemical Engineering (Formerly 10.733) - Credits: 3
Advanced research project required of students electing non-thesis option performed under the supervision of a senior faculty member in the Chemical Engineering Program. The project must be approved by an examining committee and the Department Chairperson.

CHEN.7360 Graduate Project - Chemical Engineering (Formerly 10.736) - Credits: 6
CHEN.7410 Thesis Review (Formerly 10.741) - Credits: 1
CHEN.7430 Master's Thesis - Chemical Engineering (Formerly 10.743) - Credits: 3
Advanced research work required of students electing thesis option performed under the supervision of a senior faculty member in the Chemical Engineering Program. The thesis must be approved by an examining committee and the Department Chairperson.

CHEN.7460 Master's Thesis - Chemical Engineering (Formerly 10.746) - Credits: 6
CHEN.7500 Doctoral Dissertation Review (Formerly 10.750) - Credits: 1
Doctoral Dissertation Review

CHEN.7530 Doctoral Dissertation/Chemical Engineering (Formerly 10.753) - Credits: 1-3
Advanced research work required of students performed under the supervision of a senior faculty member in the Chemical Engineering Program. The dissertation topic must be approved by the doctoral committee.

CHEN.7560 Doctoral Dissertation/Chemical Engineering (Formerly 10.756) - Credits: 6
CHEN.7590 Doctoral Dissertation/Chemical Engineering (Formerly 10.759) - Credits: 9
CHEN.7CPT Curricular Practical Training for
Engineering Doctoral Candidates - Credits: 1
Curricular Practical Training (CPT) is a training program for doctoral students in Engineering. Participation in CPT acknowledges that this an integral part of an established curriculum and directly related to the major area of study or thesis.

ENGY.5040 Energy Engineering Workshop (Formerly 24.504) - Credits: 3
A group/individual design project. The design effort will integrate many aspects of the student’s engineering background, including design concepts, technical analyses, economic and safety considerations, etc. A formal report and oral presentation are required.

ENGY.5050 Reactor Physics (Formerly 24.505) - Credits: 3
Advanced treatment of several topics in reactor physics, including cross sections and processing methods, development of transport theory, reduction to diffusion theory, and analyses of analytical and numerical solutions of the resultant balance equations.

ENGY.5070 Reactor Engineering and Safety (Formerly 24.507) - Credits: 3
Modeling and analysis of reactor thermal-hydraulics and safety systems. Topics include nuclear heat generation and transport, single and two-phase flow, boiling crisis, and safety analysis.

ENGY.5090 Dynamic Systems Analysis (Formerly 24.509) - Credits: 3
Mathematical foundation using the state-variable approach. Topics include matrix methods, Laplace and Fourier transforms, transfer functions, frequency response and stability analyses, and distributed/lumped parameter systems. Applications to mechanical and thermo-fluid systems. Modeling and simulation of systems using Matlab are emphasized. A comprehensive project, including formal written and oral reports, is required.

ENGY.5100 Nuclear Fuel Cycle (Formerly 24.510) - Credits: 3
This course will explore the various stages of the nuclear fuel cycle. The nuclear fuel cycle is broadly classified into three stages: front end, service stage, and back end. The course will introduce students to the various sub stages within the three broad stages of the nuclear fuel cycle. The course will explore the technology that is currently being used in these stages, then compare difference in approaches. Further modifications to the fuel cycle management will be discussed to make nuclear energy more sustainable. The course will provide an overview of front end fuel cycle including: mining, milling, enriching, fabrication; back end of the fuel cycle including: waste and recycling (or not); and in core fuel management, burnup calculations; and approaches to balance the cost of electricity production using nuclear reactors. The students will be introduced to nuclear burnup code such as ORIGEN. At the conclusion of the course students will be tasked to design and evaluate an aspect of the nuclear cycle that has been discussed in the class including but not limited to: enrichment plant, in-core fuel management, spent fuel management.

ENGY.5120 Nuclear Materials (Last Term 2004 Spring)(Formerly 24.522) - Credits: 3
Materials in sustainable nuclear energy applications including fission energy, fusion energy, accelerators, and medicine. Review of fundamentals of materials science, radiation physics, nuclear reactions, radioactivity, and ionizing radiation. Study of fundamental phenomena related to radiation-interactions with matter, and radiation damage in structural materials including ion-solid interactions, atomic displacement, defect kinetics, and microstructural changes under irradiation. A final project is required for the course.

ENGY.5140 Chemical and Nuclear Waste (Formerly 24.514) - Credits: 3
History of nuclear waste disposal; engineering design of disposal systems. Present status of waste and the character and quantities of future wastes. Review of disposal concepts on a generic basis. The national plan for waste disposal.

ENGY.5160 Radiation Shielding and Protection (Formerly 24.516) - Credits: 3
This course will explore the fundamental principles of the interaction of nuclear and atomic radiation with matter and the transport of radiation through materials. The students will learn characterization of radiation fields and sources, and transport radiation through material. The course will discuss radiation exposure, dose, dose equivalent in context of radiation shielding and protection. Consequently, the students will compile each of these topics to learn how to design and analyze radiation shielding and protection. The students will learn how to use both the SOURCES and ORIGEN (or equivalent) code systems for calculating radiation sources and the MCNP (or equivalent) code system for the transport of radiation. At the conclusion of the course the students are expected to develop a shielding design for a given constraints typically encountered in the nuclear field.
ENGY.5180 Energy Technology, Economics and Policy - Credits: 3

Survey course where students integrate the knowledge from previous undergraduate courses to explore and interpret energy technologies, economics and policies. This course is an elective course for engineering students and requires a good basic understanding of technical concepts related to the measurement and calculation of energy conversion and engineering economics.

ENGY.5190 Reactor Operator Training (Formerly 24.519) - Credits: 3

Training, including in-reactor experience and topical lectures, as given to Reactor Operator Trainees who will undergo Federal testing for a Reactor Operator License.

ENGY.5200 Reactor Operator Training (Formerly 24.520) - Credits: 3

Continuation of 24.519. Upon completion of this course, the student will be given a simulated Reactor Operator examination, including a written test, an oral test about reactor systems, and a controls manipulation test.

ENGY.5310 Selected Topics in Engineering (Formerly 24.531) - Credits: 3

Special problems in nuclear science and engineering assigned to the individual student, with emphasis on modern research methods and preparation of results for publication.

ENGY.5320 Selected Topics: Energy Science (Formerly 24.532) - Credits: 3

Special problems in nuclear science and engineering assigned to the individual student, with emphasis on modern research methods and preparation of results for publication.

ENGY.5340 Fundamentals of Nuclear Security and Safeguards (Formerly 24.534) - Credits: 3

This course will include technical and policy matters related to nuclear security and safeguards. The students will explore in interplay between technical and social science disciplines. Students will be introduced to fundamental nuclear physics and engineering, material science, risk assessment, computational techniques, modeling and simulation, information technology, measurement techniques, and detector development. Those technical disciplines will be combined with social science fields such as political science, international relations, international law, energy policies, and regional studies.

ENGY.5360 Reactor Experiments (Formerly 24.536) - Credits: 3

A laboratory-based course using the U Mass Lowell Research Reactor (UMLRR) to illustrate, validate, and expand upon a mix of topics from reactor core physics, reactor operations, and balance-of-plant/energy removal considerations in nuclear systems. Typical experiments may include an approach to critical demo, reactivity measurements, generation of blade worth curves, analysis of various reactor kinetics and dynamic scenarios (including temperature and xenon effects), measurement of axial flux profiles and temperature/void coefficients, analysis of loss of flow and other pump transients, etc. Matlab will be used for data analysis and for reactor simulation. Other analysis tools such as VENTURE, MCNP, or PARET using existing models of the UMLRR may also be used. Comprehensive analysis reports that compare/contrast experimental and simulation data will be required. Oral presentations summarizing the results from the experiments will also be required.

ENGY.6010 Graduate Research Seminar (Formerly 24.601) - Credits: 0

ENGY.6510 Selected Topics in Energy Engineering (Formerly 24.651) - Credits: 3

ENGY.7050 Supervised Tchg - Nuclear Engineering (Formerly 24.705) - Credits: 0

ENGY.7330 Graduate Project - Energy Engineering (Formerly 24.733) - Credits: 3

ENGY.7390 Graduate Project - Energy Engineering (Formerly 24.739) - Credits: 9

ENGY.7410 Thesis Review (Formerly 24.741) - Credits: 1

ENGY.7430 Master’s Thesis - Nuclear Engineering (Formerly 24.743) - Credits: 3

ENGY.7460 Master’s Thesis - Energy Engineering (Formerly 24.746) - Credits: 6

ENGY.7490 Master’s Thesis - Energy Engineering (Formerly 24.749) - Credits: 9

ENGY.7530 Doctoral Dissertation/Energy Engineering (Formerly 24.753) - Credits: 1-3

Advanced research work required of students performed under the supervision of a senior faculty member in the Nuclear Engineering Program. The dissertation topic must be approved by the doctoral committee.
ENGY.7560 Doctoral Dissertation/Energy Engineering (Formerly 24.756) - Credits: 6

ENGY.7590 Doctoral Dissertation/Energy (Formerly 24.759) - Credits: 9

Advanced research work required of students performed under the supervision of a senior faculty member in the Energy Engineering Program. The dissertation topic must be approved by the doctoral committee.

ENGY.7660 Continued Graduate Research (Formerly 24.766) - Credits: 6

ENGY.7690 Continued Graduate Research (Formerly 24.769) - Credits: 9

ENGY.7CPT Curricular Practical Training for Engineering Doctoral Candidates - Credits: 1

Curricular Practical Training (CPT) is a training program for doctoral students in Engineering. Participation in CPT acknowledges that this an integral part of an established curriculum and directly related to the major area of study or thesis.
Masters Program

Civil Engineering Master’s Programs

The UMass Lowell Department of Civil & Environmental Engineering offers master’s degree programs in Civil Engineering and in Environmental Studies. Options within the Master of Science in Civil Engineering include: Environmental Engineering, Geotechnical Engineering, Geoenvironmental, Structural Engineering, and Transportation Engineering. There are two concentrations within the Master of Science in Environmental Engineering - one in Atmospheric Sciences, and another in Environmental Engineering Sciences.

- Master of Science in Civil Engineering
  Environmental Engineering Option
  Geotechnical Engineering Option
  Geoenvironmental Option
  Structural Engineering Option
- Master of Science in Environmental Studies
  Atmospheric Sciences Concentration
  Environmental Engineering Sciences Concentration
- Co-op Option in Engineering

The Department of Civil & Environmental Engineering participates in the Graduate Master’s Co-op Option in Engineering. For detailed information about the Co-op Program and curriculum requirements, please see the Graduate Catalog Engineering Co-op page (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf).

Master of Science in Civil Engineering

Program Description and General Requirements

Graduate study in Civil Engineering is an intensive program of instruction at an advanced technical level. The program permits students to design, in consultation with their advisor, a plan of study that meets individual goals and career objectives.

Program options include environmental engineering, geoenvironmental engineering, geotechnical engineering, structural engineering and transportation engineering.

Admission to a particular engineering option is open to applicants with undergraduate degrees in engineering, mathematics or science. The degree requires successful completion of 30 credit hours of course work, or 24 credit hours of instruction and a publishable thesis, or 27 hours of course work and preparation of a project report.

Courses are scheduled in the late afternoon and evening to provide study opportunities for students with full-time employment. Successful completion of undergraduate prerequisite courses is required prior to registering for graduate courses. However, undergraduate prerequisites and selected graduate courses, that do not have prerequisites, may be taken during the first year of study, but only with the written permission of the students advisor. Required undergraduate prerequisite courses are listed in descriptions of the core graduate courses shown below.

Applicants who satisfy graduate admission requirements will be assigned to a faculty member who will serve as their academic advisor. Students receiving a teaching or research assistantship will normally be required to submit a publishable thesis. Those admitted to graduate study as non-degree students may apply for matriculated status. However, no more than 12 credits of work completed while in non-degree student status or transferred from another department or college will be used toward a degree. Matriculated status is preferred before initial registration and is mandatory prior to registration for second semester courses. Faculty will review a petitioner’s performance in all courses attempted.

Visit the Civil & Environmental Engineering Department (https://www.uml.edu/Engineering/Civil-Environmental/default.aspx) website for more information.

Master of Science in Civil Engineering (Environmental Engineering Option)

The program offers an opportunity to pursue a broad range of interests in the field of environmental engineering. The course of study is designed to meet an individual student’s interests and career goals. Programs consist of civil engineering courses in water and wastewater treatment, groundwater remediation, solid waste management, environmental chemistry, hydrology, hydraulics, air pollution control and may include courses from allied disciplines such as biological and health sciences, environmental studies, chemistry and work environment. The program of study consists of five core courses and elective courses. Undergraduate core course prerequisites must be completed before beginning graduate course work.

Prerequisite Undergraduate Courses for MS Environmental Engineering Option

In order to obtain the MS Degree in Civil and Environmental Engineering, Environmental Engineering Option, a student is required to have completed undergraduate courses in the areas of chemistry, physics, mathematics and engineering. At a minimum, the following courses are required. University of Massachusetts Lowell (UML) course numbers are provided for
reference purposes. Course work that is equivalent to the UML courses specified are acceptable. However, an official determination of prerequisite course equivalency will be conducted by UML faculty that teach the specified undergraduate course, or by the Department of Civil and Environmental Engineering Graduate Coordinator, only after the student has applied and been accepted into the graduate program. This list represents the minimum prerequisite course requirements. Additional undergraduate course work may be required to remedy academic deficiencies. Students will be notified of deficiencies in an acceptance letter. All deficiencies must be eliminated before a student can be classified as "fully matriculated".

The undergraduate prerequisite courses are as follows:

- **CHEM.1210**
  (https://www.uml.edu/catalog/courses/CHEM/1210) Chemistry I
- **CHEM.1230L**
  (https://www.uml.edu/catalog/courses/CHEM/1230L) Chemistry I Lab
- **CHEM.1220**
  (https://www.uml.edu/catalog/courses/CHEM/1220) Chemistry II
- **CHEM.1240L**
  (https://www.uml.edu/catalog/courses/CHEM/1240L) Chemistry II Lab
- **MATH.1310**
  (https://www.uml.edu/catalog/courses/MATH/1310) Calculus I
- **MATH.1320**
  (https://www.uml.edu/catalog/courses/MATH/1320) Calculus II
- **MATH.2310**
  (https://www.uml.edu/catalog/courses/MATH/2310) Calculus III
- **MATH.2340**
  (https://stage.uml.edu/catalog/courses/MATH/2340) Differential Equations
- **PHYS.1410**
  (https://www.uml.edu/catalog/courses/PHYS/1410) Physics I
- **PHYS.1410L**
  (https://www.uml.edu/catalog/courses/PHYS/1410L) Physics I Lab
- **CIVE.2030**
  (https://www.uml.edu/catalog/courses/CIVE/2030) Statics
- **CIVE.2050**
  (https://www.uml.edu/catalog/courses/CIVE/2050) Dynamics
- **CIVE.3010**
  (https://www.uml.edu/catalog/courses/CIVE/3010) Fluid Mechanics
- **CIVE.3620**
  (https://www.uml.edu/catalog/courses/CIVE/3620) Environmental Engineering

### Core Courses (5 total)

- **CIVE.5610**
  (https://www.uml.edu/catalog/courses/CIVE/5610) Physical and Chemical Treatment Processes
- **CIVE.5620**
  (https://www.uml.edu/catalog/courses/CIVE/5620) Physical and Chemical Hydrogeology
- **CIVE.5670**
  (https://www.uml.edu/catalog/courses/CIVE/5670) Environmental Aquatic Chemistry
- **CIVE.5680**
  (https://www.uml.edu/catalog/courses/CIVE/5680) Environmental Fate and Transport
- **CIVE.5780**
  (https://www.uml.edu/catalog/courses/CIVE/5780) Biological Wastewater Treatment

### Elective Courses (select 5)

Individual student programs consist of a complement of elective courses usually taken from the following list:

- **CIVE.5270**
  (https://www.uml.edu/catalog/courses/CIVE/5270)
Geotechnical and Environmental Site Characterization
- CIVE.5290
  (https://www.uml.edu/catalog/courses/CIVE/5290)
- CIVE.5640
  (https://www.uml.edu/catalog/courses/CIVE/5640)
  Hydraulics and Hydrology
- CIVE.5660
  (https://www.uml.edu/catalog/courses/CIVE/5660)
  Environmental Applications & Implications of Nanomaterials
- CIVE.5670
  (https://www.uml.edu/catalog/courses/CIVE/5670)
  Environmental Aquatic Chemistry
- CIVE.5690
  (https://www.uml.edu/catalog/courses/CIVE/5690)
  Micropollutants in the Environment
- CIVE.5720
  (https://www.uml.edu/catalog/courses/CIVE/5720)
  Marine and Coastal Processes
- CIVE.5730
  (https://www.uml.edu/catalog/courses/CIVE/5730)
  Solid Waste Engineering
- CIVE.5750
  (https://www.uml.edu/catalog/courses/CIVE/5750)
  Groundwater Modeling
- CIVE.5760
  (https://www.uml.edu/catalog/courses/CIVE/5760)
  GIS Applications in Civil & Environmental Engineering
- CIVE.5950
  (https://www.uml.edu/catalog/courses/CIVE/5950)
  Hazardous Waste Site Remediation
- ATMO.5230
  (https://www.uml.edu/catalog/courses/ATMO/5230)
  Air Pollution Control
- ATMO.5710
  (https://www.uml.edu/catalog/courses/ATMO/5710)
  Air Pollution Phenomenology
- CHEM.5140
  (https://www.uml.edu/catalog/courses/CHEM/5140)
  Advanced Analytical Chemistry
- ENVS.5010
  (https://stage.uml.edu/catalog/courses/ENVS/5010)
  Wetlands Ecology
- ENVS.5020
  (https://stage.uml.edu/catalog/courses/ENVS/5020)
  Freshwater Ecology
- ENVS.5810
  (https://www.uml.edu/catalog/courses/ENVS/5810)
  Understanding the Massachusetts Contingency Plan
- GEOL.5100
  (https://www.uml.edu/catalog/courses/GEOL/5100)
  Geology of New England

Additional advanced courses may be taken as electives after consultation with a faculty advisor and approval from the department.

Master of Science in Civil Engineering (Geotechnical Engineering Option)?

The master’s degree program in geotechnical engineering encompasses soil mechanics theory and applications in the fields of foundation and soil engineering. Course work emphasizes the engineering behavior of soil, soil property determination, and the use of advanced soil mechanics theory and soil structure interaction in the solution of soil and foundation engineering problems. Elementary courses in soil mechanics, statics, strength of materials and fluid mechanics are required as prerequisites for graduate core courses. Students receiving a teaching or research assistantship are required to submit a publishable thesis.

The program of study consists of one required course: CIVE.5310
  (https://www.uml.edu/catalog/courses/CIVE/5310)
  Advanced Soil Mechanics, any five courses from a list of core geotechnical electives and four other elective courses, selected with the consent of a students faculty advisor. Additional advanced structural, geoenvironmental and geology courses may be taken as electives after consultation with a faculty advisor and approval from the Department. Program and course details are included in the graduate course list and the graduate catalog.

Core Courses

- CIVE.5310
Elective Core course (Select 5; courses not taken may be used as electives)

- CIVE.5270
  Geotechnical and Environmental Site Characterization
- CIVE.5280
  Drilled Deep Foundations
- CIVE.5290
  Engineering with Geosynthetics
- CIVE.5300
  Driven Deep Foundations
- CIVE.5320
  Theoretical and Numerical Soil Mechanics
- CIVE.5330
  Advanced Foundation Engineering
- CIVE.5340
  Soil Dynamics and Earthquake Engineering
- CIVE.5360
  Soil Engineering
- CIVE.5370
  Experimental Soil Mechanics
- CIVE.5380
  Soil Behavior
- CIVE.5390
  Ground Improvement

Elective Courses (4 total)

- CIVE.5040
  Advanced Strength of Materials
- CIVE.5110
  Inspection and Monitoring of Civil Infrastructure
- CIVE.5210
  Reliability Analysis in Engineering
- CIVE.5460
  Pavement Design
- CIVE.5500
  Behavior of Structures
- CIVE.5560
  Finite Element Analysis
- CIVE.5620
  Physical and Chemical Hydrogeology
- CIVE.5720
  Marine and Coastal Processes
- CIVE.5750
  Groundwater Modeling
- CIVE.5760
  GIS Applications in Civil & Environmental Engineering
- CIVE.5810
  Engineering Systems Analysis
- GEOL.5560
  Applied Geophysics
(Geoenvironmental Option)

The solution of environmental problems related to soil and/or groundwater often requires knowledge of both Geotechnical and Environmental Engineering. The Geoenvironmental program provides fundamental training in soil mechanics, groundwater hydrology, environmental chemistry, and soil engineering. Course work is offered in each area as well as in courses that combine disciplines generally required in the solution of complex site problems, such as, landfill design, remediation of hazardous waste sites, dewatering and soil improvement.

Core Courses (2 total)

- CIVE.5310
  [Advanced Soil Mechanics](https://www.uml.edu/catalog/courses/CIVE/5310)
- CIVE.5620
  [Physical and Chemical Hydrogeology](https://stage.uml.edu/catalog/courses/CIVE/5620)

Geotechnical Core Course (Select 1; courses not taken may be used as electives):

- CIVE.5270
  [Geotechnical Environmental Site Characterization](https://www.uml.edu/catalog/courses/CIVE/5270)
- CIVE.5290
  [Engineering with Geosynthetics](https://www.uml.edu/catalog/courses/CIVE/5290)
- CIVE.5360
  [Soil Engineering](https://www.uml.edu/catalog/courses/CIVE/5360)
- CIVE.5380
  [Soil Behavior](https://stage.uml.edu/catalog/courses/CIVE/5380)

Environmental Core Course (Select 1; courses not taken may be used as electives):

- CIVE.5670
  [Environmental Aquatic Chemistry](https://www.uml.edu/catalog/courses/CIVE/5670)
- CIVE.5950
  [Hazardous Waste Site Remediation](https://www.uml.edu/catalog/courses/CIVE/5950)

Elective Courses (6 total)

- CIVE.5210
  [Reliability Analysis in Engineering](https://www.uml.edu/catalog/courses/CIVE/5210)
- CIVE.5280
  [Drilled Deep Foundations](https://www.uml.edu/catalog/courses/CIVE/5280)
- CIVE.5300
  [Driven Deep Foundations](https://www.uml.edu/catalog/courses/CIVE/5300)
- CIVE.5320
  [Theoretical and Numerical Methods in Soil Mechanics](https://www.uml.edu/catalog/courses/CIVE/5320)
- CIVE.5330
  [Advanced Foundation Engineering](https://www.uml.edu/catalog/courses/CIVE/5330)
- CIVE.5340
  [Soil Dynamics and Earthquake Engineering](https://www.uml.edu/catalog/courses/CIVE/5340)
- CIVE.5370
  [Experimental Soil Mechanics](https://www.uml.edu/catalog/courses/CIVE/5370)
- CIVE.5390
  [Ground Improvement](https://www.uml.edu/catalog/courses/CIVE/5390)
- CIVE.5610
  [Physical and Chemical Treatment Process](https://www.uml.edu/catalog/courses/CIVE/5610)
- CIVE.5640
  [Hydraulics and Hydrology](https://www.uml.edu/catalog/courses/CIVE/5640)
- CIVE.5660
  [Environmental Applications & Implications of Nanomaterials](https://www.uml.edu/catalog/courses/CIVE/5660)
Master of Science in Civil Engineering (Structural Engineering Option)?

The structural option within Civil Engineering offers instruction and research in advanced concepts and techniques to develop innovative solutions for critical and challenging problems in Structural Engineering. A student seeking an MS Engineering in Structural Engineering must have at least one core course from each group (A, B, and C) to meet the core course requirements. Student study programs in structural engineering are developed with a faculty advisor to meet the needs of the individual. Students should also meet the prerequisite requirement in each graduate-level course by receiving an approval from the instructor.

Core Course Requirement (3 total)

Group A (Design; select 1; courses not taken may be used as elective):

- CIVE.5510
  (https://www.uml.edu/catalog/courses/CIVE/5510)
  Advanced Steel Design

Group B (Analysis; select 1; courses not taken may be used as elective):

- CIVE.5030
  (https://www.uml.edu/catalog/courses/CIVE/5030)
  Computer-Based Analysis of Structures

- CIVE.5040
  (https://www.uml.edu/catalog/courses/CIVE/5040)
  Advanced Strength of Materials

- CIVE.5500
  (https://www.uml.edu/catalog/courses/CIVE/5500)
  Behavior of Structures

- CIVE.5560
  (https://www.uml.edu/catalog/courses/CIVE/5560)
  Finite Element of Analysis (or equivalent)

Group C (Dynamics, Stability, and Materials; select 1; courses not taken may be used as elective):

- CIVE.5050
  (https://www.uml.edu/catalog/courses/CIVE/5050)
  Concrete Materials

- CIVE.5120
  (https://www.uml.edu/catalog/courses/CIVE/5120)
  Structural Stability

- CIVE.5150
  (https://www.uml.edu/catalog/courses/CIVE/5150)
  Cementitious Materials for Sustainable Concrete

- CIVE.5570
  (https://www.uml.edu/catalog/courses/CIVE/5570)
  Structural Dynamics

Elective Courses (7 total)

- CIVE.5080
Practice of Structural Engineering

CIVE.5110

Inspection and Monitoring of Civil Infrastructure

CIVE.5210

Reliability Analysis in Engineering

CIVE.5280

Drilled Deep Foundations

CIVE.5300

Drive Deep Foundations

CIVE.5310

Advanced Soil Mechanics

CIVE.5330

Advanced Foundation Engineering

CIVE.5340

Soil Dynamics and Earthquake Engineering

CIVE.5360

Soil Engineering

CIVE.5390

Ground Improvement

CIVE.5410

Traffic Engineering

CIVE.5460

Pavement Design

CIVE.5530

Wood Structures

CIVE.5590

Pre-stressed Concrete Design

CIVE.5590

Masonry Design

CIVE.5760

GIS Application in Civil and Environmental Engineering

CIVE.5810

Engineering Systems Analysis

CIVE.5830

Stochastic Concepts for Engineering

Notes:

1. Additional geotechnical and geoenvironmental courses and appropriate advanced courses from the Departments of Mathematics and Mechanical Engineering may be taken as electives after consultation with a faculty advisor and with the approval of the Department.

2. With the approval of the Department, a student may substitute one of the core requirements with another advanced Mathematics or Engineering course.

Master of Science in Civil Engineering (Transportation Engineering Option)?

The program in Transportation Engineering offers courses in planning, design and operation of multimodal transportation facilities. It emphasizes the interdisciplinary nature of the subject, supplementing engineering concepts with techniques from management, economics, operations research and environmental studies. It is designed to provide students with advanced technical knowledge for addressing transportation problems in a variety of practical situations. Specialization in a specific area can be achieved through thesis and project work. Graduate study plans are designed based upon student interest, professional needs and undergraduate preparation. Students are expected to have completed or show proficiency in the following courses in partial fulfillment of degree requirements:

The undergraduate prerequisite courses are as follows:

- MATH.1310
Core Courses Requirements (Select 3; courses not taken may be used as elective)

- CIVE.5400
  (https://www.uml.edu/catalog/courses/CIVE/5400) Urban Transportation Planning
- CIVE.5410
  (https://www.uml.edu/catalog/courses/CIVE/5410) Traffic Engineering
- CIVE.5420
  (https://www.uml.edu/catalog/courses/CIVE/5420) Transportation Network Analysis
- CIVE.5480
  (https://www.uml.edu/catalog/courses/CIVE/5480) Traffic Management and Control
- CIVE.5490
  (https://www.uml.edu/catalog/courses/CIVE/5490) Traffic Flow and Emerging Transportation Technologies

Elective Courses (7 total)

- CIVE.5405
  (https://www.uml.edu/catalog/courses/CIVE/5405) Advanced Highway Geometric Design
- CIVE.5415
- CIVE.5430
  (https://www.uml.edu/catalog/courses/CIVE/5430) Traffic Principles for Intelligent Transportation Systems
- CIVE.5440
- CIVE.5450
  (https://www.uml.edu/catalog/courses/CIVE/5450) Public Transit Planning and Design
- CIVE.5460
  (https://www.uml.edu/catalog/courses/CIVE/5460) Pavement Design
- CIVE.5470
  (https://www.uml.edu/catalog/courses/CIVE/5470) Airport Planning and Design
- CIVE.5760
  (https://www.uml.edu/catalog/courses/CIVE/5760) GIS Applications in Civil and Environmental Engineering
- CIVE.5810
  (https://www.uml.edu/catalog/courses/CIVE/5810) Engineering Systems Analysis
- CIVE.5830
  (https://www.uml.edu/catalog/courses/CIVE/5830) Stochastic Processes for Engineering
- CIVE.5850
Transportation Safety

- **CRIM.5660**
  [Transportation Systems Safety and Security](https://www.uml.edu/catalog/courses/CRIM/5660)

Other than the above listed elective courses, students may take courses from other appropriate disciplines such as engineering, management, computer science, and mathematics as electives after consultation with a faculty advisor and with the approval of the Department. A few examples are:

- **Engineering**: CIVE.5210
  [Reliability Analysis in Engineering](https://www.uml.edu/catalog/courses/CIVE/5210); MECH.5760
  [Engineering Project Management](https://www.uml.edu/catalog/courses/MECH/5760); CHEN.5390
  [Mathematical Methods for Engineers](https://www.uml.edu/catalog/courses/CHEN/5390)

- **Management**: MIST.6030
  [Database Management](https://www.uml.edu/catalog/courses/MIST/6030); MIST.6170
  [Advanced Machine Learning](https://www.uml.edu/catalog/courses/MIST/6170); MIST.7060
  [Data Analytics](https://www.uml.edu/catalog/courses/MIST/7060); MIST.6160
  [Advanced Data Mining](https://www.uml.edu/catalog/courses/MIST/6160); MIST.6060
  [Business Intelligence and Data Mining](https://www.uml.edu/catalog/courses/MIST/6060); POMS.4050
  [Predictive Data Analytics](https://www.uml.edu/catalog/courses/POMS/4050); POMS.6220
  [Decision Analytics](https://www.uml.edu/catalog/courses/POMS/6220)

- **Math and Science**: COMP.5730
  [Data Base I](https://www.uml.edu/catalog/courses/COMP/5730); COMP.5450
  [Machine Learning](https://www.uml.edu/catalog/courses/COMP/5450); MATH.5910
  [Linear Statistics Modeling and Regression](https://www.uml.edu/catalog/courses/MATH/5910)
  [Applied Statistics with R](https://www.uml.edu/catalog/courses/MATH/5750); MATH.5500
  [Mathematical Modeling](https://www.uml.edu/catalog/courses/MATH/5500); COMP.4200
  [Artificial Intelligence](https://www.uml.edu/catalog/courses/MATH/6040); MATH.5720
  [Network Optimization](https://www.uml.edu/catalog/courses/MATH/5720); Optimization

- **Other**: PUBH.6890
  [Advanced Regression Modeling](https://www.uml.edu/catalog/courses/PUBH/6890); BIOL.5071
  [Data Science for Biologists in Python](https://www.uml.edu/catalog/courses/BIOL/5071)

**Master of Science in Environmental Studies?**

**Environmental Engineering Sciences Concentration?**

This interdisciplinary program offers a Master of Science in Environmental Studies with a thesis or a non-thesis track. Enrollment in the program is open to individuals with a baccalaureate degree in technology, biology or a physical science. Others may be admitted with the approval of the Graduate Coordinator. Such students may make up course prerequisite deficiencies while in the program, although those credits will not count toward the total required for the masters degree. Frequently, students entering the program are required to take a number of undergraduate courses to develop analytical skills and to prepare for advanced level course work. Undergraduate courses may include calculus, statistics, chemistry, computer programming or courses designed to develop problem-solving skills. Course requirements are determined by discussion with the Program Coordinator. The thesis track requires completion of an approved program of study involving a minimum of 24 credits of core courses and electives, and 6 credits of thesis, consisting of laboratory research or scholarly investigation, for a total of 30 credits. Students may only register for thesis research with the prior approval of a thesis advisor. The thesis work is to be guided by a principal advisor who is a member of the University of Massachusetts Lowell faculty and by two additional committee members, at least one of whom must be a member of the faculty. Committee selection and the thesis topic are subject to the approval of the graduate coordinator. The non-thesis track requires completion of an approved program of study involving 30 credits of core courses and electives. All individual programs of study must include the core courses listed below.
Prerequisite Undergraduate Courses for M.S. Environmental Studies Option?

In order to obtain the M.S. Degree in Environmental Studies, a student is required to have completed undergraduate courses in the areas of chemistry, physics, and mathematics. At a minimum, the following courses are required. University of Massachusetts Lowell (UML) course numbers are provided for reference purposes. Course work that is equivalent to the UML courses specified are acceptable. However, an official determination of prerequisite course equivalency will be conducted by UML faculty that teach the specified undergraduate course, or by the Environmental Studies Graduate Coordinator, only after the student has applied and been accepted into the graduate program. This list represents the minimum prerequisite course requirements. Additional undergraduate course work may be required to remedy academic deficiencies. Students will be notified of deficiencies in an acceptance letter. All deficiencies must be eliminated before a student can be classified as “fully matriculated”.

The undergraduate prerequisite courses are as follows:

- **CHEM.1210**  
  (https://www.uml.edu/catalog/courses/CHEM/1210)  
  Chemistry I
- **CHEM.1230L**  
  (https://www.uml.edu/catalog/courses/CHEM/1230L)  
  Chemistry I Lab
- **CHEM.1220**  
  (https://www.uml.edu/catalog/courses/CHEM/1220)  
  Chemistry II
- **CHEM.1240L**  
  (https://www.uml.edu/catalog/courses/CHEM/1240L)  
  Chemistry II Lab
- **MATH.1310**  
  (https://www.uml.edu/catalog/courses/MATH/1310)  
  Calculus I
- **MATH.1320**  
  (https://www.uml.edu/catalog/courses/MATH/1320)  
  Calculus II
- **PHYS.1410**  
  (https://www.uml.edu/catalog/courses/PHYS/1410)  
  Physics I
- **PHYS.1410L**  
  (https://www.uml.edu/catalog/courses/PHYS/1410L)  
  Physics I Lab

Core Courses

- **CIVE.5670**  
  (https://www.uml.edu/catalog/courses/CIVE/5670)  
  Environmental Aquatic Chemistry
- **CIVE.5730**  
  (https://www.uml.edu/catalog/courses/CIVE/5730)  
  Solid Waste Engineering
- **ATMO.5230**  
  (https://stage.uml.edu/catalog/courses/ATMO/5230)  
  Air Pollution Control or **ATMO.5710**  
  (https://stage.uml.edu/catalog/courses/ATMO/5710)  
  Air Pollution Phenomenology

Elective Courses

- **CIVE.5610**  
  (https://www.uml.edu/catalog/courses/CIVE/5610)  
  Physical and Chemical Treatment Processes
- **CIVE.5620**  
  (https://www.uml.edu/catalog/courses/CIVE/5620)  
  Physical and Chemical Hydrogeology
- **CIVE.5640**  
  (https://www.uml.edu/catalog/courses/CIVE/5640)  
  Hydraulics and Hydrology
- **CIVE.5660**  
  (https://www.uml.edu/catalog/courses/CIVE/5660)  
  Environmental Application & Implications of Nanomaterials
- **CIVE.5680**  
  (https://www.uml.edu/catalog/courses/CIVE/5680)  
  Environmental Fate and Transport
- **CIVE.5690**  
  (https://www.uml.edu/catalog/courses/CIVE/5690)  
  Micropollutants in the Environment
- **CIVE.5720**  
  (https://www.uml.edu/catalog/courses/CIVE/5720)  
  Marine and Coastal Processes
Enrollment in this program is open to individuals with a bachelor’s degree in sciences, mathematics and engineering. Others may be admitted with the approval of the Graduate Program Coordinator. Such students may make up course prerequisite deficiencies while in the program, although these credits will not count toward the total required for the masters degree. Frequently, students entering the program are required to take a number of undergraduate courses to develop the analytical skills, and to prepare for the advanced level courses.

The M.Sc. program requires the completion of 30 credits, 9 in core courses, and 15 in elective courses listed below. Six credits may be achieved by completing a Master’s Thesis. The thesis involves original laboratory or theoretical work, usually publishable in accredited and peer reviewed technical journals. With the Graduate Program Coordinators approval, the thesis work may be performed at home or at the students employment facilities. The thesis advisory committee will consist of a Principal Advisor who is the member of the EEAS faculty, and two members chosen from EEAS or associated UMass Lowell faculty. One member may be from outside the University, with the approval of the Graduate Coordinator. Students may elect to take additional courses instead of writing a thesis.

Most of the courses are offered in the evening, usually from 6 to 9 p.m., once per week. This enables working students to complete the course requirements while the student is employed. A maximum of 5 years is allowed for completion of the masters degree, including the thesis.

Core Courses

- **ATMO.5010**
  (https://www.uml.edu/catalog/courses/ATMO/5010)
  Boundary Layer Meteorology
- **ENVI.5750**
  (https://www.uml.edu/catalog/courses/ENVI/5750)
  Groundwater Modeling
- **CHEM.5750**
  (https://www.uml.edu/catalog/courses/CHEM/5750)
  Physical Chemistry for Environmental Studies
- **ENVI.5270**
  (https://www.uml.edu/catalog/courses/ENVI/5270)
  Energy and Environment
- **ENVI.5280**
  (https://www.uml.edu/catalog/courses/ENVI/5280)
  Methods in Environmental Impact Assessment and Analysis
- **ENVS.5010**
  (https://www.uml.edu/catalog/courses/ENVS/5010)
  Wetlands Ecology
- **ENVS.5020**
  (https://www.uml.edu/catalog/courses/ENVS/5020)
  Freshwater Ecology
- **ENVS.5016**
  (https://www.uml.edu/catalog/courses/ENVS/5016)
  Freshwater Ecology
- **ENVS.5810**
  (https://www.uml.edu/catalog/courses/ENVS/5810)
  Understanding the Massachusetts Contingency Plan
- **GEOL.5100**
  (https://www.uml.edu/catalog/courses/GEOL/5100)
  Geology of New England
- **GEOL.5200**
  (https://www.uml.edu/catalog/courses/GEOL/5200)
  Groundwater Modeling
- **ATMOSPHERIC Sciences Concentration**
Environmental and Natural Resources Economics

Elective Courses

- ATMO.5020
  (https://www.uml.edu/catalog/courses/ATMO/5020)
  Advanced Synoptic Meteorology
- ATMO.5030
  (https://www.uml.edu/catalog/courses/ATMO/5030)
  Remote Sensing of the Atmosphere
- ATMO.5110
  (https://www.uml.edu/catalog/courses/ATMO/5110)
  Solar Terrestrial Relations
- ATMO.5150
  (https://www.uml.edu/catalog/courses/ATMO/5150)
  Atmospheric Structure and Dynamics
- ATMO.5230
  (https://www.uml.edu/catalog/courses/ATMO/5230)
  Air Pollution Control
- ATMO.5710
  (https://www.uml.edu/catalog/courses/ATMO/5710)
  Air Pollution Phenomenology
- ATMO.6730
  (https://www.uml.edu/catalog/courses/ATMO/6730)
  / PUBH.6170
  (https://www.uml.edu/catalog/courses/PUBH/6170)
  Air Pollution Laboratory/Measurement of Airborne Contaminants
- ATMO.6740
  (https://www.uml.edu/catalog/courses/ATMO/6740)
  Air Quality Modeling
- ENVI.5720
  (https://www.uml.edu/catalog/courses/ENVI/5720)
  Energy and the Environment
- PUBH.5140
  (https://www.uml.edu/catalog/courses/PUBH/5140)
  Aerosol Science
- MATH.5500
  (https://www.uml.edu/catalog/courses/MATH/5500)

Mathematical Modeling
- RADI.6130
  (https://www.uml.edu/catalog/courses/RADI/6130)
  Environmental Monitoring and Surveillance (Radionuclides)
CIVE.5010 Civil Engineering Research Seminar - Credits: 0
Research seminar for doctoral and Master’s students to listen to researchers from academia, industry, and government of research-related topics in civil and environmental engineering. Invited speakers will present recent research advances in fields of environmental engineering, geotechnical engineering, structural engineering and transportation engineering. Attendance is mandatory for doctoral and MS students with thesis option. Thesis requirements and research methods will be introduced in various talks.

CIVE.5030 Computer Based Analysis of Structures (Formerly 14.503) - Credits: 3
The course is an introduction to the finite element displacement method for framed structures. It identifies the basic steps involved in applying the displacement method that can be represented as computer procedures. The course covers the modeling and analysis of 2-dimensional and 3-dimensional structures, such as cable-stayed structures, arches, and space trusses, space frames, shear walls, and so on. The analysis is done for both static and dynamic loading. The study is done by using MATLAB, GTSTRUDL, and Mathcad software.

CIVE.5040 Advanced Strength Of Material (Formerly 14/10.504) - Credits: 3
Stress and strain at a point; curved beam theory, unsymmetrical bending, shear center, torsion of non-circular sections; theories of failure; selected topics in solid mechanics.

CIVE.5050 Concrete Materials (Formerly 14.505) - Credits: 3
This course introduces fundamental and advanced topics on the properties of concrete materials. Fundamental topics include the formation, structure, mechanical behavior, durability, fracture, and deterioration of concrete. Theoretical treatments on the deformation, fracture and deterioration of concrete are also addressed. Advanced topics include the electromagnetic properties of concrete, high performance concrete (HPC), high-strength concrete (HSC), fiber-reinforced concrete, other special concretes, and the green construction of concrete.

CIVE.5080 Practice of Structural Engineering (Formerly 14.508) - Credits: 3
This course covers the practice of structural engineering as it deals with the design of structures such as buildings and bridges, the identification of loads, and design variables, and design detailing for concrete and steel structures. The emphasis will be placed on the use and interpretation of the ACI318-09, AISD and AASHTO codes and the GTSTRUDL software.

CIVE.5110 Inspection and Monitoring of Civil Infrastructure (Formerly 14.511) - Credits: 3
In this course, principles and applications of inspection and monitoring techniques for the condition assessment of aged/damaged/deteriorated civil infrastructure systems such as buildings, bridges, and pipelines, are introduced. Current nondestructive testing/evaluation (NDT/E) methods including optical, acoustic/ultrasonic, thermal, magnetic/electrical, radiographic, microwave/radar techniques are addressed with a consideration of their theoretical background. Wired and wireless structural health monitoring (SHM) systems for civil infrastructure are also covered. Applications using inspection and monitoring techniques are discussed with practical issues in each application.

CIVE.5120 Structural Stability (Formerly 14.512) - Credits: 3
This course provides a concise introduction to the principles and applications of structural stability for their practical use in the design of steel frame structures. Concepts of elastic and plastic theories are introduced. Stability problems of structural members including columns, beam-columns, rigid frames, and beams are studied. Approaches in evaluating stability problems, including energy and numerical methods, are also addressed.

CIVE.5150 Cementitious Materials for Sustainable Concrete - Credits: 3
This course is designed for introducing advanced topics in cement hydration chemistry, materials characterization and concrete sustainability. Advanced topics in chemistry of commonly used cementitious materials, micro-structure, mechanical properties, durability and sustainability will be offered. Students will learn and practice to characterize and analyze the roles of chemical admixtures and supplementary cementitious materials in concrete property improvement. Chemical issues involved in the engineering behavior of concrete will be offered. A service-learning project about sustainable concrete will be provided. Emerging topics such as self-healing concrete, self-consolidating concrete, mart concrete, 3D concrete printing and ultra-high performance concrete will also be covered.

CIVE.5210 Reliability Analysis (Formerly 14.521) - Credits: 3
A review of the elementary principles of probability and statistics followed by advanced topics including decision
### CIVE.5270 Geotechnical and Environmental Site Characterization (Formerly 14.527) - Credits: 3

This course is designed to give students a comprehensive understanding of various site investigation and site assessment technologies employed in geotechnical and environmental engineering. The course begins with an introduction to site investigation planning and various geophysical methods including: seismic measurements, ground penetrating radar, electrical resistivity, electromagnetic conductivity, time domain reflectometry. Drilling methods for soil, gas and ground water sampling; decontamination procedures; and long term monitoring methods are studied. Emphasis in this course is placed on conventional and state-of-the-art in situ methods for geotechnical and environmental site characterization: standard penetration test, vane shear test, dilatometer test, pressuremeter test and cone penetration tests. Modern advances in cone penetrometer technology, instrumented with various sensors (capable of monitoring a wide range of physical and environmental parameters: load, pressure, sound, electrical resistivity, temperature, PH, oxidation reduction potential, chemical contaminants) are playing a major role in site characterization. Principles underlying these methods along with the interpretation of test data will be covered in detail. The course will also look into emerging technologies in the area of site characterization. (3-0)3

### CIVE.5280 Drilled Deep Foundations (Formerly 14.528) - Credits: 3


### CIVE.5290 Engineering with Geosynthetics (Formerly 14.529) - Credits: 3

Rigorous treatment in the mechanism and behavior of reinforced soil materials. Laboratory and insitu tests for determining the engineering properties of geosynthetics (geotextiles, geomembranes, geogrids and geocomposites). Design principles and examples of geosynthetics for separation, soil reinforcement and stabilization, filtration and drainage.

### CIVE.5300 Driven Deep Foundations (Formerly 14.530) - Credits: 3

Design and analyses of driven deep foundations including: Deep foundations classification and historical perspective. Effects of pile installation. Static capacity and settlement analysis of a single pile and a pile group under vertical loads. Insight of pile resistance including soil behavior and interfacial friction. Driven pile load test standards, construction, interpretation, and simulation. Dynamic analysis of driven piles, the wave equation analysis, dynamic measurements during driving and their interpretation. Reliability based design using the Load and Resistance Factor design (LRFD) methodology application for driven deep foundations.

### CIVE.5310 Advanced Soil Mechanics (Formerly 14.531) - Credits: 3

Theories of soil mechanics and their application. Drained and undrained stress-strain and strength behavior of soils. Lateral earth pressures, bearing capacity, slope stability, seepage and consolidation. Lab and insitu testing.

### CIVE.5320 Theoretical & Numerical Methods in Soil Mechanics (Formerly 14.532) - Credits: 3

Geotechnical practice employs computer programs that incorporate numerical methods to address problems of stability, settlement, deformation, and seepage. These methods are based on theoretical understanding of the behavior of soils, and correct use of commercial software requires that the engineer understand theoretical bases of the numerical algorithms and how they work. This course addresses the description of stress and strain in the context of geotechnical engineering and the basic concepts of numerical and computational methods, including discretization errors, computational procedures appropriate to different classes of problem, and numerical instability. It will then apply the insights to the three major problems of geotechnical analysis: settlement, stability, and fluid flow.

### CIVE.5330 Advanced Foundation Engineering (Formerly 14.533) - Credits: 3

Design and analysis of shallow foundations, excavations and retaining structures including: site exploration, bearing capacity and settlement theories, earth pressures, braced and unbraced excavations, rigid and flexible retaining structures, reinforced earth, dewatering methods and monitoring techniques.

### CIVE.5340 Soil Dynamics and Earthquake Engineering (Formerly 14.534) - Credits: 3
This course addresses the dynamic properties of soils and basic mechanical theory of dynamic response. It will apply these results to analysis and design of dynamically loaded foundations. A basic understanding of earthquakes - where they occur, their quantitate description, how the complicated patterns of motions are captured by techniques such as the response spectrum, and how engineers design facilities to withstand earthquakes, will be addressed. In particular, the course will consider three topics of current professional and research interest: probabilistic seismic hazard analysis (PHSA), soil liquefaction, and seismically induced displacements. The emphasis will be on geotechnical issues, but some time will be devoted to structural considerations in earthquake resistant design.

CIVE.5360 Soil Engineering (Formerly 14.536) - Credits: 3
The study of soil as an engineering material, and its use in earth structures (e.g. dams, road embankments), flow control, and compacted fills. Stability of natural and man made slopes, soil reinforcement and stabilization.

CIVE.5370 Experimental Soil Mechanics (Formerly 14.537) - Credits: 3
Application of testing procedures to the evaluation of soil type and engineering properties. Testing for classification, permeability, consolidation, direct and triaxial shear and field parameters. The technical procedures are followed by data analysis, evaluation and presentation. Critical examination of standard testing procedures, evaluation of engineering parameters, error estimation and research devices.

CIVE.5380 Soil Behavior - Credits: 3
Study of the physico-chemical and mechanical behavior of soil. Topics include: soil mineralogy, formation, composition, concepts of drained and undrained stress-strain and strength behavior, frozen soils.

CIVE.5390 Ground Improvement (Formerly 14.539) - Credits: 3
Design and construction methods for strengthening the properties and behavior of soils. Highway embankments, soil nailing, soil grouting, landslide investigation and mitigation, dynamic compaction, stone columns.

CIVE.5400 Urban Transportation Planning (Formerly 14.540) - Credits: 3
Objectives and procedures of the urban transportation planning process. Characteristics and current issues of urban transportation in the United States (both supply and demand). Techniques of analysis, prediction and evaluation of transportation system alternatives. Consideration of economic, environmental, ethical, social and safety impacts in the design and analysis of transportation systems.

CIVE.5405 Advanced Highway Geometric Design - Credits: 3
Development of the principals of modern roadway design while addressing context specific design requirements and constraints. Topics will include guidelines for highway design, design and review of complex geometry, geometric design to address safety and operational concerns, multi-modal design for signalized and un-signalized intersections, complete streets design concepts, and superelevation. Course-work will also include principals to present transportation designs to the public, transportation advocates, and private clients.

CIVE.5410 Traffic Engineering (Formerly 14.541) - Credits: 3
Engineering principles for safe and efficient movement of goods and people on streets and highways, including aspects of (a) transportation planning; (b) geometric design; (c) traffic operations and control; (d) traffic safety, and; (e) management of transportation facilities. Topics include: traffic stream characteristics; traffic engineering studies; capacity and level-of-service analysis; traffic control; simulation of traffic operations; accident studies; parking studies; environmental impacts.

CIVE.5415 Hazardous Materials Transportation - Credits: 3
Hazmat transportation, safety and security are a convergence of operations, policies and regulation, and planning and design. This course will address the multimodal operations, vessels, technologies, packaging and placarding involved in the safe and secure transportation of hazmat. Safety and security rules, regulations, emergency preparedness and response, industry initiatives and programs, and U.S. government agencies governing hazmat transportation will be included, as well as international impacts on hazmat transportation safety and security.

CIVE.5420 Transportation Network Analysis (Formerly 14.542) - Credits: 3
This course is to introduce engineering students to basic transportation network analysis skills. Topics covered include fundamentals of linear and nonlinear programming, mathematical representations of transportation networks, various shortest path algorithms, deterministic user equilibrium

CIVE.5425 Advanced Traffic Engineering - Credits: 3
Application of traffic engineering principles and techniques to the analysis, design and operation of transportation facilities. Topics include traffic operation and control, traffic safety, and management of transportation facilities.
traffic assignment, stochastic user equilibrium traffic assignment, dynamic traffic assignment, heuristic algorithms for solving traffic assignment problems, and transportation network design.

CIVE.5430 Traffic Principles for Intelligent Transportation Systems (Formerly 14.543) - Credits: 3

The objective of this course is to introduce the student to the traffic principles that are pertinent for the planning, design and analysis of Intelligent Transportation Systems (ITS). The course is oriented toward students that come from different disciplines and who do not have previous background in traffic or transportation principles. It is designed as an introductory course that will enable the student to pursue more advanced courses in transportation systems subsequently.

CIVE.5440 Transportation Economics and Project Evaluation (Formerly 14.544) - Credits: 3

The course offers an overview of the fundamental principles of transportation economics. Emphasizes theory and applications concerning demand, supply and economics of transportation systems. Covers topics such as pricing, regulation and the evaluation of transportation services and projects. Prerequisites: Students should have knowledge of transportation systems and basic microeconomics.

CIVE.5450 Public Transit Plan and Design (Formerly 14.545) - Credits: 3

Planning and design of public transportation systems and their technical, operational and cost characteristics. Discussion of the impact of public transportation on urban development; the different transit modes, including regional and rapid rail transit (RRT), light rail transit (LRT), buses, and paratransit, and their relative role in urban transportation; planning, design, operation and performance of transit systems (service frequency and headways, speed, capacity, productivity, utilization); routes and networks; scheduling; terminal layout; innovative transit technologies and their feasibility.

CIVE.5460 Pavement Design (Formerly 14.546) - Credits: 3

Fundamentals of planning, design, construction and management of roadway and airport pavements. Introduction to the theory and the analytical techniques used in pavement engineering. Principal topics covered: pavement performance, analysis of traffic, pavement materials; evaluation of subgrade; flexible and rigid pavement structural analysis; reliability design; drainage evaluation; design of overlays; and pavement distresses.

CIVE.5470 Airport Planning and Design (Formerly 14.547) - Credits: 3

Planning and design of civil airports. Estimation of air travel demand. Aircraft characteristics related to design; payload, range, runway requirements. Analysis of wind data, runway orientation and obstruction free requirements. Airport configuration, aircraft operations, and capacity of airfield elements. Design of the terminal system, ground access system, and parking facilities.

CIVE.5480 Traffic Management and Control (Formerly 14.548) - Credits: 3

The course presents modern methods of traffic management, traffic control strategies and traffic control systems technology. Main topics covered, include: transportation systems management (TSM); traffic control systems technology; control concepts - urban and suburban streets; control and management concepts - freeways; control and management concepts - integrated systems; traveler information systems; system selection, design and implementation; systems management; ITS plans and programs. The course will also include exercises in the use and application of traffic simulation and optimization models such as: CORSIM, TRANSYT and MAXBAND/ MULTIBAND.

CIVE.5490 Traffic Flow and Emerging Transportation Technologies (Formerly 14.549) - Credits: 3

Traffic flow theories seek to describe through precise mathematical models (a) the interactions between vehicles and the roadway system and (b) the interactions among vehicles. This course covers both conventional human-driven vehicles and the emerging connected and automated vehicles. Such theories form the basis of the models and procedures used in design and operational analysis of streets and highways. In particular, the course examines the fundamental traffic flow characteristics and the flow-speed-density relationship, as well as time and space headway, string stability, traffic flow stability, popular analytical techniques for traffic stream modeling at both microscopic and macroscopic levels, shock wave analysis, and simulation modeling of traffic systems.

CIVE.5500 Behavior of Structures (Formerly 14.550) - Credits: 3

Classical and matrix methods of structural analysis applied to complex plane trusses. Elementary space truss analysis. Elementary model analysis through the use of influence lines for indeterminate structures. The digital computer and problem oriented languages as analytical tools.

CIVE.5510 Advanced Steel Design (Formerly 14.551) -
Credits: 3
Elastic and plastic design of structural steel systems, residual stresses, local buckling, beam-columns, torsion and biaxial bending, composite steel-concrete members, load and resistance factor design.

CIVE.5520 Design of Concrete Structures (Formerly 14.552) - Credits: 3
The main objective of this course is to expand the students’ knowledge and understanding of reinforced concrete behavior and design. Advanced topics at material, element, and system level are built on quick reviews of undergraduate level knowledge and are related to current design codes.

CIVE.5530 Wood Structures (Formerly 14.553) - Credits: 3
Review of properties of wood, lumber, glued laminated timber and structural-use panels. Review of design loads and their distribution in wood-frame buildings. Design of wood members in tension, compression and bending; and design of connections.

CIVE.5560 Finite Element Analysis (Formerly 14.556) - Credits: 3
Finite element theory and formulation, software applications, static and dynamic finite element analysis of structures and components.

CIVE.5570 Structural Dynamics (Formerly 14.557) - Credits: 3
Analysis of typical structures subjected to dynamic force or ground excitation using direct integration of equations of motion, modal analysis and approximate methods.

CIVE.5580 Bridge Design (Formerly 14.558) - Credits: 3
Analysis and design of modern bridges, using computer software for the 3-D modeling of sample bridges under dead and live loading and seismic excitation. AASHTO specifications are used for the design of superstructures and substructures (abutments, piers, and bearings) under group load combinations.

CIVE.5590 Design of Masonry Structures (Formerly 14.559) - Credits: 3
Fundamental characteristics of masonry construction. The nomenclature, properties, and material specifications associated with basic components of masonry. The behavior of masonry assemblages subjected to stresses and deformations. Design of un-reinforced and reinforced masonry structures in accordance with current codes.

CIVE.5610 Physical Chemical Treatment Processes (Formerly 14.561) - Credits: 3
Course provides a theoretical understanding of various chemical and physical unit operations, with direct application of these operations to the design and operation of water and wastewater treatment processes. Topics include colloid destabilization, flocculation, softening, precipitation, neutralization, aeration, and gas transfer, packed tray towers, oxidation, disinfection, reverse osmosis, ultrafiltration, settlements, activated carbon adsorption, ion exchange, and filtration.

CIVE.5620 Physical and Chemical Hydrology Geology (Formerly 14.562) - Credits: 3
Well hydraulics for the analysis of groundwater movement. A review of the processes of diffusion, dispersion, sorption, and retardation as related to the fate and transport of organic contaminants in groundwater systems. Factors influencing multi-dimensional contaminant plume formation and migration are addressed. It is the goal of this course to provide environmental scientists and engineers with the technical skills required to understand groundwater hydrology and contaminant transport within aquifers. A term paper and professional presentation in class regarding a relevant topic is required.

CIVE.5640 Hydrology & Hydraulics (Formerly 14.564) - Credits: 3
This course utilizes engineering principles to quantitatively describe the movement of water in natural and manmade environmental systems. Topics include: hydrologic cycle, stream flow and hydrographs, flood routing, watershed modeling, subsurface hydrology, and probability concepts in hydrology, hydraulic structures, flow in closed conduits, pumps, open channel flow, elements of storm and sanitary sewer design will be addressed.

CIVE.5660 Environmental Applications and Implications of Nanomaterials - Credits: 3
This course will cover (I) novel properties, synthesis, and characterization of nanomaterials; (II) environmental engineering applications of nanomaterials, with an emphasis on nano-enabled water and wastewater treatment technologies such as membrane processes, adsorption, photo-catalysis, and
(Formerly 14.571) - Credits: 3
Theory and application of surface water quality modeling will be combined interactively throughout the course. Data from a stream will be utilized in order to bring a public domain model into operation

CIVE.5720 Marine and Coastal Processes (Formerly 14.572) - Credits: 3
This course focuses on the coastal dynamics of currents, tides, waves, wave morphology and their effects on beaches, estuaries, mixing and sediment transport/accretion processes. Generalized global aspects of atmospheric and hydroospheric interactions with ocean currents are also presented.

CIVE.5730 Solid Waste Engineering (Formerly 14.573) - Credits: 3
Characterization, handling and disposal of municipal, industrial and hazardous wastes. Technologies such as landfills, recycling, incineration and composting are examined. A term paper and professional presentation in class regarding a relevant topic is required.

CIVE.5750 Groundwater Modeling (Formerly 14.575) - Credits: 3
Groundwater Modeling is designed to present the student with fundamentals, both mathematical and intuitive, of analytic and numeric groundwater modeling. An introductory course in groundwater hydrology is a prerequisite for Groundwater Modeling, and the student should be familiar with IBM computers in running text editors and spreadsheets. The semester will start with basic analytic solutions and image theory to aid in the development of more complex numeric models. Emphasis will then switch to numeric ground water flow models (MODFLOW) and the use of particle tracking models (GWPATH) to simulate the movement of solutes in ground water. The numeric modeling process will focus on forming the problem description, selecting boundary conditions, assigning the model parameters, calibrating the model, and preparing the model report. Course topics include: Analytic Methods, Numeric Methods, Conceptual Model and Grid design, Boundary Conditions, Sources, and Sinks, and Particle Tracking.

CIVE.5760 GIS Applications in Civil and Environmental Engineering (Formerly 14.576) - Credits: 3
This course is to introduce students to the basic concepts of Geographic Information Systems (GIS) and GIS applications in Civil and Environmental Engineering. Topics to be covered
include GIS data and maps, queries, map digitization, data management, spatial analysis, network analysis, geocoding, coordination systems and map projections, editing. Examples related to transportation, environmental, geotechnical and structural engineering will be provided to help students better understand how to apply GIS in the real world and gain hands-on experience. This course will consist of lectures and computer work.

**CIVE.5790 Green and Sustainable Civil Engineering**
(Formerly 14.579) - Credits: 3

This course focuses on various green and sustainable materials and technologies applicable to five areas of civil engineering: environmental engineering, water resources engineering, structural engineering, transportation engineering, and geotechnical engineering. This course also covers current green building laws and introduces fundamentals of entrepreneurship and patent/copyright laws.

**CIVE.5810 Engineering Systems Analysis**
(Formerly 14.581) - Credits: 3

The course presents advanced methods of operations research, management science and economic analysis that are used in the design, planning and management of engineering systems. Main topics covered, include: the systems analysis methodology, optimization concepts, mathematical programming techniques, Network analysis and design, project planning and scheduling, decision analysis, queuing systems, simulation methods, economic evaluation. The examples and problems presented in the course illustrate how the analysis methods are used in a variety of systems applications, such as: civil engineering, environmental systems, transportation systems, construction management, water resources, urban development, etc.

**CIVE.5850 Transportation Safety**
(Formerly 14.585) - Credits: 3

Transportation Safety goes beyond the accepted standards for highway design. Providing a safe and efficient transportation system for all users is the primary objective of federal, state, and local transportation agencies throughout the nation. This class addresses fundamentals of highway design and operation, human factors, accident investigation, vehicle characteristics and highway safety analysis.

**CIVE.5950 Hazardous Waste Site Remediation**
(Formerly 14.595) - Credits: 3

This course focuses on the principles of hazardous waste site remediation (with an emphasis on organic contaminants) using physical, chemical or biological remediation technologies. Both established and emerging remediation technologies including: bioremediation, intrinsic remediation, soil vapor extraction (SVE), in situ air sparging (IAS), vacuum-enhanced recovery (VER), application of surfactants for enhanced in situ soil washing, hydraulic and pneumatic fracturing, electrokinetics, in situ reactive walls, phyto remediation, and in situ oxidation, will be addressed. A term paper and professional presentation in class regarding a relevant topic is required.

**CIVE.5960 Grad Industrial Exposure**
(Formerly 14.596) - Credits: 0

**CIVE.6510 Special Topics in Civil Engineering**
(Formerly 14.651) - Credits: 3

Course content and credits to be arranged with instructor who agrees to direct the student.

**CIVE.6930 Civil Engineering Individual Project**
(Formerly 14.693) - Credits: 3

**CIVE.7050 Supervised Teaching in Civil Engineering**
(Formerly 14.705) - Credits: 0

**CIVE.7330 Masters Project in Civil Engineering**
(Formerly 14.733) - Credits: 3

**CIVE.7360 Masters Project in Civil Engineering**
(Formerly 14.736) - Credits: 6

**CIVE.7410 Master's Thesis - Civil Engineering**
(Formerly 14.741) - Credits: 1

**CIVE.7430 Master's Thesis - Civil Engineering**
(Formerly 14.743) - Credits: 3

**CIVE.7460 Master's Thesis - Civil Engineering**
(Formerly 14.746) - Credits: 6

**CIVE.7490 Master's Thesis - Civil Engineering**
(Formerly 14.749) - Credits: 9

**CIVE.7510 Doctoral Dissertation**
(Formerly 14.751) - Credits: 1

**CIVE.7520 Independent Study in Civil Engineering**
(Formerly 14.752) - Credits: 3

**CIVE.7530 Doctoral Dissertation**
(Formerly 14.753) - Credits: 3

**CIVE.7560 Doctoral Dissertation/Civil Engineering**
(Formerly 14.756) - Credits: 6

**CIVE.7570 Doctoral Dissertation**
(Formerly 14.757) - Credits: 6
Credits: 7
CIVE.7590 Doctoral Dissertation (Formerly 14.759) - Credits: 9
CIVE.7610 Continued Graduate Research - Credits: 1
CIVE.7630 Continued Graduate Research (Formerly 14.763) - Credits: 3
CIVE.7660 Continued Graduate Research (Formerly 14.766) - Credits: 6
CIVE.7690 Continued Graduate Research (Formerly 14.769) - Credits: 9
CIVE.7CPT Curricular Practical Training for Engineering Doctoral Candidates - Credits: 1

Curricular Practical Training (CPT) is a training program for doctoral students in Engineering. Participation in CPT acknowledges that this an integral part of an established curriculum and directly related to the major area of study or thesis.
ENGN.5010 Engineering for Teachers (Formerly 25.501) - Credits: 3

The course will focus on increasing teachers' understanding of the Engineering Design Process. The linkage between science, engineering and technology will be discovered as teachers engage in a variety of home-based projects requiring them to apply design principles to the building, testing and evaluating of prototypes. Teachers will also gain knowledge of the various fields of engineering. Through their participation in the course, teachers will discuss how they might integrate engineering-technology concepts with other areas of their curriculum.

ENGN.5030 American Culture, Ethics and Communications in Engineering - Credits: 1

Overview of American culture and how it has been shaped by immigrants from the colonial era to the present and cultural influences from immigrants and their role in contributing to accomplishments in engineering, technology, science and the arts will be explored. Students will learn about the history of Lowell, MA in the context of key events. The concepts and practice of engineering ethics and the ethical principles and responsibilities that students should exercise in academia and professional careers will be introduced. The impact of engineering on society and the environment will be discussed through case studies. The course will promote communication skills through reading, listening and viewing assignments and responding with written reports and presentations to the class.

ENGN.5200 Aerospace Systems Design and Integration - Credits: 3

This introductory course discusses the basics of Aerospace Systems design and integration as they apply to modern advanced aircraft platforms (both military and civilian). Detailed analyses of individual aircraft engine systems- and sub-systems will be studied as well as their intended interaction with other aircraft-based systems (e.g., hydraulic, lubrication, fuel, pneumatic, electronic, electrical, etc.). Emphasis will be given on modern advanced controls through study of EEC (Electronic Engine Controls) and FADEC (Full-Authority Digital Engine Controls), and their performance as part of the overall aircraft avionics systems. A brief review of appropriate requirements and protocols for systems- and sub-systems design, testing, validation &verification, performance is examined.

ENGN.5300 Gas Turbine Engine Theory and Design - Credits: 3

This introductory course discusses the basics of open Brayton cycles for Gas Turbine Engines (GTEs) followed by a comprehensive review of the various GTE architectures (e.g., turbojet, turbofan, turboshaft, turboprop, ramjets, etc.) for applications in both civil and military platforms. Detailed analyses of individual engine components (fan, LP/IP/HP compressors combustors, HP/IP/LP turbines, nozzles, etc.) as well as overall engine system interaction and integration. GTE design conceptualization, testing, validation &verification, performance, emissions, and other parameters are examined with respect to overall design goal and intended operability and durability. Concluded by a broad review of popular airframe-engine models and their brief history of conceptualization and development.

ENGN.5400 Designing Sustainable Products - Credits: 3

The course introduces students to the sustainability aspects of product design. Sustainable products are designed to conserve materials and energy, select low-impact materials, eliminate toxic substances, extend product life, re-use materials, and reduce the generation of wastes. The entire product life cycle will be considered including: material extraction, material processing, manufacturing, transportation, product use, and disposal. Students will learn the impact of design solutions in a global, economic, environmental, and societal context. The students will learn strategies to identify the sustainability impacts throughout the product life cycle, as well as the application of sustainable product design principles and strategies to address these impacts.

ENGN.5500 Introduction to Nanotechnology (Formerly 25.550) - Credits: 3

This course is designed to provide you with a broad overview to the multi-disciplinary field of nanotechnology. The course is team-taught by researchers from science, engineering, health and environment, management, and humanities disciplines. The topics include an introduction to nanoscale phenomena; fundamental theoretical concepts and experimental techniques in nanotechnology; nanoscale manufacturing and processing; innovative nanomaterials for various applications; applications of the technology; and environmental and health impacts of nanotechnology.

ENGN.5700 Selected Issues in Nanomanufacturing (Formerly 25.570) - Credits: 0

A seminar course that examines the issues associated with high rate template-based nanomanufacturing, including: technologies for nanoscale templates, high rate assembly of nanoelements and polymer systems, registration at the nanoscale, interfacing with biological systems, measurement of nanoelements, and molecular modeling. Environmental, regulatory, and ethical issues associated with new technologies are also addressed. The course is co-taught by faculty from Northeastern University, the University of Massachusetts...
Lowell, and the University of New Hampshire. Meeting dates: January 27, February 10, February 24, March 10, March 24, and April 7. Time: 12:00 to 3:30, including lunch.

ENGN.5800 Thesis Review (Formerly 25.580) - Credits: 1
ENGN.5810 Project Review (Formerly 25.581) - Credits: 1
ENGN.5900 Graduate Industrial Cooperative Educational Experience I (Formerly 25.590) - Credits: 1
Industrial experience credit for co-op and internships with industry. Students must register with department co-op coordinator.

ENGN.5910 Graduate Industrial Cooperative Educational Experience II (Formerly 25.591) - Credits: 1
Industrial experience credit for co-op and internships with industry. Students must register with department co-op coordinator.

ENGN.5920 Graduate Industrial Cooperative Educational Experience III (Formerly 25.592) - Credits: 1
Industrial experience credit for co-op and internships with industry. Students must register with department co-op coordinator.

ENGN.5930 Graduate Industrial Cooperative Educational Experience (Formerly 25.593) - Credits: 3
Industrial experience credit for co-op and internships with industry. Students must register with department co-op coordinator.

ENGN.5980 Seminar for Teaching Assistants in Engineering - Credits: 0
Prepare graduate students for their role as teaching assistants in labs and lectures. Topics include: (1) classroom management, (2) grading strategies, (3) how to prepare for lecture and lab, (4) understanding the cultural differences that come with the diverse campus population, (5) balancing teaching and research responsibilities, (6) how to do graduate-level research. This course is mandatory for all new teaching assistants in the College of Engineering.

ENGN.6010 Academic and Technical Writing for Research in Engineering - Credits: 0
This course addresses the complex nature of academic language and academic writing by focusing on sentence, paragraph and text structures, purposeful and appropriate word choices, and the writing process. Through attention to details and critical reading of various materials, students will enhance their writing skills by applying effective planning, drafting, rewriting and editing strategies. Students will further become adept at critically and creatively evaluating, analyzing, constructing and presenting their ideas and arguments. As a workshop class, the final product of the class will be one or more of (1) a journal paper that is ready for submission, (2) a conference paper, and (3) one or more chapters of a dissertation or thesis. Please Note: Advanced English language proficiency required.

ENGN.6020 Graduate Professional Development for Engineers - Credits: 1
This course is designed to provide master's students with the requisite preparation in understanding the expectations of the workplace and tools needed to engage in an effective job search process. The course will facilitate the transition and preparation to meet the increased expectations of a graduate student while on a graduate cooperative experience. The course will be comprised of a series of workshops and offer resources intended to provide students a good understanding of the US work environment, work culture and expectations. Topics include: workplace culture and expectations, professional communication skills, job search strategies, resume writing, mock interviews, technical writing.

ENGN.6030 Graduate Cooperative Experience - Credits: 0-1
This one-credit course is for co-op internship experience. There will be one credit whether the co-op experience is for three or six months. Learning objectives a s mutually agreed upon by the student and co-op supervisor will be required to be submitted at the beginning of the experience. A final evaluation by supervisor will be due before final grading. Full-time co-op is typically expected to be at a minimum of 30 hours per week. "Variable credit course, student chooses appropriate amount of credits when registering."

ENGN.6040 Workforce Development - Credits: 1
Optional seminar series which will be comprised of weekly speakers from industry, government, academia and non-profit sectors with a focus on workforce development talks.
EECE.5010 Introduction to Phased Arrays - Credits: 3
This course covers the fundamentals of phased array systems, including contemporary and advanced methods. The principles apply to both high capability sensors and low-cost systems. Applications range from advanced and commercial radar to remote sensing, and multiple channel communications. The subject matter includes: fields and waves analysis, domain analysis, fundamentals of array theory, far field synthesis, Floquet theory, aperture weighting functions, impedance and mutual coupling theory, aperture design, beamforming methods, feed networks, array error analysis, system requirements and sizing, and system design.

EECE.5040 VLSI Fabrication (Formerly 16.504) - Credits: 3
Fabrication of resistors, capacitors, p-n junction and Schottky Barrier diodes, BJTs and MOS devices and Integrated circuits. Topics include: silicon structure, wafer preparation, sequential techniques in micro-electronic processing, testing and packaging, yield and clean room environments. MOS structures, crystal defects, Fick's laws of diffusion; oxidation of silicon, photolithography including photoresist, development and stripping. Metallization for conductors, Ion implantation for depletion mode and CMOS transistors for better yield speed, low power dissipation and reliability. Students will fabricate circuits using the DSIPL Laboratory.

EECE.5050 Microwave Electronics (Formerly 16.505) - Credits: 3
Review of p-n junction theory, depletion layer width and junction capacitance, Schottky barrier diodes, pin diodes and applications in switches and phase shifters, varactors and step recovery diodes, tunnel diodes and circuits, Gunn devices and circuits, avalanche diodes, IMPATT, TRAPATT and BARRITT diodes, microwave bipolar junction transistors (BJT) and field effect transistors (FET), small signal amplifier design, new devices like HEMT and Si-Ge devices, traveling wave tubes and klystrons.

EECE.5060 Antenna Theory and Design (Formerly 16.506) - Credits: 3

EECE.5070 Electromagnetic Materials and Waves (Formerly 16.507) - Credits: 3
This is a graduate core course, which serves the needs of students who study electromagnetics as a basis for a number of electromagnetic technologies including photonic technologies. Study of Electromagnetic Wave Interactions with Bounded Simple Media: transmission lines, Green's function, fibers, conducting waveguides and cavity resonators, Plane waves in Complex Electromagnetic Materials: plasmas, dispersive dielectrics, mixing formulas, optical waves in metals, super conductors, chiral media, crystals, magnetized plasma and time-varying media, layered and periodic media.

EECE.5080 Quantum Electronics for Engineers (Formerly 16.508) - Credits: 3
Introduction to the fundamental postulates of quantum theory: Planck's quantization hypothesis; wave-particle duality; time-dependent & time-independent Schrodinger's Equation; simple quantum mechanical systems. Radiation and quanta; quantization of the radiation field and cavity modes; absorption and emission of radiation; coherence functions; coherent states; importance of quantum fluctuations and quantum nature of light; laser amplifiers and amplifier nonlinearity; electromagnetics and quantum theory of laser oscillators; photons in semiconductors; semiconductor photon sources and detectors.

EECE.5090 Linear Systems Analysis (Formerly 16.509) - Credits: 3

EECE.5100 Digital Signal Processing (Formerly 16.510) - Credits: 3
**EECE.5110 Medical Diagnostic Imaging (Formerly 16.511 & IB.511) - Credits: 3**

This course covers the physics and electrical engineering aspects of how signals are acquired from which images will be formed, and the principal methods by which the signals are processed to form useful medical diagnostic images. Modalities studied include: x-rays, ultra-sound, computed tomography, and magnetic resonance imaging. The principles of signal processing via Fourier transform will be reviewed. Noise and other artifacts that degrade the medical diagnostic of images are considered. MATLAB is heavily used in simulation and verification.

**EECE.5120 Mixed-Signal VLSI Design (Formerly 16.512) - Credits: 3**

The course covers a wide spectrum of topics related to challenges in modern VLSI design. Students will learn the skills of overcoming these problems when two opposing signal domains are integrated onto a single chip. Understanding physical layout representation and the effects of alternative layout solutions on circuit and system specifications is critical in modern designs. Students will learn to use the CAD tools widely used by the semiconductor industry for layout, schematic capture, advanced simulation, parasitic extraction, floorplanning and place and route. Specifically, the course provides a review of fundamentals of semiconductor components. In the next step, basic building blocks of digital and analog design are described. The course concludes with challenges of large scale integration under varying operation conditions. An individual project involving a layout design from specification to implementation is included.

**EECE.5130 Control Systems (Formerly 16.513) - Credits: 3**

System representations, state variables, transfer functions, controllability and observability, phase variables, canonical variables, representation of nonlinear systems, Lagrange's equations, generalized co-ordinates, time response of linear systems, state transition matrix, Sylvester's expansion theorem, stability and state function of Liapunov, transient behavior estimation, optimal control, state function of Pontryagin, variational calculus, Hamilton Jacobi method, matrix Riccati equation, linear system synthesis.

**EECE.5140 Integrated Power Systems (Formerly 16.414/514) - Credits: 3**

Power System Operations and Electricity Markets provide a comprehensive overview to understand and meet the challenges of the new competitive highly deregulated power industry. The course presents new methods for power systems operations in a unified integrated framework combining the business and technical aspects of the restructured power industry. An outlook on power policy models, regulation, reliability, and economics is attentively reviewed. The course lay the groundwork for the coming era of unbundling, open access, power marketing, self-generation, and regional transmission operations.

**EECE.5160 Biomedical Imaging and Data Science - Credits: 3**


**EECE.5170 MMIC Design and Fabrication (Formerly 16.517) - Credits: 3**

The domain of microwave monolithic integrated circuits (MMIC) design and fabrication engineer stretches from realms of device physics and microwave circuit theory in the frequency range from 300 MHz to 300 GHz. The main goal of the course is to embody most of the application of the spectrum that have been deployed during the past five decades due to advances of many microwave solid-state devices. The principles of semiconductors emphasizing 1) the properties which predominate at microwave frequencies, 2) the theories for circuit design techniques required to utilize them at microwave frequencies, and 3) practical engineering applications for controlling microwave signals in amplitude and phase using semiconductors, will be treated in great details. Special emphasis will be laid on correlation of S'parameters with microwave device parameters and their usage in designing Low-noise amplifiers, High-power amplifiers and oscillators and their integration in MMIC design.

**EECE.5180 Wireless Communications (Formerly 16.582/EECE.5820) - Credits: 3**

Cellular systems and design principles, co-channel and adjacent channel interference, mobile radio propagation and determination of large scale path loss, propagation mechanisms like reflection, diffraction and scattering, outdoor propagation models, Okumura and Hata models, small scale fading and
multipath, Doppler shift and effects, statistical models for multipath, digital modulation techniques QPSK, DPSK, GMSK, multiple access techniques, TDMA, FDMA, CDMA, spread spectrum techniques, frequency hopped systems, wireless systems and worldwide standards.

EECE.5190 Engineering of Submicron Machines (Formerly 16.519) - Credits: 3

Recently fabrication of Very Large Scale Integrated circuits has spun-off a new technology of micro-machines (MEMS) and sensors on a semiconductor wafer. These new devices are ideally located next to a microprocessor on the same wafer or a separate chip. The data transfer to and from a miniature machine, sensor or transducer is processed and controlled on site. Topics include design of mechanical, electrical and biological transducers; properties of electronic materials; pattern generation on a semiconductor wafer; interface of a micromachine and processor; applications and markets for submicron machines.

EECE.5200 Computer Aided Engineering Analysis (Formerly 16.520) - Credits: 3

An advanced programming course, which considers the digital computer as a tool for solving significant engineering problems. The course is based on a specific area in engineering which will be selected from such topics as digital and image processing, spectral estimation, optimization techniques, etc. Typical algorithms related to the specific topic will be studied. User oriented programs or subroutine packages will be developed in a project.

EECE.5210 Real Time Digital Signal Processing (Formerly 16.521 & IB.511) - Credits: 3

This course provides an introduction to real-time digital signal processing techniques using the TMS320C3x floating point and TMS320C5x fixed point processors. The architecture, instruction set and software development tools for these processors are studied via a series of C and assembly language computer projects where real time adaptive filters, modems, digital control systems and speech recognition systems are implemented.

EECE.5220 Semiconductor Physics for Solid-State Electronics (Formerly 16.523) - Credits: 3

The course covers fundamental solid-state and semiconductor physics relevant for understanding electronic devices. Topics include quantum mechanics of electrons in solids, crystalline structures, band theory of semiconductors, electron statistics and dynamics in energy bands, lattice dynamics and phonons, carrier transport, and optical processes in semiconductors.

EECE.5240 Computational Methods for Power System Analysis (Formerly 16.424/524) - Credits: 3

The course explores some of the mathematical and simulation tools used for the design, analysis and operation of electric power systems. Computational methods based on linear and nonlinear optimization algorithms are used to solve load flow problems, to analyze and characterize system faults and contingencies, and to complete economic dispatch of electric power systems. Real case studies and theoretical projects are assigned to implement the techniques learned and to propose recommendations. Different software applications will be used concurrently including ATP, PowerWorld Simulator, Aspen, MatLab with Simulink and Power System Toolbox, PSCAD, etc.

EECE.5250 Power Distribution Systems (Formerly 16.525) - Credits: 3

An intermediate course in analysis and operation of electrical power distribution systems using applied calculus and matrix algebra. Topics include electrical loads characteristics, modeling, metering, customer billing, voltage regulation, voltage levels, and power factor correction. The design and operation of the power distribution system components will be introduced: distribution transformers, distribution substation, distribution networks, and distribution equipment.

EECE.5260 Power Systems Stability and Control (Formerly 16.426/526) - Credits: 3


EECE.5270 Advanced VLSI Design Techniques (Formerly 16.427/527) - Credits: 3

This course builds on the previous experience with Cadence design tools and covers advanced VLSI design techniques for low power circuits. Topics covered include aspects of the design of low voltage and low power circuits including process technology, device modeling, CMOS circuit design, memory circuits and subsystem design. This will be a research-oriented course based on team projects.

EECE.5280 Alternative Energy Sources (Formerly 16.528) - Credits: 3

PV conversion, cell efficiency, cell response, systems and
applications. Wind Energy conversion systems: Wind and its characteristics; aerodynamic theory of windmills; wind turbines and generators; wind farms; siting of windmills. Other alternative energy sources: Tidal energy, wave energy, ocean thermal energy conversion, geothermal energy, solar thermal power, satellite power, biofuels. Energy storage: Batteries, fuel cells, hydro pump storage, flywheels, compressed air.

EECE.5290 Electric Vehicle Technology (Formerly 16.529) - Credits: 3

Electric vehicle VS internal combustion engine vehicle. Electric vehicle (EV) saves the environment. EV design, EV motors, EV batteries, EV battery chargers and charging algorithms, EV instrumentation and EV wiring diagram. Hybrid electric vehicles. Fuel cells. Fuel cell electric vehicles. The course includes independent work.

EECE.5300 Introduction to Medical Image Reconstruction - Credits: 3

This course provides both traditional and state-of-the-art tomographic reconstruction algorithms in a unified way. It includes analytic reconstruction, iterative reconstruction, and deep reconstruction based on the state-of-the-art deep learning techniques. This course provides fundamental knowledge for careers in medical image reconstruction.

EECE.5310 RF Design (Formerly 16.531) - Credits: 3

Two-port network parameters, Smith chart applications for impedance matching, transmission line structures like stripline, microstrip line and coaxial line, filter designs for low-pass, high-pass and band-pass characteristics, amplifier design based on s-parameters, bias network designs, one port and two port oscillator circuits, noise in RF systems.

EECE.5320 Computational Electromagnetics (Formerly 16.532) - Credits: 3


EECE.5330 Microwave Engineering (Formerly 16.533) - Credits: 3

An introductory course in the analysis and design of passive microwave circuits beginning with review of time-varying electromagnetic field concepts and transmission lines. Smith Chart problems; single and double stub matching; impedance transformer design; maximally flat and Chebyshev transformers; microstrip transmission lines, slot lines, coplanar lines; rectangular and circular waveguides; waveguide windows and their use in impedance matching; design of directional couplers; features of weak and strong couplings; microwave filter design; characteristics of low-pass, high-pass, band-pass, band-stop filter designs; two-port network representation of junctions; Z and Y parameters, ABCD parameters, scattering matrix; microwave measurements; measurement of VSWR, complex impedance, dielectric constant, attenuation, and power. A design project constitutes a major part of the course.

EECE.5340 Microwave Engineering Lab - Credits: 1

This lab course is offered as a practical supplement to the material taught in EECE.5330 Microwave Engineering. The students will develop skills in EM modeling (Ansys HFSS) and measurement of microwave transmission lines, waveguides and passive structures such as combiners and filters. Students will design basic microwave structures utilizing EM modeling tools, measure the resulting performance and provide justification of differences. Students will also perform basic antenna measurements of gain and patterns in an anechoic chamber. This course will consist of five three-hour labs, each requiring a detailed report of the results.

EECE.5350 Microwave Metrology - Credits: 3

Laboratory measurement techniques that are typical of those used to characterize wireless devices and systems, including network analyzer calibration, measurements of noise in amplifiers, mixers and oscillators; measurements of distortion in amplifiers and mixers; and characterizing the dynamic range of a receiver.

EECE.5360 Microwave Metrology Lab - Credits: 1

This lab course is offered as a practical supplement to the material taught in EECE.5350 Microwave Metrology. Students will calibrate test equipment and perform measurements of the following parameters: phase noise, noise figure, intermodulation distortion, translated frequency, gain compression, and high-power characterization. Students will also perform probe measurements and demonstrate de-embedding techniques. This course will consist of five three-hour labs, each requiring a detailed report of the results.

EECE.5370 Microwave Systems Engineering - Credits: 3

This course will explore concepts related to the design, analysis, and construction of systems and will examine the fundamental tradeoffs governing microwave system design: the hardware components and technologies that comprise working systems, the models used for characterizing the transmission and reception of signals, the physics of wave propagation and interaction, and estimation theory which seeks to separate
signals from sources of error and guide algorithms for extracting information from received signals.

**EECE.5380 Microwave Systems Engineering Lab -**
**Credits: 1**

This lab course is offered as a practical Supplement to the material taught in EECE.5370 Microwave Systems Engineering. The students will perform cascade analyses using measured data to compare with analysis computed from nominal values given in component specifications. Monte Carlo analyses will also be performed to predict performance variation. Students will configure test setups to illustrate signal generation, up/down conversion and signal detection. Additionally, the students will configure a radiated test setup in an anechoic chamber to measure and validate link budget calculations based on the Friis transmission equation. This course will consist of five three-hour labs, each requiring a detailed report of the results.

**EECE.5410 Introduction to Biosensors (Formerly 16.441/541) - Credits: 3**

This course introduces the theory and design of biosensors and their applications for pathology, pharmacogenetics, public health, food safety civil defense, and environmental monitoring. Optical, electrochemical and mechanical sensing techniques will be discussed.

**EECE.5430 Theory of Communication (Formerly 16.543) - Credits: 3**

Information transmission and deterministic signals in time and frequency domains. Relationship between correlation and power or energy spectra. Statistical properties of noise. Spectral analysis and design of AM, FM and pulse modulation systems, continuous and discrete. AM, FM, and various pulse modulation methods, in the presence of noise. Digital modulation & demodulation technique.

**EECE.5440 Computational Data-Driven Modeling I -**
**Credits: 3**

Computational Data-Driven Modeling (CDM) I is the first in a sequence of two courses designed to introduce the student to basics skills in exploratory data analysis and data-driven computational modeling using foundational concepts drawn from linear algebra, probability, statistics, random processes, time-series analysis and dynamical systems. In CDM-I students will learn to apply regression and classification algorithms on multivariate data and assess performance of these models. An interactive project-driven approach is taken using the Python programming platform and its associated open-source libraries for statistical modeling, data analysis and machine-learning. A review of the tools and techniques from probability and statistics will be undertaken.

**EECE.5460 Communication Networks (Formerly 16.546) - Credits: 3**

An in depth survey of the elements of the modern computer based telecommunications system. Discussion of media used to transport voice and data traffic including twisted pair, baseband and broadband coaxial cable, fiber optic systems and wireless systems. Techniques for sending data over the media are presented including modems, baseband encoding, modulation and specific cases such as DSL, cable modems, telephone modems. Architecture and functionality of telephone system that serves as backbone for moving data, including multiplexing, switching, ATM, ISDN, SONET. Layered software architectures are discussed including TCP/IP protocol stack and the ISO/OSI seven layer stacks are examined in depth from data link protocols to transport protocols. LAN and WAN architectures including media access control (MAC) techniques are discussed for Ethernet, token ring and wireless LAN applications. Internetworking protocols and the role of repeaters, routers, and bridges. Voice over IP and state of the art applications.

**EECE.5470 Computational Data-Driven Modeling II -**
**Credits: 3**

Computational Data-Driven Modeling (CDM) II is the second in a sequence of two courses designed to introduce the student to skills in exploratory data analysis and data-driven computational modeling. CDM-II extends the students' knowledge on application of regression and classification algorithms in CDM-1 to more complex structures such as Bayesian networks and Hidden-Markov models. The focus will be on time-varying data using time-series and stat-space models such as Kalman filters, Markov Processes and Particle filters for prediction and forecasting. The application of neural networks and deep-learning will be discussed. Students will undertake case-studies in data analytics with collaboration from professionals in industry.

**EECE.5480 Coding and Information Theory (Formerly 16.548) - Credits: 3**

Probabilistic measure of information. Introduction to compression algorithms including L-Z, MPEG, JPEG, and Huffman encoding. Determination of the information handling capacity of communication channels and fundamental coding theorems including Shannon’s first and second channel coding theorems. Introduction to error correcting codes including block codes and convolutional coding and decoding using the Viterbi algorithm. Applications of information theory and coding to advanced coding modulation such as Trellis code Modulation (TCM) and turbo modulation.
ECE.E5490 Optimization Models and Decision Analysis - Credits: 3

This course addresses the prototypical theme of how a system or organization can improve its decision-making and develops approaches for both prescriptive and predictive analytics. Whether it is a service or manufacturing entity, a firm should promulgate a mission statement with three evolving parts: strategy, tactics, and operations. For example, a strategic focus is to maximize profit, a tactical plan minimizes cost, and an operations manifesto establishes feasibility. Towards this objective, this course will present introductory and applied concepts on decision-making, optimization and simulation modeling under uncertainty. Case studies will supplement the theoretical concepts and enforce student learning. Background in engineering mathematics and/or permission of instructor. Undergraduate introduction to Probability and Statistics.

ECE.E5492 Systems, Modeling and Simulations for Digital Eng - Credits: 3

This course provides a high-level view of systems thinking, systems engineering, physical system modeling and model-based systems engineering (MBSE) in the context of digital transformation initiatives taking place in government and industry. Examples of systems engineering practice are drawn from government acquisition processes. State-space models of system dynamics are introduced considering deterministic and random effects. Security primitives and threat modeling tools are reviewed and their integration during the design phased discussed. System dynamics will be simulated using MATLAB, Simulink and Python programming platforms. Students will learn to implement MBSE using the systems modeling language (SysML) and supporting commercial or open-source software platforms. In team-based projects, students will emulate a digital transformation of stakeholder requirements examine design trade-offs by integrating the MBSE representation with dynamic system simulations.

ECE.E5494 Model-Based Systems Engineering - Credits: 3

This course provides experiential learning in implementing Model-Based Systems Engineering (MBSE) from an applications perspective. Principles of systems thinking and practices in design of engineered systems are discussed. The mapping of systems engineering stages to a model-based graphical representation in undertaken with the systems modeling (SysML) language and supporting programming platforms. Model-based representation of stakeholder requirements, use-cases and scenarios, system architecture, and interface architecture will be be taught through case studies drawn from mission operations. MBSE practitioners will present their best practices for integrating respective models for verification, validation, traceability and presentation to teams with differing backgrounds and expertise.

ECE.E5496 Cyber-Physical Systems Modeling and Simulation - Credits: 3

Physical systems and their interactions with embedded digital sub-systems and communication networks are analyzed by representing them in the context of cyber-physical systems (CPS). Related concepts of system control, hybrid dynamical systems and state estimation are presented. The application of the CPS model as a digital twin and approaches for representing the model across its lifecycle are explored. The specification of functional, behavioral and security requirements for CPS using a model-based systems engineering framework is undertaken. The performance verification with multiphysics models and simulation experiments are conducted. Particular focus will be on the verifying correctness of algorithms that control the CPS and challenges in bridging continuous and discrete event based systems that comprise a CPS.

ECE.E5498 Data-Driven Models, Decision Making, and Risk Mgmt - Credits: 3

This course addresses the application of data recorded from models, simulation or measurements for prediction, inference of estimation of system behavior. Students are introduced to AI/machine learning algorithms, data visualization and data analytics. The focus will be on the analysis of decisions driven by data and models using concepts of decision trees, multi-objective models and game theory. Methods for estimating costs and managing risks across the lifecycle of the system will be discussed. Case studies will be drawn from the government and industry that highlight mission statements with proposed strategy, tactics and operations. Optimization methods that address these directives with associated uncertainty parameters will be explored in team-based projects.

ECE.E5500 Advanced Digital System Design (Formerly 16.550) - Credits: 3

Design of logic machines. Finite state machines, gate array designs, ALU and 4 bit CPU unit designs, micro-programmed systems. Hardware design of advanced digital circuits using XILINX. Application of probability and statistics for hardware performance, and upgrading hardware systems. Laboratories incorporate specification, top-down design, modeling, implementation and testing of actual advanced digital design systems hardware. Laboratories also include simulation of circuits using VHDL before actual hardware implementation and PLDs programming.

ECE.E5540 Heterogeneous Computing (Formerly 6540) - Credits: 3
This course introduces heterogeneous computing architecture and the design and optimization of applications that best utilize the resources on such platforms. The course topics include heterogeneous computer architecture, offloading architecture/API, platform memory and execution models, GPU/FPGA acceleration, OpenCL programming framework, Data Parallel C++ programming framework, performance analysis and optimization. Labs are included to practice design methodology and development tools.

**EECE.5520 Microprocessor Systems II & Embedded Systems (Formerly 16.552) - Credits: 3**

CPU architecture, memory interfaces and management, coprocessor interfaces, bus concepts, bus arbitration techniques, serial I/O devices, DMA, interrupt control devices. Including Design, construction, and testing of dedicated microprocessor systems (static and real-time). Hardware limitations of the single-chip system. Includes microcontrollers, programming for small systems, interfacing, communications, validating hardware and software, microprogramming of controller chips, design methods and testing of embedded systems.

**EECE.5530 Software Engineering (Formerly 16.553) - Credits: 3**

Introduces software life cycle models, and engineering methods for software design and development. Design and implementation, testing, and maintenance of large software packages in a dynamic environment, and systematic approach to software design with emphasis on portability and ease of modification. Laboratories include a project where some of the software engineering methods (from modeling to testing) are applied in an engineering example.

**EECE.5540 Data Intensive Computing - Credits: 3**

This course deals with various topics in data-intensive computing to address challenges in managing large-scale data and methods for extracting values from big data. Specifically, we explore state-of-the-art techniques to build parallel systems and applications for scalable data analysis on a massive and complex dataset, those from scientific and engineering problems. Topics include: 1) Storage requirements of big data; 2) parallel and distributed computing systems in both high-performance computing (HPC) and commercial domains; 3) Data-parallel frameworks such as MapReduce/Hadoop/Spark; 4) parallel file systems such as HDFS/Lustre; 5) NoSQL data models such as Dynamo/BigTable/Cassandra; and 6) time-series data models such as InfluxDB/Prometheus.

**EECE.5550 Computer System Security - Credits: 3**

An introduction to computer system security. This course introduces the threats and vulnerabilities in computer systems. This course covers the elementary cryptography, program security, security in operating system, database security, legal, ethical and privacy issues in computer system security.

**EECE.5560 Fundamentals of Robotics (Formerly 16.556) - Credits: 3**

The material in this course is a combination of essential topics, techniques, algorithms, and tools that will be used in future robotics courses. Fundamental topics relevant to robots (linear algebra, numerical methods, programming) will be reinforced throughout the course using introductions to other robotics topics that are each worthy of a full semester of study (dynamics, Kinematics, controls, planning, sensing). Students will program real robots to further refine their skills and experience the material fully.

**EECE.5590 Introduction to Nanoelectronics (Formerly 16.459/559) - Credits: 3**

This course introduces the use of nanomaterials for electronic devices such as sensors and transistors. Synthesis methods for nanoparticles, nanotubes, nanowires, and 2-D materials such as graphene will be covered. The challenges in incorporating nanomaterials into devices will also be discussed. These methods will be compared to techniques used in the semiconductor industry and what challenges, technically and financially, exist for their widespread adoption will be addressed. Finally, examples of devices that use nanomaterials will be reviewed. The course will have some hands on demonstrations.

**EECE.5600 Biomedical Instrumentation (Formerly 16.460/560) - Credits: 3**

A survey of biomedical instrumentation that leads to the analysis of various medical system designs and the related factors involved in medical device innovation. In addition to the technical aspects of system integration of biosensors and physiological transducers there will be coverage of a biodesign innovation process that can translate clinical needs into designs. A significant course component will be project-based prototyping of mobile health applications. The overall goals of the course are to provide the theoretical background as well as specific requirements for medical device development along with some practical project experience that would thereby enable students to design electrical and computer based medical systems.

**EECE.5620 VHDL/Verilog Synthesis & Design (Formerly 16.562) - Credits: 3**

This course covers digital chip design, synthesis, verification, and test using Hardware Description Languages (HDLs). This
### EECE.5625L VHDL/Verilog Synthesis & Design Lab - Credits: 1

This lab course is offered to provide the student practical applications of advanced FPGA topics. The lab will focus on advanced language constructs and effective coding for synthesis. Timing closure techniques and synthesis optimization for speed vs power will be explored. Features of synthesis tools including partial reconfiguration, tool reports and clock domain crossing will be evaluated. This course will consist of seven 2-hour labs, each requiring either completion of a worksheet or a detailed report of the results.

### EECE.5670 Advanced Logic Design (Formerly 16.574) - Credits: 3

Introduction to optoelectronics and laser safety; geometrical optics; waves and polarization; Fourier optics; coherence of light and holography; properties of optical fibers; acousto-optic and electro-optic modulation; elementary quantum concepts and photon emission processes; optical resonators; Fabry Perot etalon; laser theory and types; review of semiconductor lasers and detectors; nonlinear optics.

### EECE.5700 Radar Systems Lab - Credits: 1

This lab course is offered as a practical supplement to the material taught in EECE.5710 Radar Systems. Students will build functional radar using a COTS-based radio system to demonstrate the detection of canonical targets (plates, spheres, corner reflectors) of known radar cross sections. This course will consist of five three-hour labs, each requiring a detailed report of the results.

### EECE.5710 Radar Systems (Formerly 16.571) - Credits: 3


### EECE.5720 Embedded Real Time Systems (Formerly 16.572) - Credits: 3

Designing embedded real-time computer systems. Types of real-time systems, including foreground/background, non-preemptive multitasking, and priority-based pre-emptive multitasking systems. Soft vs. hard real time systems. Task scheduling algorithms and deterministic behavior. Ask synchronization: semaphores, mailboxes and message queues. Robust memory management schemes. Application and design of a real-time kernel. A project is required.

### EECE.5740 Advanced Logic Design (Formerly 16.574) - Credits: 3


### EECE.5750 Field Programmable Gate Arrays Logic Design Techniques (Formerly 16.575) - Credits: 3

Advanced logic design techniques using field programmable gate arrays (FPGAs), programmable logic devices, programmable array logic devices, and other forms of reconfigurable logic. Architectural descriptions and design flow will be covered as well as rapid prototyping techniques, ASIC conversions, in-system programmability, high level language design techniques, and case studies highlighting the tradeoffs involved in designing digital systems with programmable devices. This course is generally offered summers only.
EECE.5755 FPGA Logic Design Techniques Lab - Credits: 1

This lab course is offered to provide the student with the practical skills required to design and implement an FPGA. The student will design commonly used FPGA structures such as state machines and data processing elements and learn how to include library components such as FIFOs, memory interfaces and computer/debug interfaces. The student will work through all phases of development: coding, simulation, building and testing the FPGA on hardware. This course will consist of seven 2-hour labs, each requiring either completion of a worksheet or a detailed report of the results.

EECE.5760 Principles of Solid State Devices (Formerly 16.576) - Credits: 3

This course introduces the operating principles of Solid State Devices. Basic semiconductor science is covered including crystallographic properties, quantum mechanics principles, energy bands and the behavior of atoms and electrons in solids. The transport of electrons and holes (drift and diffusion) and the concepts of carrier lifetime and mobility are covered. The course describes the physics of operation of several semiconductor devices including p-n junction diodes (forward/reverse bias, avalanche breakdown), MOSFETs (including the calculation of MOSFET threshold voltages), bipolar transistor operation, and optoelectronic devices (LEDs, lasers, photodiodes).

EECE.5770 Verification of Digital Systems (Formerly 16.577) - Credits: 3

The increasing complexity of digital designs coupled with the requirement for first pass success creates a need for an engineered approach to verification. This course defines the goals for verification, presents techniques and applications, and develops a framework for managing the verification process from concept to reality.

EECE.5775L Verification of Digital Systems Lab - Credits: 1

This lab course is offered to provide the student with the practical skills to verify an FPGA design in simulation environment. The student will build various components of a test environment beginning with a basic testbench using manual verification and progressing to a more robust self-checking test environment. This includes generating constrained random stimulus and predicting, monitoring, and checking responses. The students will also create a regression test suite and evaluate coverage. This course will consist of seven 2-hour labs, each requiring either completion of a worksheet or a detailed report of the results.

EECE.5780 Modeling and Implementation of Digital Systems using MATLAB - Credits: 3

The course covers the methodology and tools to design digital systems with MATLAB. Topics include algorithm design and analysis with MATLAB, MATLAB Simulink development, conversion from algorithm to VHDL implementation, synthesis to FPGA and performance evaluation. Labs are included to practice design methodology and tools with FPGA or other platforms.

EECE.5800 Robotics, Automation and Machine Intelligence (Formerly 16.580) - Credits: 3

Covers advanced foundations and principles of robotic manipulation; includes the study of advanced robot motion planning, task level programming and architectures for building perception and systems for intelligent robots. Autonomous robot navigation and obstacle avoidance are addressed. Topics include computational models of objects and motion, the mechanics of robotic manipulators, the structure of manipulator control systems, planning and programming of robot actions. Components of mobile robots, perception, mechanism, planning and architecture; detailed case studies of existing systems.

EECE.5811 Operating Systems (Formerly 16.573/EECE.5730) - Credits: 3

Covers the components, design, implementation, and internal operations of computer operating systems. Topics include basic structure of operating systems, Kernel, user interface, I/O device management, device drivers, process environment, concurrent processes and synchronization, inter-process communication, process scheduling, memory management, deadlock management and resolution, and file system structures. Laboratories include examples of components design of a real operating systems.

EECE.5821 Computer Architecture and Design (Formerly 16.561/EECE.5610) - Credits: 3


EECE.5830 Network Design: Principles, Protocols and Applications (Formerly 16.583) - Credits: 3

Covers design and implementation of network software that
transforms raw hardware into a richly functional
communication system. Real networks (such as the Internet,
ATM, Ethernet, Token Ring) will be used as examples.
Provides the different harmonizing functions needed for the
interconnection of many heterogeneous computer networks.
Internet protocols, such as UDP, TCP, IP, ARP, BGP and
IGMP, are used as examples to demonstrate how
internetworking is realized. Applications such as electronic
mail and the WWW are studied.

**EECE.5840 Probability and Random Processes**
(Formerly 16.584) - Credits: 3

Sample space, Field and Probability Measure. Axiomatic
Continuous and discrete random variables and their
probability distribution and density functions. Functions of
random variables and their distribution and density functions.
Expectation, variance and higher order moments.
Characteristic and generating functions. Vector formulation of
random variables and their parameters. Mean square
estimation and orthogonality principle. Criteria for estimators.
Introduction to random processes: distribution and density
functions; Ensemble and time averages; correlation functions
and spectral densities. Classification of random processes.
Random processes through linear systems. Weiner filters and
Kalman filters.

**EECE.5841 Computer Vision and Digital Image
Processing** (Formerly 16.581/EECE.5810) - Credits: 3

Introduces the principles and the fundamental techniques for
Image Processing and Computer Vision. Topics include
programming aspects of vision, image formation and
representation, multi-scale analysis, boundary detection,
texture analysis, shape from shading, object modeling, stereo-
vision, motion and optical flow, shape description and objects
recognition (classification), and hardware design of video
cards. AI techniques for Computer Vision are also covered.
Laboratories include real applications from industry and the
latest research areas.

**EECE.5850 Network and Cyber Security** (Formerly
16.658 and EECE.6580) - Credits: 3

This course will cover two categories of topics: One part is the
fundamental principles of cryptography and its applications to
network and communication security in general. This part
focuses on cryptography algorithms and the fundamental
network security enabling mechanisms. Topics include attack
analysis and classifications, public key cryptography (RSA,
Diffie-Hellman), secret key cryptography (DES, IDEA), Hash
(MD5, SHA-1) algorithms, key distribution and management,
security handshake pitfalls and authentications, and well
known network security protocols such as Kerberos, IPSec,
SSL/SET, PGP & PKI, WEP. The second part reviews unique
challenges and the security & privacy solutions for the emerging
data/communication/information/computing networks (e.g., Ad
Hoc & sensor network, IoT, cloud and edge computing, big
data, social networks, cyber-physical systems, critical
infrastructures such as smart grids and smart transportation
systems, etc.).

**EECE.5900 Fiber Optic Communication** (Formerly
16.590) - Credits: 3

Optical fiber; waveguide modes, multimode vs single mode;
bandwidth and data rates; fiber losses; splices, couplers,
connectors, taps and gratings; optical transmitters; optical
receivers; high speed optoelectronic devices; optical link design;
broadband switching; single wavelength systems (FDDI,
SONET, ATM); coherent transmission; wavelength division
multiplexing and CDMA; fiber amplifiers.

**EECE.5930 Industrial Experience** (Formerly 16.593) -
Credits: 1

**EECE.5950 Solid State RF Electronics** (Formerly
16.595) - Credits: 3

This course provides a physical understanding of advanced
solid-state devices with an emphasis on high-speed designs for
RF applications. Topics include semiconductor
heterostructures, heterojunction bipolar transistors, field-effect
transistors, high-electron-mobility transistors, hot-electron
devices, charge transport, quantum confinement effects, and
small-signal analysis. Technologies to be discussed draw from
group IV elemental semiconductors (silicon, germanium),
group III-V compound semiconductor families (arsenides,
phosphides, nitrides), and emerging oxide materials. Case
studies of state-of-the-art examples taken from the literature
will be used to motivate more in-depth discussions.

**EECE.5980 Seminar for Teaching Assistants**
(Formerly 16.598) - Credits: 0

This course will meet once per week and attendance in
mandatory for all TAs. The course will cover an overview of
laboratories for the following week.

**EECE.5990 Thesis Review** - Credits: 1

**EECE.6010 Graduate Seminar** (Formerly 16.601) -
Credits: 0

There will be a series of seminars by distinguished researchers
form academia and industry in addition to UML faculty.
Moreover, there will be seminars dedicated to instructional
sessions in library services, introduction to Department and
Faculty research, and information on thesis requirements and
professional ethics. Attendance is mandatory for doctoral and MS students with thesis option. The students are required to write short reports summarizing the talk after each seminar. This course is offered in the fall semester.

EECE.6120 Converged Voice and Data Network (Formerly 16.612) - Credits: 3
Covers the technologies and protocols used to transport voice and data traffic over a common communication network, with emphasis on voice over IP (VoIP). The specific topics covered include voice communication network fundamentals, data networking fundamentals, voice packet processing, voice over packet networking, ITU-T VoIP architecture, IETF VoIP architecture, VoIP over WLAN, access networks for converged services: xDSL and HFC networks, and IP TV service.

EECE.6150 Medical Image Reconstruction - Credits: 3
This course will deliver the students both traditional and state-of-the-art algorithms in a unified way, which can make the students qualify for a medical image reconstruction engineer. The topics includes central slice theorem, 2D parallel-beam, 2D fan-beam and 3D cone-beam reconstruction algorithms in terms of analytic and iterative methods. It will cover the state-of-the-art Katsevich algorithm, interior tomography, compressive sensing, and spectral CT.

EECE.6160 Computational Power Systems Analysis (Formerly 16.616) - Credits: 3
Power system matrices, power flow studies, fault studies, state estimation, optimal power dispatch, and stability studies.

EECE.6170 Modelling Of Communication Networks (Formerly 16.617) - Credits: 3
Overview of general architectures for B-ISDN and Internet, network layering, signaling, performance requirements, traffic management strategies, usage parameter control, connection admission control, congestion control, stochastic processes, Markov chains and processes, stochastic models for voice, video and data traffic, Poisson processes, Markov-modulated processes, traffic analysis, queuing systems, M/M/1, M/M/m, M/G/1 queues, fluid buffer models, effective band-width approaches, simulation modeling, discrete event simulation of transport and multiplexing protocols using OPNET software, statistical techniques for validation and sensitivity analysis.

EECE.6500 Advanced Computing Systems Hardware Architecture (Formerly 16.650) - Credits: 3
Covers the latest advanced techniques in CPU design, floating point unit design, vector processors, branch prediction, shared memory versus networks, scalable shared memory systems, Asynchronous shared memory algorithms, systems performance issues, advanced prototype hardware structures, and future trends including TeraDash systems.

EECE.6510 Advanced Embedded System Design with FPGA - Credits: 3
This course covers the topics related to FPGA based embedded systems, including microprocessor architectures, embedded system architecture, firmware, bootloader, JTAG etc., bare metal processor vs embedded OS, ard core and soft core IP's, interconnects between processor and FPGA, buses and interfaces, and external devices such as sensors and cameras. Labs are included for practice the design of FPGA based embedded systems.

EECE.6515L Advanced Embedded System Design with FPGA Lab - Credits: 1
This lab course is offered to provide the student with the practical skills required to use embedded processors in FPGAs. The student will design, implement, test, debug, and configure embedded systems in FPGAs using both soft and hard cores. Students will connect various memories, bus interfaces and external devices to build a system in an FPGA. Basic programming of the embedded processor will also be performed. This course will consist of seven 2-hour labs, each requiring either completion of a worksheet or a detailed report of the results.

EECE.6520 Parallel & Mp Architect (Formerly 16.652) - Credits: 3

EECE.6530 AI and Machine Learning (Formerly 16.653) - Credits: 3

EECE.6570 High Speed Integrated Network (Last Term 2004 Fall)(Formerly 16.657) - Credits: 3

EECE.6600 Mobile Communication Networks (Formerly 16.660) - Credits: 3
The goal of this course is to enable students to understand communication systems that permit a user to be either continuously or intermittently connected to a communication network as he/she moves from one place to another. The key issue in these communications systems, which are referred to as mobile communication systems, is that there is provision for handling a device, service or user, over from on network to another. That is, mobility management is an essential aspect of mobile communication networks. The learning objectives of the course include enabling the student to understand mobile radio propagation, antenna and communications systems; the
so-called 2G, 2.5G, 3G and 4G networks; mobile IP and mobile TCP; mobile ad hoc networks; WiMAX networks; and cognitive radio networks.

EECE.6660 Storage Area Networks (Formerly 16.666) - Credits: 3
EECE.6690 Opto Electronic Devices (Formerly 16.669) - Credits: 3
EECE.6870 Applied Stochastic Estimation (Formerly 16.687) - Credits: 3


EECE.6880 Theoretical Acoustics (Formerly 16.688) - Credits: 3
EECE.6920 Directed Studies/Electrical Engineering (Formerly 16.692) - Credits: 3

Provides opportunity for students to get a specialized or customized course in consultation with a faculty member.

EECE.7100 Selected Topics (Formerly 16.710) - Credits: 3
Topics of current interest in electrical Engineering. Subject matter to be announced in advance.

EECE.7110 Special Topics (Formerly 16.711) - Credits: 3
Topics of current interest in Electrical Engineering. Subject matter to be announced in advance.

EECE.7120 Special Topics in Electrical Engineering (Formerly 16.712) - Credits: 3
Topics of current interest in Electrical Engineering. Subject matter to be announced in advance.

EECE.7150 Special Topics (Formerly 16.715) - Credits: 3

EECE.7290 Selected Topics in Electrical Engineering (Formerly 16.729) - Credits: 3
Advanced topics in various areas of Electrical Engineering and related fields. Prerequisite: specified a the time of offering.

EECE.7300 Thesis - Electrical Engineering (Formerly 16.730) - Credits: 6
EECE.7320 Systems Engineering Thesis (Formerly 16.732) - Credits: 3
EECE.7330 Advance Graduate Project (Formerly 16.733) - Credits: 3

The Advanced Project is a substantial investigation of a research topic under the supervision of a faculty member. A written proposal must be on file in the Electrical & Engineering Graduate Office before enrollment. A written report is required upon completion of the project. This course can be taken only once, and may evolve into a master’s thesis. However, credit for this course will not be given if thesis credit is received.

EECE.7360 Graduate Project - Electrical Engineering (Formerly 16.736) - Credits: 6
EECE.7390 Graduate Project - Electrical Engineering (Formerly 16.739) - Credits: 9
EECE.7400 Advanced Project In Electrical Engineering (Formerly 16.740) - Credits: 3
EECE.7430 Master’s Thesis in Electrical Engineering (Formerly 16.743) - Credits: 1-3

Master’s Thesis Research

EECE.7460 Master’s Thesis in Electrical Engineering (Formerly 16.746) - Credits: 6

Co-requisites: Minimum of 6 credit-hours of graduate courses at an acceptable level when registering for first three credits and 12 credit hours when registering for subsequent credits; matriculated status in the M.S. Eng. Program in Electrical, Computer or Systems Engineering; approval of a written proposal outlining the extent and nature of proposed research work. The report on the research work, performed under the supervision of a faculty member, must be published in appropriate form and presented to a committee of three faculty members appointed at the time of acceptance of the thesis proposal. The student is required to give an oral defense of the thesis before the committee and other faculty members.

EECE.7490 Master’s Thesis - Electrical Engineering
(Formerly 16.749) - Credits: 9
EECE.7510 Doctoral Thesis (Formerly 16.751) - 
Credits: 1
EECE.7520 PhD Thesis (Formerly 16.752) - Credits: 2
EECE.7530 Doctoral Dissertation/EE (Formerly 
16.753) - Credits: 3
Doctoral Dissertation Research
EECE.7540 Doctoral Thesis - Electrical Engineering 
(Formerly 16.754) - Credits: 4
EECE.7550 Doctoral Dissertation (Formerly 16.755) - 
Credits: 5
EECE.7560 Doctoral Dissertation/Electrical Engineering (Formerly 16.756) - Credits: 6
Doctoral Dissertation Research
EECE.7570 Doctoral Dissertation (Formerly 16.757) - 
Credits: 7
EECE.7590 Doctoral Dissertation/Electrical Engineering (Formerly 16.759) - Credits: 9
No more than 9 credits of doctoral dissertation research may 
be taken before passing the doctoral qualifying examination. 
No more than 15 credits of doctoral dissertation research may 
be taken before passing the defense of the thesis proposal 
examination.
EECE.7660 Continued Grad Research (Formerly 
16.766) - Credits: 1-6
EECE.7710 Eng Sys Analysis I (Formerly 16.771) - 
Credits: 3
Study of the key areas in multiple engineering disciplines 
including Mechanical, Electrical, Software, Systems and 
Optical. Students are introduced to weekly topics and then 
work in multidiscipline teams to solve technical assignments. 
Topics covered include: Concept of Operations and 
Requirements development, integration, test and verification, 
vibration/shock analysis, thermal analysis, power supply 
design, digital electronics &FPGA, intro to optical engineering, 
SCRUM planning, continuous integration and UML/SW 
design. Content may vary year to year. This course is part of 
the Engineering Leadership Development Program (ELDP) and 
team taught by industry experts at BAE Systems.
EECE.7720 Eng Sys Analysis II (Formerly 16.772) -
Credits: 3
Introduction and analysis of complex systems aligned with the 
key product lines of BAE Systems. Students are introduced to 
multiple types of systems and then work in multidiscipline 
teams to solve technical assignments. The systems covered 
include but are limited to: Electronic Warfare (EW), 
Communications Electronic Attack (Comms EA), Wide Area 
Airborne Surveillance (WAAS), Signal Intelligence (SIGINT), 
RADAR Navigation, Radio Communications, and Infrared 
Countermeasures (IRCM). Content may vary year to year. This 
course is part of the Engineering Leadership Development 
Program (ELDP) and team taught by industry experts at BAE 
Systems.
EECE.7730 Eng Sys Analysis III (Formerly 16.773) - 
Credits: 3
Study of project management concepts, product development 
methods, transition to operations and new business capture. 
Topics covered include but are not limited to risks and 
opportunities management, earned value management, lean 
product development, business strategy, design for 
manufacturability/maintainability (DFM^2), and request for 
information (RFI) response. Content may vary year to year. 
This course is part of the Engineering Leadership Development 
Program (ELDP) and team taught by industry experts at BAE 
Systems.
EECE.7CPT Curricular Practical Training for 
Engineering Doctoral Candidates - Credits: 1
Curricular Practical Training (CPT) is a training program for 
doctoral students in Engineering. Participation in CPT 
acknowledges that this an integral part of an established 
curriculum and directly related to the major area of study or 
thesis.
Master of Science in Engineering - Industrial Engineering

Industrial Engineering

- Degree Requirements
- Industrial Engineering Concentrations
  - Analytics and Operation Concentration
  - Ergonomics and Safety Concentration
  - Healthcare System Engineering Concentration
  - Manufacturing and Automation Concentration

The Department of Mechanical Engineering offers Master of Science in Industrial Engineering (MSIE) program. The program offers a choice of either a thesis track or a non-thesis track. To receive the MSE degree requires a minimum of thirty (30) credit hours of acceptable graduate work with at least 21 from Engineering. The thesis option including nine (9) credit hours of research for the thesis track.

The entrance requirement for the MSE program is a BSE in Industrial Engineering, or other engineering discipline, at an acceptable grade point average providing strong performance in mathematics and science courses. Students with a non-IE bachelors degree can be required to take up to 5 undergraduate IE courses in order to ensure that the student has adequate background knowledge.

Students on the thesis track may register for thesis credits after submitting a thesis agreement signed by his/her thesis advisor to the graduate coordinator. Upon completing the thesis, the student is required to defend it orally before a committee of at least three faculty members including the advisor. The committee members must receive a completed version of the thesis manuscript at least 14 days before the thesis is defended. The thesis defense is open to the public.

Co-op Option in Engineering

The Department of Mechanical Engineering participates in the Graduate Master’s Co-op Option in Engineering. For detailed information about the Co-op Program and curriculum requirements, please see the Graduate Catalog Engineering Co-op page.

Degree Requirement

All MSIE degree candidates must satisfy the following requirements:

1. Core courses (four three-credit courses):
   - IENG.5010 (Advanced Deterministic Modeling & Analysis)
   - IENG.5020 (Advanced Stochastic Modeling & Analysis)
   - IENG.5050 (Industrial Automation)
   - BMEN.5310 (Occupational Biomechanics)

2. In addition to the core, each student must complete either a thesis or non-thesis track.
   1. Thesis Track:
      Nine (9) credit hours of thesis research, nine (9) credit hours of coursework approved by the thesis advisor, and at least one semester of the 0 credit research seminar (MECH.5010).
      M.S. students on the thesis track will design a student-specific curriculum sequence of twelve credit hours of coursework (in consultation with the thesis advisor and approved in writing by the student and their thesis advisor) within the first semester of graduate study. The contract will be sent to the graduate coordinator and to the Registrar’s office.

   2. Non-Thesis Track:
      Six (6) credit hours of coursework in an Industrial Engineering Concentration and twelve (12) credit hours of coursework approved by the graduate coordinator.
      In their first year students must submit a non-thesis track must submit a plan of study to the graduate coordinator and obtain his/her approval. Any change to the submitted plan requires the approval of the graduate coordinator.
Industrial Engineering Concentrations

1. Analytics and Operations
   - Degree pathway
     (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

2. Ergonomics and Safety
   - Degree pathway
     (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

3. Health System Engineering
   - Degree pathway
     (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

4. Manufacturing and Automation
   - Degree pathway
     (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

Doctoral Program

Doctor of Philosophy in Mechanical Engineering

The UMass Lowell Department of Mechanical Engineering offers a Doctor of Philosophy (Ph.D.) option in Mechanical Engineering.

Ph.D. Option in Mechanical Engineering

The intent of the Doctor of Philosophy program is to prepare engineers for leadership positions in industry, academia and government. The program includes advanced graduate course work in engineering and allied subjects and research, culminating in a doctoral dissertation. The Ph.D. degree is oriented toward academic research.

Admission Requirements

- Applicants must have a minimum of a B.S. in Mechanical Engineering, or a closely related field with a minimum grade point average of 3.0 and a min GPA of 3.25 in science and engineering courses. Applicants with a M.S. in Mechanical Engineering, or a closely related field, must have a minimum graduate GPA of 3.25.
- Applicants must take the GRE
- Applicants from abroad whose native language is not English, must take The TOEFL exam (other UMass Lowell graduate admission approved exam)
- Applicants must fully completed application per the graduate admissions office.

Transfer Credits

- A student with an earned master’s degree in Engineering or a closely related field may transfer the entire degree (coursework and thesis) up to total number of credits granted by UMass Lowell with approval of the Department Graduate Coordinator.
- A student with graduate-level work completed at an accredited US or Canadian university may apply for transfer of up to 24 semester credits in acceptable graduate engineering courses (with grade of B or better) towards the doctoral program, upon approval by the Department Graduate Coordinator.

Note: Students may be required to make up prerequisites which they lack in comparison to the equivalent Engineering curriculum at the UMass Lowell.

Degree Requirements

A total of 63 credit hours of graduate level courses are required for the Ph.D. degree. The Ph.D. degree must involve a traditional research-based dissertation, plus:

- A minimum of 30 approved credit hours of graduate-level engineering courses, including associated science and math courses.
- A minimum of 21 credit hours of doctoral dissertation.
- The balance of the remaining 12 credits can be a mix of graduate-level engineering courses including associated science and math coursework and dissertation credits at the discretion of the department, faculty advisor and dissertation committee.
- At least two semesters of the 0 credit research seminar MECH.5010
In addition to these 63 semester hours of approved graduate courses and thesis:

- The student must have a minimum grade point average of 3.25 in order to graduate.
- The student is required to take and pass the doctoral proposal defense, complete and pass the dissertation defense, and submit fully approved dissertation per university requirements.

Concerning graduate-level STEM courses, the Ph.D. candidate must take the following:

- One Course in advanced mathematics: MECH.5200 Numerical Methods for Partial Differential Equations
- CHEN.5390 Mathematical Methods for Engineers
- MATH.5300 Applied Math
- MATH.5450 Partial Differential Equations
  Or another advanced mathematics approved by the doctoral dissertation advisor

Dissertation Proposal

The Dissertation Proposal stage will consist of a written dissertation proposal (a document of typically 20 to 50 pages without appendices) and associated oral presentation by the examinee to an audience of peers and a committee of faculty members (minimum of three) where one of whom must be the examinee’s dissertation advisor. The committee should have in addition one or more members from outside UMass Lowell (or outside the UMass Lowell Mechanical Engineering department).

At least two weeks (14 days) prior to the date of the presentation of the dissertation proposal, an announcement document must be submitted to the department graduate coordinator and to the Associate Dean of Graduate Studies in the College of Engineering by the Associate Dean of Graduate Studies. The template for posting these and the dissertation announcement can be found at: Thesis/Dissertation Submission (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

The dissertation proposal is open to the public. The proposal will outline the motivation for the research, give a summary of the related past work in the area and present the scope of the proposed dissertation research. The presentation should be approximately 30 minutes. The proposal should clearly articulate the proposed contribution of the student to the knowledge base and how it differs from the past work. The examinee will be expected to answer questions from the audience to demonstrate his/her understanding of the proposed research, as well as his/her proficiency in the general research field related to the dissertation proposal.

Doctoral of Philosophy in Industrial Engineering

Doctoral Program in Industrial Engineering (Anticipated Start Fall 2022)

The UMass Lowell Department of Mechanical Engineering offers a Doctor of Philosophy (Ph.D.), Option in Industrial Engineering.

Ph.D. Option in Industrial Engineering

The intent of the Doctor of Philosophy program is to prepare engineers for leadership positions in industry, academia, and government. The program includes advanced graduate course work in engineering and allied subjects and research, culminating in a doctoral dissertation.

Admission Requirements

Applicants must have a minimum of a B.S. in Industrial Engineering, or a closely related field with a minimum grade point average of 3.0 and a min GPA of 3.25 in science and engineering courses.

Applicants with a M.S. in Industrial Engineering, or a closely related field, must have a minimum graduate GPA of 3.25.

Transfer Credits

1. A student with an earned master’s degree in Engineering or a closely related field may apply to transfer coursework for the master’s degree up to a total of 24 credits.
2. A student with graduate-level work completed at an accredited US or Canadian university may apply to transfer up to 24 course credits in acceptable graduate engineering courses (with an earned grade of B or better) towards the doctoral program, upon approval by the Department Graduate Coordinator.
Note: Students may be required to make up prerequisites which they lack in comparison to the equivalent Engineering curriculum at the University of Massachusetts Lowell.

**Degree Requirements**

A total of 63 credit hours of graduate level courses are required for the Ph.D. degree. The Ph.D. degree must involve a traditional research-based dissertation, plus:

- A minimum of 30 approved credit hours of graduate-level engineering courses, including Master of Science in Engineering core courses.
- A minimum of 21 credit hours of doctoral dissertation.
- The balance of the remaining 12 credits can be a mix of graduate-level engineering and science, including associated physic (PHYS), chemistry (CHEMS), production & operation management (POMS), public health (PUBH) and math (MATH) course and dissertation credits at the discretion of the department, faculty advisor and dissertation committee.
- At least two semesters of the 0 credit research seminar MECH.5010.

In addition to these 63 semester hours of approved graduate courses and thesis, the student must:

- have a minimum grade point average of 3.25 in order to graduate.
- take and pass the doctoral qualifying examination/dissertation proposal.
- Successfully defend and complete a dissertation.
- Meet all other University requirements for the degree.

**Combined Qualifying Examination and Dissertation Proposal**

The Doctoral Qualifying Exam will consist of a written dissertation proposal (a document of typically 20 to 50 pages without appendices) and associated oral presentation by the examinee to an audience of peers and the dissertation committee composed of faculty members (minimum of three) where one of whom must be the examinee's dissertation advisor. The committee may have in addition one or more members from outside UML.

At least one week prior to the date of the presentation of the dissertation proposal, an announcement document must be submitted to the department graduate coordinator and to the Associate Dean of Graduate Studies in the College of Engineering.

The dissertation proposal is open to the public. The proposal will outline the motivation for the research, give a summary of the related past work in the area and present the scope of the proposed dissertation research. The presentation should be approximately 30 minutes. The proposal should clearly articulate the proposed contribution of the student to the knowledge base and how it differs from the past work. The examinee will be expected to answer questions from the audience to demonstrate his/her understanding of the proposed research, as well as his/her proficiency in the general research field related to the dissertation proposal.

**Doctoral Core Requirement**

Students must satisfy the following doctoral core requirement:

- Four core courses
  1. IENG.5010
  2. IENG.5020
  3. IENG.5050
  4. BMEN.5310
- Six courses from one the following four areas of concentration
  - IENG.7530
  - IENG.7560
  - IENG.7590
  - IENG.7550
- Industrial Engineering Concentration
  1. Analytics and Operations
  - Degree pathway
2. Ergonomics and Safety
   • Degree pathway
     (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

3. Health System Engineering
   • Degree pathway
     (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)

4. Manufacturing and Automation
   • Degree pathway
     (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf)
MECH.5010 Graduate Research Seminar - Credits: 0-1

Research seminar for students to listen to and engage with engineering-relevant researchers. Invited speakers will present recent research advances in fields relevant to mechanical engineering, and engage with the audience through a question and answer session. "Variable credit course, student chooses appropriate amount of credits when registering."

MECH.5040 Energy Engineering Workshop (Formerly 22.504) - Credits: 3

A group design of an innovative energy system. Integration of many aspects of the student's engineering background, including design concepts, technical analyses, economic and safety considerations. Ideally the whole design cycle of design, build, test. A formal report and oral presentation.

MECH.5050 Directed Studies - ME (Formerly 22.505) - Credits: 1-3

MECH.5100 Dynamics and Diagnostics of Rotating Machinery (Formerly 22.510) - Credits: 3

Course provides the theoretical and practical background in the fundamentals of dynamics and diagnostics of rotating machinery. The course starts with an overview of rotating machinery components and systems with emphasis on their designs, and then builds and in-depth understanding of the dynamics of rotating systems by analyzing the design and dynamics of their component. Diagnostics, health monitoring, and associated signal processing theories regarding rotating machinery are emphasized, with applied examples such as aircraft engines, gas turbines, rotorcrafts, wind turbines, and automotive drivetrains, along with other turbomachines.

MECH.5110 FEA of Textiles and Composites - Credits: 3

This course covers applications of finite element analysis to the mechanical behavior of textiles and composites, including topics such as mechanics of anisotropic materials, elasticity and strength of laminates, computational micromechanics, meso-scale finite element modeling, material testing, modeling techniques. These topics will be studied using software packages such as Abaqus and Matlab.

MECH.5120 Applied Finite Element Analysis (Formerly 22.512) - Credits: 3

An introduction to finite element methods using popular commercial packages. The features common to different programs as well as special features of particular programs are presented. Primary focus is on hands-on familiarity with the software with a limited discussion of the underlying finite element theory. ALGOR, ADINA, ABAQUS, LS-DYNA, HyperMesh, and ANSYS are among the pre/post-processing and analysis packages used in the class. This is a WWW based course and access to a PC, the Internet, and a frames-capable browser is required.

MECH.5130 Theory of Finite Element Analysis (Formerly 22.513) - Credits: 3

Matrix algebra and the Rayleigh-Ritz technique are applied to the development of the finite element method. The minimum potential energy theorem, calculus of variations, Galerkin’s and the direct-stiffness method are used. Restraint and constraint conditions are covered. C0 and C1 continuous shape functions are developed for bar, beam, and two and three dimensional solid elements. Recovery methods, convergence and modeling techniques are studied. Applications to problems in static stress analysis and heat conduction.

MECH.5140 Finite Element Analysis of Composites (Formerly 22.514) - Credits: 3

MECH.5150 Structural Dynamic Modeling Techniques (Formerly 22.515) - Credits: 3


MECH.5160 Experimental Modal Analysis (Formerly 22.516) - Credits: 3

Prerequisite: 22.4xx/5xx Experimental Modal Analysis I (or permission of instructor) Review of system transfer and FRF matrices for development of a modal model. Review of DSP techniques for experimental modal analysis. Excitation techniques for the development of the system FRF matrix; SISO and MIMO techniques. Modal parameter estimation using time and frequency domain techniques. Advanced data manipulation for dynamic analysis. Introduction to structural dynamic modification and system modeling concepts. Models developed using MATLAB and commercially available software.

MECH.5170 Structural Dynamics (Formerly 22.517) - Credits: 3

Prerequisite: MECH.5150 Development of system equations of

**MECH.5180 Signal Proc Techniques (Formerly 22.518)** - Credits: 3

The course covers analytical/numerical modeling and analysis of signal processing. The course topics include: Fourier Series, Linear Systems and Transfer Functions, Laplace Transforms, Analog filters, Fourier Transforms, Analog to Digital Conversion (A/D &D/A), Quantization, Sampling and Nyquist Theorem, Aliasing, Discrete Fourier Transform (DFT), Windowing &Leakage, FFT &STFT, Spectrograms, Spectral Analysis and Estimation, Convolution, ARMA processes, Correlation, Coherence, Kurtosis, Multi-rate filters and the Wavelet Transform, FIR &IIR Filters, Adaptive Filters, Signal Processing Hardware and Implementation.

**MECH.5190 Engineering Spectral Analysis (Formerly 22.519)** - Credits: 3

Analytical and experimental background for the fundamental understanding of time and frequency domain signals, required for digital signal processing, vibration, and acoustic signal analysis. Introductory theory is based on simplified concepts form different mechanical signatures in the time domain. The spectral conversion from time domain to frequency domain is illustrated from a phenomenological perspective using examples and dynamic signal analyzer illustrations. The concepts of vibration and acoustic measurement methods are studied through practical projects and LabVIEW exercises. Students will be prepared for more advanced topics on dynamic systems, controls, vibrations, advanced signal processing, acoustics, and experimental structural dynamics. Familiarity with Matlab required.

**MECH.5195 Principles and Applications of Sensors for Engineering** - Credits: 3

The course focuses on defining concepts and operational principles of various sensing technologies and their applications for assessing the conditions of aerospace, civil, and mechanical engineering systems and materials. Analytical and experimental background of commonly used wire-based and wireless transducers, their data acquisition protocols, and signal processing techniques in time and frequency domains are discussed. A strong emphasis is provided to non-contact and optical techniques, including mono/stereo computer-vision and thermal infrared for nondestructive evaluation and subsurface inspection. The concepts discussed in the lectures are analyzed in deep and applied through practical projects, demonstrations, and hands-on experiments on laboratory scale structures.

**MECH.5200 Numerical Methods for Partial Differential Equations (Formerly 22.520)** - Credits: 3

Mathematical approaches for numerically solving partial differential equations. The focus will be (a) iterative solution methods for linear and non-linear equations, (b) spatial discretization and meshing (c) finite difference methods (FDM), (d) finite volume methods (FVM), (e) finite element methods (FEM) and (f) boundary element methods (BEM). The theory behind of each of these methods will be developed and discussed. Computer programming applications involving the solution of linear and non-linear PDEs in multiple dimensions will play a key role in this course. Unique computer programming assignments will be selected from different engineering/science fields (possibilities include: fluid flow, heat transfer, electrostatics, electromagnetism, structural analysis, medical, ocean engineering etc.) to illustrate the broad applicability of numerical methods. Students will be expected to complete programming assignments -- while most class examples will deal with pseudo code and/or matlab, a working knowledge of one of the following programming languages is recommended: Matlab, Octave, C, C++, fortran, Java, BASIC, or Python.

**MECH.5210 Solar Fundamentals (Formerly 22.521)** - Credits: 3

Utilization Terrestrial irradiation on tilted surfaces; radiation, conduction, convection in collectors; absorbance, emittance, reflection, transmittance of solar irradiation; energy flow in flat plate and concentrator collectors; storage; design tools; small project; web-based.

**MECH.5220 Wind Energy Fundamentals** - Credits: 3

An overview of all aspects of wind energy power generation: The nature of and statistics of wind, turbine siting requirements, aerodynamics of the rotor system, mechanical power transmission, generators, blade construction, structural analysis of turbine components, electrical power distribution.

**MECH.5230 Structural Health Monitoring (Formerly 22.523)** - Credits: 3

Detail the entire process of structural health monitoring applications, including operational evaluation, data acquisition, normalization and cleansing, feature extraction and data compression, and statistical model development and pattern recognition. Aiming at detecting, localizing, and evaluating the damage severeness, topics that will be covered in this course include: sensors and sensor networks, signal processing and detection theory, nondestructive evaluation techniques, time and frequency modeling, damage prognosis, unsupervised/supervised learning, probability and statistics in feature evaluation. Case study of SHM activities will be
conducted throughout the entire course, including mechanical, aerospace and civil structures.

MECH.5240 Fund of Acoustics (Formerly 22.524) - Credits: 3
Fundamentals of acoustics are introduced. Topics include: Motivation for studying acoustics, oscillatory motion, harmonic waves, the wave equation, sound pressure levels, decibel scale, frequency analysis, sound power, intensity, acoustic sources, directivity, sound radiation, sound power measurement, sound in enclosures, acoustic mode shapes, reverberation time, sound absorbing material, impedance, transmission loss, cavity resonators, reactive and dissipative mufflers, and applications to noise control.

MECH.5250 Grid-Connected Solar Electric Systems (Formerly 22.525) - Credits: 3
Students will study the concepts and design considerations of grid-connected, solar-powered, electrical generation systems, from residential through utility scale. Emphasis will be on practical applications that help make the student "work ready" at graduation. Grading consists of two tests during semester; one individual project (residential scale PV system); and one group project (commercial-scale system). This course fulfills an elective requirement for renewable energy students.

MECH.5255 Hydropower - Credits: 3
The fundamentals of hydropower engineering and the related parameters for the design of hydropower plants, including, hydraulic, hydromechanics and hydroelectric components, are presented in this course. References are also made to dams and water conduit systems, in multi-purpose hydro development projects, as well as small hydroelectric plants. The hydrological, environmental and economical aspects of hydro projects are also briefly addressed. At the end of the course, students should be able to calculate the basic parameters of hydropower projects, at a preliminary level, such as powerhouse capacity, turbine and generator technical parameters and dimensions, water conduit and hydro mechanical equipment types and sizes, and perform a cost-benefit evaluation.

MECH.5260 Transport Processes in Energy Systems (Formerly 22.526) - Credits: 3
Course focuses on the development of a fundamental understanding of transport processes from a multi-scale and multi-physics perspective, and the application of such understanding to the analysis of energy engineering systems. Derivations of the equations describing the mechanisms for mass, momentum, and energy transport are presented, together with approaches for the evaluation of material properties and constitutive relations. Emphasis is placed on a holistic view of transport processes as combinations of transient, advective, diffusive, and reactive phenomena.

MECH.5270 Solar Energy Engineering (Formerly 22.527) - Credits: 3
Systems engineering, stochastic modeling, design, and life-cycle cost analysis of several solar systems: photovoltaics, passive heating, solar cooling, and daylighting; Web Based.

MECH.5280 Photovoltaics Manufacturing (Formerly 22.528) - Credits: 3
Overview of the manufacturing processes used to make a typical crystalline solar cell. Detailed study of selected processes and manufacturing problems, such as solar cell testing, characterization, reliability issues, factors affecting yields, automated material handling, affect of impurities in crystal growth.

MECH.5285 Energy Policy and Energy Codes - Credits: 3
Explore and codify the status of the world’s energy infrastructure and discuss energy-related policies. Identify areas of energy inefficiency and examine pathways to a future dominated by renewable and sustainable resources.

MECH.5290 Fuel Cell Fundamentals (Formerly 22.529) - Credits: 3
The primary objective of this course is to understand the fundamental science and engineering of fuel cells and redox flow batteries (i.e., reversible fuel cells). The fundamental principles of electrochemistry, thermodynamics, and kinetics of electrochemical reaction processes, as well as mass transport in electrochemical energy systems will be considered. Emphasis will be placed on operating principles and the design and diagnostics of the proton exchange membrane fuel cell as a portable energy conversion system, and the vanadium redox flow battery as a large-scale energy storage system. Cell components and their influence on the overall performance of these systems will be discussed in detail. An introduction to the cost analysis of electrochemical energy storage will be presented.

MECH.5300 Autonomous Robotic Systems (Formerly 22.530) - Credits: 3
This course covers concepts related to autonomous robotic systems, emphasizing the synthesis and design of control algorithms for autonomous robotic vehicles. Topics that will be covered in the course include: Linear and nonlinear systems
analysis, stability in the sense of Lyapunov, linearization of nonlinear dynamic equations, rigid body equations of motion in three dimensions, dynamic model derivation of aerial, space, marine and ground vehicles, fundamentals of flight dynamics, feedback control design for autonomous robotic vehicles, guidance and navigation, description of components typically encountered to autonomous robotic vehicles, guidance and navigation, description of components typically encountered to autonomous robotic vehicles, cooperative control of multirobot teams and state estimation.

MECH.5305 Introduction to Legged Locomotion - Credits: 3

Introduction to the modeling, analysis, planning, and control of legged robotic locomotion systems. Topics covered include: basic components of robotic systems, selection of coordinate frames, homogeneous transformations, solutions to kinematic equations, velocity and force/torque relations, legged Locomotion dynamics in Lagrange's formulation and Newton-Euler formulation, digital simulation of kinematic and dynamic models, kinematics of legged robots, zero-moment-point (ZMP) stability, hybrid-zero-dynamics (HZD) methods, and motion planning and locomotion control.

MECH.5310 Math Methods In Mechanical Engineering (Formerly 22.531) - Credits: 3

MECH.5315 Modern Control Systems - Credits: 3

Introduction to the analysis and design of feedback controllers for linear systems using the state-space formulation. Topics covered include: linear algebra, vector spaces, state-space representation, realization theory, stability in the sense of Lyapunov, controllability and observability, Kalman decomposition, pole placement via state-feedback, observer design, linear quadratic regulators and introduction to nonlinear systems.

MECH.5320 Off-Grid Solar Electric System (Formerly 22.532) - Credits: 3

This course examines the technical, financial and societal aspects of photovoltaic (PV) systems that are not connected to the electrical grid. Topics include: reasons for going off the grid, the components of an off-grid PV system, how to size a PV system to meet the required load, site impacts on performance, determining the loss of load probability (LOLP) for a system, hybrid systems, e.g. solar plus a generator, energy storage solutions, regulatory issues, and cost. Systems sized to meet the annual load requirements of a remote communication system, a net-zero home, and a small village will be examined. HOMER/Microgrid, PVWatts, and other software will be used to design these systems.

MECH.5330 Nanomaterials for Energy - Credits: 3

Introduction of fundamental materials development and principles in addressing issues associated with affordable and sustainable energy. The course starts with basic concepts in materials science and engineering, with special attention paid to the origin of size effects in controlling the properties of nanomaterials. Then a range of materials issues related to development of renewable energy resources and sustainable energy technologies will be discussed. Topics to be covered include: photovoltaic materials and solar energy conversion; thermoelectric materials; materials for electrical energy storage and generation; materials for hydrogen production; piezoelectric energy harvesting; and materials for other emerging energy processes.

MECH.5340 Green Combustion and Biofuels (Formerly 22.534) - Credits: 3

Fundamentals of combustion and pollutant formations in application to internal combustion engines, turbines, and fire safety. Concepts include flame structure, flame speed, flammability, ignition, reaction kinetics, nonequilibrium processes, diffusion flames, and boundary layer combustion. Additional specific emphasis on combustion modeling, green approaches to energy production, and biofuels.

MECH.5350 Fundamentals of Sustainable Energy - Credits: 3

Introduction to scientific principles associated with sustainable energy technologies. Topics include: thermodynamic laws and engineering fundamentals in energy processes, thermodynamic energy conversion, wind and geothermal energy, photovoltaics, ocean thermal energy conversion, electrochemical energy, biomass, and selected emerging energy technologies.

MECH.5410 Advanced Heat Transfer - Credits: 3

Advanced Heat Transfer is one of the core courses for graduate students to build the foundation and knowledge for the subsequent studies of specialized subjects. This course mainly comprises two parts: thermal conduction and convection. The thermal conduction part covers conduction formulations, analytical methods, and numerical technique to solve the multidimensional steady-state and transient conduction problems. The convection part covers the fundamental concepts of convection, governing equations, boundary layers and analytical solutions for external and internal flows, natural convection, boiling and condensation heat transfer.

MECH.5420 Convective Heat/Mass Transfer (Formerly 22.542) - Credits: 3

Conservation equations. Heat transfer in laminar and turbulent
boundary layer and duct flow. Free convection. Convective mass transfer.

**MECH.5440 Combustion Modeling - Credits: 3**

This course is focused on combustion modeling and computational combustion. It will introduce methods for modeling laminar and turbulent premixed and non-premixed flames, as well as particulate combustion. Specific emphasis will be placed on the theory and derivation of the methods, their implementation, and the use of existing computational tools. Models will include combustion kinetics, convective and diffusive transport, equilibrium, simple reactors, canonical premixed and non-premixed flames, and methods for treating turbulent flows. Practical applications include internal combustion engines and gas turbines.

**MECH.5450 Advanced Industrial Heat and Mass Transfer (Formerly 22.545) - Credits: 3**

This course specializes in obtaining practical solutions for applied and industrial heat transfer problems related to device development and production processes. Topics include review of heat transfer modes (i.e. conduction, convection and radiation), transport phenomena in material processing and manufacturing, analytical models and numerical simulations. Representative problems include curing of polymers, thermal conditioning of human body, food packaging and long-term food preservation, thermal management of electrical and electronic equipment, control of water vapor and pollutant transfer, material processing, and heat and mass exchangers.

**MECH.5490 Cooling of Electronic Equipment (Formerly 22.549) - Credits: 3**

This course focuses on teaching the primary techniques for cooling electronics, and methods for modeling their performance. Heat-transfer fundamentals: conduction, convection, radiation, phase change, and heat transfer across solid interfaces. Heat-generating electronic equipment: ICs, power converters, circuit cards and electrical connectors. Thermal management equipment: heat sinks, interface materials, heat spreaders including liquid loops, and air movers. System design: system packaging architectures, facilities, system analysis. Advanced Topics: spray cooling, refrigeration.

**MECH.5491 Advanced Thermodynamics - Credits: 3**

The primary objective of this course is to prepare upper-level engineering students to effectively solve problems directly related to the fundamental science and engineering of thermodynamic systems. The course expands upon the first and second laws of thermodynamics. A significant emphasis is placed on the concepts of entropy generation and its transport mechanisms with respect to single-phase, multi-phase, chemically reacting and non-reacting systems. The methods of entropy generation minimization for commonly studied thermodynamic systems are discussed.

**MECH.5500 Vibrations (Formerly 22.550) - Credits: 3**

This course provides the analytical background for the fundamental understanding of vibration analysis, modeling and testing of mechanical systems. The course starts with an overview of the concepts in vibrations and later builds an in-depth understanding of the vibrations of single degree of freedom and multi degree of freedom systems. Both free and forced vibrations of these systems under steady-state and transient mechanical excitations will be investigated. The important concepts of modal analysis and vibration measurement methods will be studied. The continuous system modeling, nonlinear and random vibrations will also be touched upon.

**MECH.5520 Probabilistic Methods and Analysis - Credits: 3**

The course will review the fundamentals of probability and statistics, and introduce the methodologies that are commonly adopted in mechanical engineering domain. The concepts of uncertainty, confidence and risk of engineering decision-making will be emphasized. Specific topic areas will include: random vibration and analysis, random data processing, probability evolution, uncertainty quantification in system modeling, model validation and verification, data fusion and model updating, Bayesian inference and statistical learning. Course assignments will be primarily deployed in Matlab environment.

**MECH.5530 MEMS & Microsystems (Formerly 22.553) - Credits: 3**

The purpose of this course is to give a broad introduction to Micro-electro-mechanical Systems (MEMS) technology, and will provide graduate students in mechanical, electrical, manufacturing and related engineering disciplines with necessary fundamental knowledge and experience in the design, manufacture, and packaging of microsystems. The topics include basic sensing and actuating principles, modeling of electromechanical components, material properties, fabrication technologies, process integration, system design, and packaging of MEMS and microsystems. The course will also cover current literature, MEMS markets and applications. The course will be a combination of lectures, case studies and homework assignments. The students are expected to possess prerequisite knowledge in college mathematics, physics, and chemistry, as well as in engineering subjects such as fundamental materials science, electronics, thermal-fluid, and machine design.
MECH.5540 Dynamic Systems and Controls  
(Formerly 22.554) - Credits: 3
Matrix-based classical and modern techniques are applied to the dynamics of control systems. Design of controllers, and full and reduced-order observers. Introduction to optimal control and Kalman filters.

MECH.5550 Networked Multi-Agent Systems - 
Credits: 3
Our world is increasingly becoming more connected, with multiple natural and engineered entities operating in a common space, and possessing the capability to sense, react to, and manipulate the physical world around us. Many modern world systems such as the traffic networks, multi-robot systems, stock exchanges, and even human societies, exist as multi-agent systems (or system-of-systems). In this course, we will discuss approaches to model, quantify, and influence (or control) the global behaviors of these multi-agent systems. The course will provide introductory dynamic modeling techniques for multi-agent systems. The course will provide introductory dynamic modeling techniques for multi-agent systems, discuss information-theoretic measures for quantifying the behaviors of these systems, and provide techniques to design stat-of-the-art controllers for these systems.

MECH.5570 Microsystem Design (Formerly 22.557) - 
Credits: 3
Design aspects of Microsystems (MEMS). Topics covered include working principles of various microsystems, analytical and numerical modelling, and case studies. Course incorporates lectures, computer laboratories and term project presentations.

MECH.5580 Aero/Wind Eng (Formerly 22.558) - 
Credits: 3
This course will introduce and examine classical and modern theoretical and computational two and three dimensional aerodynamics and aeroelastic modeling with applications in wind and subsonic aero/hydrodynamics applications. In addition, wind and meteorological science as well as simple FEM structural modeling and coupling concepts will be examined. The class will comprise scheduled lectures and discussions. Students will be expected to perform presentations and directed projects which involve computer programming.

MECH.5590 Multi-Scale Computational Fluid 
Dynamics I (Formerly 22.559) - Credits: 3
Derivation of governing equations; Scale analysis; Role of relative dimensionless parameters; Discretization of the governing equations; Finite-Difference, Finite-Volume, and/or Finite Element Techniques; Solutions of several problems in micro/meso/macro scale applications.

MECH.5600 Multi-Scale Computational Fluid 
Dynamics II (Formerly 22.560) - Credits: 3
Applications of CFD methods to the solution of multi-phase problems such as: heat pipes, fuel cells, nanofluidics, material processing and manufacturing, etc.

MECH.5620 Solid Mechanics I (Formerly 22.562) - 
Credits: 3
Topics covered include the theory of stress, kinematics of strain, Hooke’s Law, work and energy, equations of stress equilibrium, Navier’s equations, strain compatibility, and the Beltrami-Michell equations. Problems for uniformly varying 3-D states of stress, torsion, and plane deformation are studied. Axisymmetric deformation is considered. Green’s function solutions for plane and axisymmetric problems are studied.

MECH.5630 Dynamic Behavior of Materials - Credits: 3
The time-dependent material behavior and stress-wave propagation in solids. Topics will be selected from applied mechanics and materials science, e.g. mathematical and physical description of one dimensional and three dimensional waves in solids, strain rate-dependent behavior of materials, viscoelasticity of materials and its time-and frequency-domain descriptions including relaxation and creep, introduction to shock waves, introduction to experimental techniques for material characterization in dynamic environment such as ultrasonic testing, split Hopkinson bar technique, dynamic mechanical analysis, and drop tower and impact experiments.

MECH.5710 Quality Engineering (Formerly 22.571) - 
Credits: 3
Focuses on methodologies used by world class companies to guide the design and development of high quality, low cost products in the most timely manner through the use of analytical tools in case studies: Topics include: new product creation strategy and process, organizational aspects of multi-disciplinary design teams, concurrent project management, and structural methodologies for identifying customer requirements and manufacturing process design, control and selection. In particular, focus is on the interrelationship of CE, manufacturing and Quality tools and methodologies and how they contribute in determining the appropriate level of product/process quality and design efficiency.

MECH.5720 Manufacturing Processes - Credits: 3
Ferrous and non-ferrous, plastic and ceramic material behavior and properties. Electronic manufacturing processes, including printed circuit board fabrication, population and soldering. Castings, materials forming and shaping. Surface preparations and heat treatment. Additive manufacturing and fabrication of composites.

MECH.5740 Design For Reliability Engineering
(Formerly 22.574) - Credits: 3
(3-0)3 Design for Reliability Engineering provides a systematic approach to the design process that is focused on reliability and the physics of failure. It provides the requirements on how, why, and when to use the wide variety of reliability engineering tools available in order to achieve the reliability goals of the total design cycle. Topics include the product design cycle and customer requirements, analytical physics, reliability statistics, accelerated testing, accelerated reliability growth, industry standard predictive models, design reliability assessment, reliability FMEA, product risk evaluation and thermodynamic reliability.

MECH.5750 Industrial Design of Experiment
(Formerly 22.575) - Credits: 3
Concepts of Robust Design and statistical Design Of Experiments (DOE) as applied to the design and manufacturing of new high technology products. Classical and current methodologies of DOE including Full Factorial, Fractional Factorial, Taguchi, Central Composite and Yates Algorithms. The course will also provide for different methods for experimental design and analysis, including average and variability analysis. Commercial software packages and case studies using industrial experiments will be used to illustrate the material.

MECH.5760 Engineering Project Management
(Formerly 22.576) - Credits: 3
Skills are developed enabling engineers to be effective decision makers and technical leaders in an environment where technology management, business operations and strategies for contract compliance are critical to achieving competitive advantage. Elements of the Project Planning and Control System are presented along with analytical methods important for maintaining Projects on schedule and within budget.

MECH.5790 Robotics (Formerly 22.579) - Credits: 3
Common robotics joints and robotics classification. Planes of motion and fold lines. Robotics capability. Forward and inverse kinematics and the RobSim software package. Trajectory planning and elementary obstacle avoidance. Robotics dynamics and feasible trajectory evaluation. Design of the control system for the non-linear robotics problem. Classroom studies are followed by hands-on applications in the Automated Manufacturing Assembly and Robotics Laboratory.

MECH.5810 Advanced Fluid Mechanics (Formerly 22.581) - Credits: 3
Fundamental equations of fluid motion, kinematics, vorticity, circulation, Crocco’s theorem, Kelvin’s theorem, Helmholtz’s velocity laws, secondary flows. Stream function, velocity potential, potential flows. Unsteady Bernoulli equation, gravity water waves.

MECH.5830 Advanced Aerodynamics (Formerly 22.583) - Credits: 3

MECH.5840 Ocean Engineering (Formerly 22.584) - Credits: 3
Physical Properties of the Ocean Environment, ocean wave mechanics, computer solutions of wave interactions, physical modeling of marine vehicles and coastal environments (modeling and scaling laws), resistance and propulsion of surface ships and submarines, and forces on floating and submerged objects such as buoys, pipelines, piers, and breakwaters. Research report required summarizing some aspect of ocean engineering.

MECH.5890 Finite Element in Thermofluids (Formerly 22.589) - Credits: 3
The Galerkin finite element technique is first applied to a simple one-dimensional steady state convection/conduction equation. The element equations are derived and the assembly process is described. These concepts are then extended to two-dimensional transient problems. A finite element package is used to solve a variety of fluid flow problems. All course materials are available on the WWW.

MECH.5910 Mechanical Behavior of Materials
(Formerly 22.591) - Credits: 3
Quantification of structure-property relationships requires application of solid mechanics concepts to materials microstructure. Using micromechanics approach, the course
focuses on the deformation and fracture behavior of metals, ceramics, composites and polymeric materials. Topics include: elastic behavior, dislocations, crystal plasticity, strengthening mechanisms, composite materials, glassy materials, creep and creep fracture, tensile fracture, and fatigue.

MECH.5930 Graduate Co-op Education (Formerly 22.593) - Credits: 0

The prediction, analysis, and prevention of failure in mechanical design is covered. Failure mechanisms such as creep, plastic deformation, crack propagation, cyclic fatigue, thermal fatigue, fretting and galling are considered. Theories of failure such as Colomb-Mohr, Beltrami, and Huber-Von Mises are used to predict failure. Cumulative damage theories such as those of Gatts, Corten and Dolan, Marin, and Manson will be studied. Statistical methods of analysis and test data interpretation are studied. Materials such as steels, aluminum alloys, solders, plastics, and composites will be considered.

MECH.5950 Graduate Co-op II (Formerly 22.595) - Credits: 0

MECH.5960 Mechanics of Composite Materials (Formerly 22.596) - Credits: 3

Analysis of anisotropic lamina and laminated composites. Methods of fabrication and testing of composites. Other topics include environmental effects, joining and machining.

MECH.5970 Processing of Composites (Formerly 22.597) - Credits: 3

Methods of fabrication. Analysis of forming, fiber orientation, permeability, polymer rheology, flow through porous media, consolidation, cure kinetics, combined flow and cure models. Effect of manufacturing defects

MECH.5980 Experimental Characterization of Composites - Credits: 3


MECH.5CO-OP Curricula Practical Training (Formerly 22.5CO-OP) - Credits: 0-1

Curricula Practical Training. "Variable credit course, student chooses appropriate amount of credits when registering."

MECH.6020 Special Topic: Thermo-Fluids (Formerly 22.602) - Credits: 3

Study of advanced topics in thermo-fluid energy systems and processes not covered in the regular curriculum. Contents may vary from year to year.

MECH.6030 Special Topic: Vibration Dynamics (Formerly 22.603) - Credits: 3

Study of advanced topics in vibrations/dynamics not covered in the regular curriculum. Contents may vary from year to year.

MECH.6040 Special Topic: Finite Element Methods - Credits: 3

Study of advanced topics in finite element methods not covered in the regular curriculum. Contents may vary from year to year.

MECH.6110 Matrix Methods for Structural Dynamics (Formerly 22.611) - Credits: 3

3-0-3 Prerequisite: 22.515 Matrix linear algebra. Solution of algebraic equations using Gaussian elimination and decomposition variants. Eigenanalysis using various direct similarity techniques and simultaneous vector iteration methods. Algorithm development of solution techniques. Solution techniques for structural mechanics, dynamic systems and stability. Models developed using MATLAB.

MECH.6140 Advanced Finite Element Methods (Formerly 22.614) - Credits: 3

Nonlinear finite element methods as applied to large deformation and nonlinear material behavior are the focus of this course. Various classical and contemporary constitutive models and their implementation in the finite element method are considered. Procedures for determining material parameters from a matrix of material test results are investigated.

MECH.6150 Micromechanics of Composites and Metamaterials - Credits: 3

Overall behavior of composite materials and metamaterials. The fundamentals of homogenization for elastic composites, variational principles and energy-based bounds, and dynamic homogenization concepts and techniques are introduced. Voigt and Reuss mixture rules are discussed and expanded to dilute distribution, self-consistent, Mori-Tanaka, and periodic approaches with examples from particulate, whisker, platelet, and fiber-reinforced composites. The effects of damage and cracks and the concept of metamaterial are discussed and
examples are presented. The use of finite element calculations for static, nonlinear, and dynamic homogenization will be discussed and the application to non-mechanical and coupled problems are explored.

MECH.6500 Nano. Transport Phen. for Manufacturing Nanodevice (Formerly 22.650) - Credits: 3

This course on nanoscale transport phenomena constitutes a bridge between existing fluid and heat transfer courses in multiple disciplines and emerging nanoscale science and engineering concepts to reflect the forefront of nanomanufacturing. The course is designed to incorporate recent advances in manufacturing polymer-based nanodevices. Key issues of the implementation and maintenance costs for fabrication will be addressed. Hands-on laboratory experiments will be performed to complement the lectures with the ultimate goal of designing and building a complete nanodevice at the end of the course. The course will prepare graduates for employment focused on designing and manufacturing nano/microfluidic systems, lab-on-a-chip devices, electronics devices, medical devices, and other emerging.

MECH.6690 Fracture Mechanics (Formerly 22.569) - Credits: 3

The application of fracture mechanics and approaches for exploring the impact of cracks on engineering structures. Topics will be chosen from a range of mathematical techniques, applied mechanics, and materials science, e.g. theoretical strength, stress concentration, linear and nonlinear fracture mechanics, stress singularity, fracture modes, energy methods, stable and unstable crack growth thermal cracks, crack tip plastic zone, Dugdale and Irwin models, the R-curve, power-law materials, and the J-integral. Students should have a good understanding of the principles of strengths of materials and be able to apply these principles to the solution of problems in solid mechanics. The associated knowledge in complex variables and partial differential equations will be reviewed as needed.

MECH.7410 Master's Thesis - Mechanical Engineering (Formerly 22.741) - Credits: 1
MECH.7420 Master's Thesis - Mechanical Engineering (Formerly 22.742) - Credits: 2
MECH.7430 Master's Thesis - ME (Formerly 22.743) - Credits: 3
MS Thesis Research

MECH.7460 Master's Thesis - ME (Formerly 22.746) - Credits: 6
MS Thesis Research

MECH.7490 Master's Thesis - Mechanical Engineering (Formerly 22.749) - Credits: 9
MS Thesis Research

MECH.7510 Adv Projects In Mechanical Engineering (Formerly 22.751) - Credits: 1-3
MECH.7530 Doctoral Dissertation/Mechanical Engineering (Formerly 22.753) - Credits: 1-3
Doctoral Dissertation Research

MECH.7560 Doctoral Dissertation/Mechanical Engineering (Formerly 22.756) - Credits: 6
Doctoral Dissertation Research

MECH.7590 Doctoral Dissertation/Mechanical Engineering (Formerly 22.759) - Credits: 9
Masters and doctoral students who have attained the required number of thesis credits may enroll in:

MECH.7610 Continued Grad Research (Formerly 22.761) - Credits: 1
Continued Grad Research

MECH.7630 Continued Graduate Research (Formerly 22.763) - Credits: 3
Continuing Graduate Research

MECH.7660 Continued Graduate Research (Formerly 22.766) - Credits: 6
Continuing Graduate Research

MECH.7690 Continued Graduate Research (Formerly 22.769) - Credits: 9
Continuing Graduate Research

MECH.7710 Systems Analysis I (Formerly 22.771) -
Credits: 3

Study of the key areas in multiple engineering disciplines including Mechanical, Electrical, Software, Systems and Optical. Students are introduced to weekly topics and then work in multidiscipline teams to solve technical assignments. Topics covered include: Concept of Operations and Requirements development, integration, test and verification, vibration/shock analysis, thermal analysis, power supply design, digital electronics &FPGA, intro to optical engineering, SCRUM planning, continuous integration and UML/SW design. Content may vary year to year. This course is part of the Engineering Leadership Development Program (ELDP) and team taught by industry experts at BAE Systems.

MECH.7720 Systems Analysis II (Formerly 22.772) - Credits: 3

Introduction and analysis of complex systems aligned with the key product lines of BAE Systems. Students are introduced to multiple types of systems and then work in multidiscipline teams to solve technical assignments. The systems covered include but are limited to: Electronic Warfare (EW), Communications Electronic Attack (Comms EA), Wide Area Airborne Surveillance (WAAS), Signal Intelligence (SIGINT), RADAR Navigation, Radio Communications, and Infrared Countermeasures (IRCM). Content may vary year to year. This course is part of the Engineering Leadership Development Program (ELDP) and team taught by industry experts at BAE Systems.

MECH.7730 Systems Analysis III (Formerly 22.773) - Credits: 3

Study of project management concepts, product development methods, transition to operations and new business capture. Topics covered include but are not limited to risks and opportunities management, earned value management, lean product development, business strategy, design for manufacturability/maintainability (DFM^2), and request for information (RFI) response. Content may vary year to year. This course is part of the Engineering Leadership Development Program (ELDP) and team taught by industry experts at BAE Systems.

MECH.7CPT Curricular Practical Training for Engineering Doctoral Candidates - Credits: 1

Curricular Practical Training (CPT) is a training program for doctoral students in Engineering. Participation in CPT acknowledges that this an integral part of an established curriculum and directly related to the major area of study or thesis.
Master's Program - Thesis and Non-thesis Options

Master of Science in Engineering Degree Programs (M.S.E.)

In 2005, the Department of Plastics Engineering restructured its MSE Degree Program. Plastics Engineering MSE graduate students accepted into the program must follow either the "Thesis Option" Curriculum or the "Non-thesis Option" Curriculum described in the following sections. For the 30-credit hour thesis option, the student performs supervised research, prepare a written thesis manuscript, and defend the work during an oral presentation. The 33-credit hour non-thesis M.S.E. is designed for part-time graduate students working full time jobs as practicing engineers.

Note: Graduate students enrolled in the Thesis Option MSE Program prior to the Fall of 2005 may elect to follow either the new "thesis" or "non-thesis" program requirements described below, or those in effect at the time they were accepted into the degree program.

Note: Students in the Plastics Engineering B.S./M.S. program should see the requirements listed with the B.S. program.

Thesis Option

- Admission Requirements and Prerequisites
- Graduate Student Advising

Non-thesis Option

- Admission Requirements and Prerequisites
- Graduate Student Advising

Co-op Option in Engineering

The Department of Plastics Engineering participates in the Graduate Master’s Co-op Option in Engineering. For detailed information about the Co-op Program and curriculum requirements, please see the Graduate Catalog Engineering Co-op page (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf).

Thesis Option

Students who have enrolled in the thesis option Plastics Engineering M.S.E. program must complete at least 24 course credits and 6 thesis credits as outlined in the program requirements section below. Graduate students enrolled in the Thesis Option M.S.E. Program prior to the Fall of 2005 may elect to follow the either new program requirements (thesis or non-thesis program described below, or those in effect at the time they were accepted into the degree program.

Students may transfer as many as 12 science or engineering graduate course credits from other universities or from courses completed when in non-degree status at UMass Lowell provided they are approved by the Plastics Engineering Department’s M.S.E. program coordinators. (For University regulations regarding transfer credit (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf) and other regulations, see Graduate Policies (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf) in the on-line catalog.) The thesis option M.S.E. degree will be awarded upon the satisfactory completion of 30 credit hours of study as outlined below.

**Requirement 1** Complete the cluster of "core course" requirements(9 credit hours):

- **PLAS.5440** (https://www.uml.edu/catalog/courses/PLAS/5440)
  Advanced Plastics Materials (3 credits)
- **PLAS.5780** (https://www.uml.edu/catalog/courses/PLAS/5780)
  Advanced Plastics Processing (3 credits)
- **PLAS.5730** (https://www.uml.edu/catalog/courses/PLAS/5730)
  Graduate Polymer Laboratory (3 credit)

Special notes for students having a B.S. Plastics Engineering from UMass Lowell:

- Students who have a B or higher in Polymer Materials I (PLAS.2010) (https://www.uml.edu/catalog/courses/PLAS/2010) and Polymer Materials II (PLAS.2020) (https://www.uml.edu/catalog/courses/PLAS/2020) are not required to take Advanced Plastics Materials (PLAS.5440) (https://www.uml.edu/catalog/courses/PLAS/5440). These students, however, must still meet the 24 course credit hour program requirement by substituting other Plastics Engineering Graduate Courses
- Students who received a grade of B or higher in Plastics Process Engineering I (PLAS.3770) (https://www.uml.edu/catalog/courses/PLAS/3770)
(PLAS.5780 (https://www.uml.edu/catalog/courses/PLAS/5780)) are not required to take Advanced Plastic Materials (PLAS.5780 (https://www.uml.edu/catalog/courses/PLAS/5780))> These students, however, must still meet the 24-course credit hour program requirement by substituting other Plastics Engineering Graduate Courses.

Special notes for students who have a B.S. Degree in Plastics Engineering from UMass Lowell or equivalent program may elect to test out of Advanced Plastics Materials (PLAS.5440 (https://www.uml.edu/catalog/courses/PLAS/5440)) and Advanced Plastics Processing (PLAS.5780 (https://www.uml.edu/catalog/courses/PLAS/5780)). These students, however, must still meet the 24 course credit hour program requirement by substituting other Plastics Engineering Graduate Courses.

**Requirement 2** Complete the course requirements for one or more of the department's graduate "Certificates" as an "area of specialization." Some of the certificate course requirements may also be core requirements. The course requirements for each graduate certificate are also outlined below.

Note: The Graduate Certificate in Plastics Engineering Fundamentals does not satisfy Requirement 2 for the thesis option M.S.E. Plastics Engineering Program.

**(a.) Graduate Certificate in "Plastics Design"

**Required Courses:**

- **PLAS.5030** (https://www.uml.edu/catalog/courses/PLAS/5030) Mechanical Behavior of Polymers
- **PLAS.5180** (https://www.uml.edu/catalog/courses/PLAS/5180)

**Elective Courses (any two of the following):**

- **PLAS.5060** (https://www.uml.edu/catalog/courses/PLAS/5060) Polymer Structure, Properties, and Applications
- **PLAS.5230** (https://www.uml.edu/catalog/courses/PLAS/5230) Screw Design Principles
- **PLAS.5410** (https://www.uml.edu/catalog/courses/PLAS/5410) Computer Applications in Plastics
- **PLAS.5490** (https://www.uml.edu/catalog/courses/PLAS/5490) Design with Elastomers
- **PLAS.5510** (https://www.uml.edu/catalog/courses/PLAS/5510) Computer Aided Extrusion Die Design
- **PLAS.5530** (https://www.uml.edu/catalog/courses/PLAS/5530) Design of Polymer Processing Machinery
- **PLAS.5540** (https://www.uml.edu/catalog/courses/PLAS/5540) Medical Device Design I
- **PLAS.5550** (https://www.uml.edu/catalog/courses/PLAS/5550) Medical Device Design II
- **PLAS.5760** (https://www.uml.edu/catalog/courses/PLAS/5760) Advanced Mold Design
- **PLAS.5850** (https://www.uml.edu/catalog/courses/PLAS/5850) Computer Aided Engineering and Design I
- **PLAS.5990** (https://www.uml.edu/catalog/courses/PLAS/5990) Rapid Prototyping
- **PLAS.6020** (https://www.uml.edu/catalog/courses/PLAS/6020) Medical Device Development Regulation
(b.) Graduate Certificate in "Plastics Materials"

Required Courses:

- PLAS.5440
  Advanced Plastics Materials
- PLAS.5060
  Polymer Structure, Properties, and Applications

Elective Courses (any two of the following):

- PLAS.5050
  Polymer Structure II
- PLAS.5110
  Polymer Blends and Multiphase Systems
- PLAS.5120
  Porous Polymers
- PLAS.5130
  New Plastics Materials
- PLAS.5250
  Synthetic Fibers: Processing, Structure, and Properties
- PLAS.5320
  Adhesives and Adhesion
- PLAS.5330
  Coatings Science and Technology
- PLAS.5350
  Rubber Technology
- PLAS.5400
  Commercial Development of Polymeric Systems
- PLAS.5420
  Colloidal Nanoscience and Nanoscale Engineering
- PLAS.5470
  Materials for Renewable Energy and Sustainability
- PLAS.5590
  Elements of Packaging
- PLAS.5650
  Engineering Thermosetting Resins
- PLAS.5660
  Polymeric Material Systems Selection
- PLAS.5800
  Polymer Science I
- PLAS.5890
  Polymer Nanocomposites
- PLAS.5960
  Plastics, Elastomers and Additives from Renewable Resources
- PLAS.5970
  Plastics and the Environment
- PLAS.6820
  Physical Polymer Science

(c.) Graduate Certificate in "Plastics Processing"

Required Courses:

- PLAS.5180
  Plastics Product Design
- PLAS.5780
  Advanced Plastics Process Engineering
Elective Courses (any two of the following):

- PLAS.5060 (https://www.uml.edu/catalog/courses/PLAS/5060)
  Polymer Structure, Properties, and Applications
- PLAS.5090 (https://www.uml.edu/catalog/courses/PLAS/5090)
  Plastics Product Design
- PLAS.5100 (https://www.uml.edu/catalog/courses/PLAS/5100)
  Lean Plastics Manufacturing
- PLAS.5230 (https://www.uml.edu/catalog/courses/PLAS/5230)
  Screw Design Principles
- PLAS.5240 (https://www.uml.edu/catalog/courses/PLAS/5240)
  Process Analysis, Instrumentation, and Control
- PLAS.5250 (https://www.uml.edu/catalog/courses/PLAS/5250)
  Synthetic Fibers: Processing, Structure, and Properties
- PLAS.5260 (https://www.uml.edu/catalog/courses/PLAS/5260)
  Nanoscale Plastics Processing
- PLAS.5500 (https://www.uml.edu/catalog/courses/PLAS/5500)
  Processing with Elastomers
- PLAS.5510 (https://www.uml.edu/catalog/courses/PLAS/5510)
  Computer Aided Extrusion Die Design
- PLAS.5520 (https://www.uml.edu/catalog/courses/PLAS/5520)
  Design of Polymer Processing Machinery
- PLAS.5850 (https://www.uml.edu/catalog/courses/PLAS/5850)
  Computer Aided Engineering and Design I
- PLAS.5880 (https://www.uml.edu/catalog/courses/PLAS/5880)
  Injection Molding
- PLAS.6780 (https://www.uml.edu/catalog/courses/PLAS/6780)
  New Developments in Polymer Manufacturing

(d.) Graduate Certificate in "Medical Plastics Design and Manufacturing"

Required Courses:

- PLAS.5530 (https://www.uml.edu/catalog/courses/PLAS/5530)
  Medical Device Design I
- PLAS.5750 (https://www.uml.edu/catalog/courses/PLAS/5750)
  Biomaterials

Elective Courses (any two of the following):

- PLAS.5540 (https://www.uml.edu/catalog/courses/PLAS/5540)
  Medical Device Design II
- PLAS.5790 (https://www.uml.edu/catalog/courses/PLAS/5790)
  Problems in Biomaterials - (directed study)
- PLAS.6020 (https://www.uml.edu/catalog/courses/PLAS/6020)
  Medical Device Development Regulation
- PLAS.6750 (https://www.uml.edu/catalog/courses/PLAS/6750)
  Biomaterials II
- CHEN.5550 (https://www.uml.edu/catalog/courses/CHEN/5550)
  Biopharmaceutical GMP and Licensing *
  * (offered by the Chemical Engineering Department)
- BMBT.5000 (https://www.uml.edu/catalog/courses/BMBT/5000)
  Introduction to Biomedical Engineering & Biotechnology **
  ** (offered by the Biomedical Engineering program)
- PLAS.5030 (https://www.uml.edu/catalog/courses/PLAS/5030)
  Mechanical Behavior of Polymers
- PLAS.5180 (https://www.uml.edu/catalog/courses/PLAS/5180)
Plastics Product Design

(e.) Graduate Certificate in "Elastomeric Materials"

**Required Courses:**

- PLAS.5350
  [https://www.uml.edu/catalog/courses/PLAS/5350](https://www.uml.edu/catalog/courses/PLAS/5350)
  Rubber Technology
- PLAS.5950
  [https://www.uml.edu/catalog/courses/PLAS/5950](https://www.uml.edu/catalog/courses/PLAS/5950)
  Thermoplastic Elastomers

**Elective Courses (any two of the following):**

- PLAS.5490
  [https://www.uml.edu/catalog/courses/PLAS/5490](https://www.uml.edu/catalog/courses/PLAS/5490)
  Design with Elastomers
- PLAS.5500
  [https://www.uml.edu/catalog/courses/PLAS/5500](https://www.uml.edu/catalog/courses/PLAS/5500)
  Processing with Elastomers
- PLAS.5060
  [https://www.uml.edu/catalog/courses/PLAS/5060](https://www.uml.edu/catalog/courses/PLAS/5060)
  Polymer Structure, Properties, and Applications
- PLAS.5960
  [https://www.uml.edu/catalog/courses/PLAS/5960](https://www.uml.edu/catalog/courses/PLAS/5960)
  Plastics, Elastomers and Additives from Renewable Resources

**Requirement 3** Complete the requirements for an additional number of elective Plastics Engineering graduate courses such that the "total" course credit hours is at least 24 credit hours (not counting thesis credits).

Core Courses + Non-Core Certificate Courses + Electives Courses = 24 Credits.

Up to two elective courses from other engineering departments may be substituted for Plastics Engineering courses if approved by the graduate coordinator.

**Requirement 4** Complete the mandatory six-credit-hour thesis requirement. The thesis research is conducted under the supervision of a three member advisory committee (see "Thesis Committee" below). Upon completion of the thesis research work, the student must prepare the written thesis manuscript and defend the work in an oral presentation such that all three committee members approve the work.

**Thesis Committee**

As soon as a student has chosen an area of research, a Thesis Committee is selected by the student and his or her research advisor in accordance with the policy of the department. The Thesis Committee shall consist of at least three members, at least two of whom shall be from the student's major department. One member of the committee shall be the student's thesis advisor. An outside expert, such as the supervisor of a research project conducted at an industrial setting or a faculty member from another institution, may be a member of the committee, but that individual must possess academic credentials which would qualify him or her to serve as a member of the University of Massachusetts Lowell faculty.

The M.S.E. degree, and the appropriate Graduate Certificate (the area of specialization), will be awarded upon satisfactory completion of 30 credit hours of study as outlined. More detailed descriptions of the "Thesis Option" requirements are given below.

**Admission Requirements and Prerequisites:**

Admission to the program is open to candidates with a B.S. in Plastics Engineering or a related engineering or science field. The pre-requisite math requirements include Calculus II and Differential Equations. Applicants must also take the Graduate Record Examination (GRE), provide three Letters of Reference, an Official Transcript, and a Statement of Purpose as per the UMass Lowell Graduate Admissions Policy. You can apply online at [www.uml.edu/grad](https://www.uml.edu/Grad/default.aspx)

Non-matriculated students (with an appropriate B.S. Degree) may begin taking courses without application to the M.S.E. Plastics Engineering Program. It is recommended, however, that students apply to the M.S.E. Program as soon as possible (i.e. prior to taking too many course credits) since there is no guarantee of acceptance into the M.S.E. Program. In addition, no more than 12 credit hours taken as a non-matriculated student can be transferred into the M.S.E. Program upon acceptance.

Students may transfer as many as 12 science or engineering graduate course credits from other universities provided they are approved by the Plastics Engineering Department's M.S.E. program coordinator. (For University regulations regarding transfer credit [https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf](https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf) and other regulations, see the Graduate Policies [https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf](https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf) in the on-line catalog.)

**Graduate Student Advising:**

One of the graduate coordinators will be the academic advisor for students enrolled in the non-thesis M.S.E. Plastics Engineering Degree Program. The advisor will help the student remedy deficiencies in prerequisites, select electives of most value, and plan the overall study program efficiently. The thesis
advisor will be the chairperson of the thesis advisory committee that will guide the student in the thesis research and supervise the completion of the thesis requirement. Once an advisor is selected, the student and advisor should complete the Departmental Advising Form, indicating the thesis topic. Both the student and advisor must sign this form before the student can register for thesis credits. This form is available in the Plastics Engineering Department Office (B204) and should be submitted to the graduate program coordinator.

Non-thesis Option

Students enrolled in the non-thesis M.S. Plastics Engineering option must complete a total of 33 course credits as outlined in the course requirements section below.

Requirement 1 Complete the "core course" requirements (18 credits)

- PLAS.5030 [https://www.uml.edu/catalog/courses/PLAS/5030] - Mechanical Behavior of Polymers (3 credits)
- PLAS.5440 [https://www.uml.edu/catalog/courses/PLAS/5440] - Advanced Plastics Materials (3 credits)
- PLAS.5780 [https://www.uml.edu/catalog/courses/PLAS/5780] - Advanced Plastics Processing (3 credits)
- PLAS.5060 [https://www.uml.edu/catalog/courses/PLAS/5060] - Polymer Structure Properties and Applications (3 credits)
- PLAS.5180 [https://www.uml.edu/catalog/courses/PLAS/5180] - Plastics Product Design (3 credits)
- PLAS.5730 [https://stage.uml.edu/catalog/courses/PLAS/5720] Graduate Polymer Laboratory (3 credits)

Special notes for students having a Plastics Engineering B.S. Degree:

Students who have a B.S. Degree in Plastics Engineering from UMass Lowell or an equivalent program may elect to test out of Advanced Plastics Materials (PLAS.5440 [https://www.uml.edu/catalog/courses/PLAS/5440]) and Advanced Plastics Processing (PLAS.5780 [https://www.uml.edu/catalog/courses/PLAS/5780]). However, these students must still meet the 33 credit hour program requirement by substituting other Plastics Engineering Graduate Courses.

Requirement 2: Complete the course requirements for one or more of the department's graduate "Certificates".

- Plastics Design
- Plastics Materials
- Plastics Processing
- Medical Plastics Design and Manufacturing.

Some of the certificate course requirements may also be core requirements. The course requirements for each graduate certificate are also outlined below.

Note: The Graduate Certificate in "Plastics Engineering Fundamentals" does not satisfy Requirement 2 for the thesis option M.S.E. Plastics Engineering Program.

Requirement 3 Complete the requirements for an additional number of elective plastics graduate courses such that the "total" credit hours (core courses + certificate + electives) is 33 credits. Up to two elective courses from other engineering departments may be substituted if approved by the graduate coordinator.

The M.S.E. degree, and the appropriate Graduate Certificate (the area of specialization), will be awarded upon satisfactory completion of 33 credit hours of study as specified above. This non-thesis M.S.E. degree is an alternative to the more traditional 30 credit thesis option M.S.E degree.

Admission Requirements and Prerequisites:

Admission to the program is open to candidates with a B.S. in Plastics Engineering or a related engineering or science field. The pre-requisite math requirements include Calculus II and Differential Equations. Applicants must also take the Graduate Record Examination (GRE), provide three letters of reference, an official transcript, and a Statement of Purpose as per the UMass Lowell Graduate Admissions Policy. The GRE Requirement is waived for any student who has completed any one of the Plastics Engineering Graduate Certificates and have maintained a 3.5 GPA for this Certificate. You can apply online at www.uml.edu/grad. [https://www.uml.edu/Grad/default.aspx]

The foundation "Plastics" courses required in previous years are no longer required. Students who have taken these foundation graduate courses in the past can receive some graduate course credit for these courses as outlined above.

The Plastics Engineering Department makes every attempt to offer as many of these courses as possible during the evening so that students having full time jobs can complete the degree program. Return to the home page for a listing of evening graduate courses for the next few semesters.

Non-matriculated students (with an appropriate B.S. Degree) may begin taking courses without application to the M.S.E.
Plastics Engineering Program. However, it is recommended that students apply to the M.S.E. Program as soon as possible (i.e. prior to taking too many course credits) since there is no guarantee of acceptance into the M.S.E. Program. In addition, no more than 12 credit hours taken as a non-matriculated student can be transferred into the M.S.E. Program upon acceptance.

Graduate Student Advising:

The M.S.E. Coordinator will be the academic advisor for students enrolled in the non-thesis M.S.E. Plastics Engineering Degree Program. The coordinator will help the student remedy deficiencies in prerequisites, select electives of most value, and plan the overall study program efficiently.

Full Time vs. Part Time Status

Both the Thesis and Non-thesis Option M.S.E. Plastics Engineering Programs are open to full-time and part-time students. Many of the courses required for these programs are offered at night so that engineers working at local companies can take advantage of the programs. Students taking fewer than nine credits in a semester are considered part time, while those taking nine or more credits are considered full time students. Graduate students must maintain full-time student status in order to be eligible for research assistant positions (R.A.).

Funding Policy - Plastics Engineering Graduate Students

Research Assistant Positions (R.A.) positions, either "full time" or "half time", are awarded by individual faculty who conduct funded research. Accepted students must correspond with the individual faculty to inquire about R.A. positions. Faculty research interests are listed in the Faculty section of the department web site. It is recommended that applicants interested in obtaining R.A. funding should send a letter and resume to those faculty having similar research interests.

Doctoral Program

Doctoral Program in Plastics Engineering

The UMass Lowell Department of Plastics Engineering offers a Doctor of Philosophy (Ph.D.), Plastics Engineering Option.

In addition the Plastics Engineering Department has a joint program with the Chemistry Department. It offers a joint Polymer Science/Plastics Engineering Ph.D. degree. The degree is awarded by the Chemistry Department, not the Department of Plastics Engineering. This degree option is a good fit for students interested in polymer synthesis and polymer characterization.

Ph.D. in Engineering, Plastics Engineering Option

The Ph.D. degree program is designed to produce qualified professionals for technical and research positions in the plastics industry, for technical positions in government, and for teaching careers in colleges and universities. This degree is awarded by the College of Engineering. The goal of the Ph.D. program is to develop decision-making engineers with sound theoretical and technical research knowledge in the areas of plastics materials, design, and processing research and development.

Admission Requirements

Graduates with a B.S. in Engineering (e.g. Plastics, Mechanical, Chemical, Materials,...) and high academic standing may apply for admission to the Ph.D. Technical graduates who do not have a B.S. in "Engineering" but have a science degree may request admission to the program with the understanding that they will also be required to take and pass the "Fundamentals of Engineering Exam" given by the National Council of Examiners for Engineering and Surveying. Admission to the program will be based on review by the Graduate Admissions Office and by the Admissions Committee of the Plastics Engineering Department.

Plan of the Doctoral Program

Each student entering the program must develop a plan of study in consultation with his or her advisory committee. After taking at least one year of graduate courses, the student will take a qualifying examination covering all the basic elements of plastics engineering. A student who performs well on this examination will be reviewed by the Admissions Committee of the Plastics Engineering Department and admitted to degree candidacy. He or she will then complete the remaining course work, seminars and labs, do a research proposal, conduct research and prepare a written dissertation, and present an oral defense of the research before the dissertation committee.

Qualifying Examination

The qualifying examination will be administered in September (and in January if there is sufficient demand for a second exam). It will be administered as two (2) four hour long examinations, covering the following topics: plastics processing, plastics design, plastics properties, and plastics materials with a total of four questions in each subject area for a total of 16 questions. One of the two exams is open book and one is closed book. In order to pass the exams, students must pass at least two of the four questions in each subject area, and pass at least eleven questions. Any changes to the format will be indicated by the doctoral coordinator when the specific examination date is announced. The student will receive an overall exam grade of pass or fail based on the stated criteria. A student who fails the exam on a marginal basis may make a second attempt the next time the exam is administered. All decisions of the Plastics Engineering Department regarding passing of the qualifying exam are final.

Dissertation Proposal
Once the student has passed the qualifying exam, he or she will submit a dissertation proposal and defend the proposal before the Doctoral Committee. Upon approval, the student’s name will be submitted to the College Doctoral Committee and the Registrar’s Office as a candidate for the Doctor of Engineering or the Doctor of Philosophy degree.

**Transfer Credit**

Up to 24 credits in graduate engineering courses are transferable to either the Doctor of Philosophy programs upon approval by the department’s Doctoral Committee.

**Course Requirements for the Ph.D. in Engineering, Plastics Engineering Option**

(A) Students with a B.S. Plastics Engineering, Plastics Engineering degree from UMass Lowell will be required to take a placement test on the following subjects:

- **PLAS.5440**
  (https://www.uml.edu/catalog/courses/PLAS/5440) Advanced Plastics Materials
- **PLAS.5780**
  (https://www.uml.edu/catalog/courses/PLAS/5780) Advanced Plastics Processing

If they failed in the test or do not take the test, they will be required to take these courses and can be counted as electives. Student whose UMass Lowell undergraduate GPA is higher than 3.0 can waive the above two courses.

In addition the following courses are required for the Ph.D. degree:

- **PLAS.6420**
  (https://www.uml.edu/catalog/courses/PLAS/6420) Characterization of polymers and plastics (3 credits)
- **PLAS.6820**
  (https://www.uml.edu/catalog/courses/PLAS/6820) Physical Polymer Science (3 credits)
- **PLAS.6780**
  (https://www.uml.edu/catalog/courses/PLAS/6780) New Development in Polymer Manufacturing (3 credits)
- **PLAS.6180**
  (https://www.uml.edu/catalog/courses/PLAS/6180) Structure Product Design (3 credits)
- **PLAS.5090**
  (https://www.uml.edu/catalog/courses/PLAS/5090) Plastics Processing Theory I (3 credits)
- **PLAS.5480**
  (https://www.uml.edu/catalog/courses/PLAS/5480) Numerical and Analytical Methods (3 credits)
- **PLAS.5850**
  (https://www.uml.edu/catalog/courses/PLAS/5850)/PLAS.5760
  (https://www.uml.edu/catalog/courses/PLAS/5760) Computer Aided Engineering and Design (3 credits)
- **PLAS.5730**
  (https://stage.uml.edu/catalog/courses/PLAS/5720) Graduate Polymer Laboratory (3 credit)
- **PLAS.XXXX**
  (https://www.uml.edu/catalog/courses/PLAS) Engineering Elective (8 - 20 credits)
- Doctoral Research Dissertation (21 - 33 credits)

**TOTAL:** 63 credits

(B) The following courses are required for a Ph.D. degree for students with a M.S. Plastics Engineering Degree from UMass Lowell:

- **PLAS.6420**
  (https://www.uml.edu/catalog/courses/PLAS/6420) Characterization of polymers and plastics (3 credits)
- **PLAS.6820**
  (https://www.uml.edu/catalog/courses/PLAS/6820) Physical Polymer Science (3 credits)
- **PLAS.6780**
  (https://www.uml.edu/catalog/courses/PLAS/6780) New Development in Polymer Manufacturing (3 credits)
- **PLAS.6180**
  (https://www.uml.edu/catalog/courses/PLAS/6180) Structure Product Design (3 credits)
- **PLAS.5090**
  (https://www.uml.edu/catalog/courses/PLAS/5090) Plastics Processing Theory I (3 credits)
- **PLAS.5180**
  (https://www.uml.edu/catalog/courses/PLAS/5180) Plastics Product Design (3 credits)
• PLAS.5480
  (https://www.uml.edu/catalog/courses/PLAS/5480)
  Numerical and Analytical Methods (3 credits)
• PLAS.5850
  (https://www.uml.edu/catalog/courses/PLAS/5850)/PLAS.5760
  (https://www.uml.edu/catalog/courses/PLAS/5760)
  Computer Aided Engineering or Advanced Mold Design (3 credits)
• PLAS.xxxx
  (https://www.uml.edu/catalog/courses/PLAS)
  Engineering Elective and transfer credits from M.S. program (9 - 21 credits)
• Doctoral Research Dissertation (21 - 33 credits)

TOTAL: 63 Credits

(C) Students with B.S. degree in engineering or other disciplines from UML or other schools will be required to take a placement test on the following subjects:

• PLAS.5030
  (https://www.uml.edu/catalog/courses/PLAS/5030)
  Mechanical Behavior of Polymers
• PLAS.5060
  (https://www.uml.edu/catalog/courses/PLAS/5060)
  Polymer Structure, Properties and Applications
• PLAS.5180
  (https://www.uml.edu/catalog/courses/PLAS/5180)
  Plastics Product Design
• PLAS.5780
  (https://www.uml.edu/catalog/courses/PLAS/5780)
  Advanced Plastics Processing
• PLAS.5440
  (https://www.uml.edu/catalog/courses/PLAS/5440)
  Advanced Plastics Materials

If the failed in the test or do not take the test, they will be required to take these courses and can be counted as electives.

In addition, the following courses are required for the Ph.D. degree:

• PLAS.6420
  (https://www.uml.edu/catalog/courses/PLAS/6420)
  Characterization of polymers and plastics (3 credits)
• PLAS.6820
  (https://www.uml.edu/catalog/courses/PLAS/6820)
  Physical Polymer Science (3 credits)
• PLAS.6780
  (https://www.uml.edu/catalog/courses/PLAS/6780) New Development in Polymer Manufacturing (3 credits)
• PLAS.6180
  (https://www.uml.edu/catalog/courses/PLAS/6180)
  Structure Product Design (3 credits)
• PLAS.5090
  (https://www.uml.edu/catalog/courses/PLAS/5090)
  Plastics Processing Theory I (3 credits)
• PLAS.5480
  (https://www.uml.edu/catalog/courses/PLAS/5480)
  Numerical and Analytical Methods (3 credits)
• PLAS.5850
  (https://www.uml.edu/catalog/courses/PLAS/5850)/PLAS.5760
  (https://www.uml.edu/catalog/courses/PLAS/5760)
  Computer Aided Engineering or Advanced Mold Design (3 credits)
• PLAS.5730
  (https://stage.uml.edu/catalog/courses/PLAS/5720) Graduate Polymer Laboratory (3 credit)
• PLAS.xxxx
  (https://www.uml.edu/catalog/courses/PLAS)
  Engineering Elective (9 - 18 credits)
• Doctoral Research Dissertation (21 - 33 credits)

TOTAL: 63 credits

Ph.D. Polymer Science/Plastics Engineering Option

A doctoral program in Chemistry with an option in Polymer Science/Plastics Engineering is offered jointly with the Polymer Science group in the Department of Chemistry. This program is designed to provide the student with a background in advanced course work and laboratory techniques which will prepare him or her to carry out, under the guidance of experienced scientists, an original, independent investigation leading to an acceptable contribution to the body of contemporary
knowledge. Further details of the program are described in the Chemistry (https://www.uml.edu/resources/catalog-archive/current/Graduate.pdf) section of this catalog.

Certificate Programs

Graduate Certificates in Plastics Engineering

The UMass Lowell Department of Plastics Engineering offers eight graduate certificates in a wide variety of topics.

- Plastics Engineering Fundamentals
- Medical Plastics Design and Manufacturing
- Plastics Design
- Plastics Materials
- Plastics Processing

About Graduate Certificates

All Plastics Engineering graduate certificates are comprised of four courses (12 graduate credits) designed to provide specific knowledge and expertise vital to today’s changing and complex needs in the workplace. In all cases courses may be applied toward a degree program provided they meet transfer credit requirements.

Note: Courses used as credit towards one Plastics Engineering Certificate may not count towards another Plastics Engineering Certificate.

Requirements to Complete a Graduate Certificate

The four courses must be completed within a five year period with a minimum 3.0 grade point average, and with no more than 3 credits below a B. Courses completed for one certificate may not be used for another certificate, but can be used for the graduate degrees.

Certificate Application Process

Individuals must complete a simplified application, provide an official undergraduate transcript indicating that a baccalaureate degree has been awarded. Admission to the program is open to candidates with a B.S. in engineering or a related field. There is $75 application fee and the graduate record exam (GRE) is not required for admission.

For more information visit the Plastics Engineering Department website (https://www.uml.edu/Engineering/Plastics/default.aspx).

Plastics Engineering Fundamentals

Contact:

Amy Peterson, Ph.D.

Email: Amy_Peterson@uml.edu

Phone: 978-934-2937

This 12-credit certificate program is designed for students who have attained a baccalaureate degree and want more plastics materials, process, and design background. To enable students with full-time jobs to complete the certificate program, these courses are offered during the evening or on-line(*).

Required Courses (six credits)

- PLAS.5440
  (https://www.uml.edu/catalog/courses/PLAS/5440)
  Advanced Plastics Materials
- PLAS.5780
  (https://www.uml.edu/catalog/courses/PLAS/5780)
  Advanced Plastics Processing

Elective Courses (choose two - total of six credits):

- PLAS.5030
  (https://www.uml.edu/catalog/courses/PLAS/5030)
  Mechanical behavior of Polymers*
- PLAS.5060
  (https://www.uml.edu/catalog/courses/PLAS/5060)
  Polymer Structure, Properties, and Applications*
- PLAS.5180
  (https://www.uml.edu/catalog/courses/PLAS/5180)
  Product Design*
- PLAS.5760
  (https://www.uml.edu/catalog/courses/PLAS/5760)
  Advanced Mold Design*

Medical Plastics Design and Manufacturing

Contact:

Amy Peterson, Ph.D.
The use of plastics in medical products and medical devices is rapidly increasing. The Plastics Engineering Department at UMass Lowell is continuing its leadership role in Plastics Engineering Education by responding to industry’s need for Medical Plastics training. This 12 credit program will provide knowledge needed for the development of new "engineering intensive" medical products which combine complex material compositions, designs, and manufacturing processes. The certificate program is intended for medical professionals, engineers and technologists working in the medical products industry.

**Required Courses** (six credits):

- PLAS.5530  
  (https://www.uml.edu/catalog/courses/PLAS/5530)  
  Medical Device Design I
- PLAS.5750  
  (https://www.uml.edu/catalog/courses/PLAS/5750)  
  Biomaterials

**Elective Courses** (choose two - total of six credits):

- PLAS.5540  
  (https://www.uml.edu/catalog/courses/PLAS/5540)  
  Medical Device Design II
- PLAS.5790  
  (https://www.uml.edu/catalog/courses/PLAS/5790)  
  Problems in Biomaterials (Directed Study)
- PLAS.6750  
  (https://www.uml.edu/catalog/courses/PLAS/6750)  
  Biomaterials II
- CHEN.5550  
  (https://www.uml.edu/catalog/courses/CHEN/5550)  
  Biopharmaceutical GMP and Licensing (offered by the Chemical Engineering Department)
- BMBT.5000  
  (https://www.uml.edu/catalog/courses/BMBT/5000)  
  Introduction to Biomedical Engineering & Biotechnology (Offered by the Biomedical Engineering program)

**Contact:**

Amy Peterson, Ph.D.

Email:

Amy_Peterson@uml.edu  
(mailto:Amy_Peterson@uml.edu)

Phone: 978-934-2937

The certificate program is designed for students who have attained a bachelors degree and need more plastics design background.

**Required Courses** (six credits):

- PLAS.5030  
  (https://www.uml.edu/catalog/courses/PLAS/5030)  
  Mechanical Behavior of Polymers
- PLAS.5180  
  (https://www.uml.edu/catalog/courses/PLAS/5180)  
  Plastics Product Design
- PLAS.5020  
  (https://www.uml.edu/catalog/courses/PLAS/5020)  
  Medical Device Development and Regulation

**Elective Courses** (choose two - total of six credits):

- PLAS.5060  
  (https://www.uml.edu/catalog/courses/PLAS/5060)  
  Polymer Structure, Properties, and Applications
Plastics Materials

Contact:

Amy Peterson, Ph.D.

Email:

Amy_Peterson@uml.edu

Phone: 978-934-2937

This 12 credit certificate program is designed for students who have attained a Bachelor’s degree and need more plastics materials background.

**Required Courses** (six credits):

- PLAS.5440 (Advanced Plastics Materials)
- PLAS.5060 (Polymer Structure, Properties, and Applications)

**Elective Courses** (choose two - total of six credits):

- PLAS.5050 (Polymer Structure, Properties, and Applications II)
- PLAS.5110 (Polymer Blends and Multiphase Systems)
- PLAS.5120 (Foams)
- PLAS.5130 (New Plastics Materials)
- PLAS.5250 (Synthetic Fibers: Processing, Structure, and Properties)
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- **PLAS.5320** (https://www.uml.edu/catalog/courses/PLAS/5320)
  Adhesives and Adhesion
- **PLAS.5330** (https://www.uml.edu/catalog/courses/PLAS/5330)
  Green Coatings Science and Technology I
- **PLAS.5400** (https://www.uml.edu/catalog/courses/PLAS/5400)
  Commercial Development of Polymeric Systems
- **PLAS.5350** (https://www.uml.edu/catalog/courses/PLAS/5350)
  Rubber Technology
- **PLAS.5420** (https://www.uml.edu/catalog/courses/PLAS/5420)
  Colloidal Nanoscience and Nanoscale Engineering
- **PLAS.5470** (https://www.uml.edu/catalog/courses/PLAS/5470)
  Materials for Renewable Energy and Sustainability
- **PLAS.5650** (https://www.uml.edu/catalog/courses/PLAS/5650)
  Thermostets
- **PLAS.5660** (https://www.uml.edu/catalog/courses/PLAS/5660)
  Polymeric Material Systems Selection
- **PLAS.5890** (https://www.uml.edu/catalog/courses/PLAS/5890)
  Polymer Nanocomposites
- **PLAS.5960** (https://www.uml.edu/catalog/courses/PLAS/5960)
  Plastics, Elastomers and Additives from Renewable Resources
- **PLAS.5970** (https://www.uml.edu/catalog/courses/PLAS/5970)
  Plastics and the Environment
- **PLAS.6820** (https://www.uml.edu/catalog/courses/PLAS/6820)
  Physical Polymer Science

**Plastics Processing**

**Contact:**

Amy Peterson, Ph.D.

**Email:**

Amy_Peterson@uml.edu

**Phone:** 978-934-2937

This 12-credit certificate program is designed for students who have attained a bachelor's degree and need more plastics processing background.

**Required Courses** (six credits):  

- **PLAS.5180** (https://www.uml.edu/catalog/courses/PLAS/5180)
  Plastics Product Design*
- **PLAS.5780** (https://www.uml.edu/catalog/courses/PLAS/5780)
  Advanced Plastics Process Engineering*

**Elective Courses** (choose two - total of six credits):  

- **PLAS.5060** (https://www.uml.edu/catalog/courses/PLAS/5060)
  Polymer Structure, Properties, and Applications
- **PLAS.5090** (https://www.uml.edu/catalog/courses/PLAS/5090)
  Plastics Processing Theory
- **PLAS.5150** (https://www.uml.edu/catalog/courses/PLAS/5150)
  Lean Plastics Manufacturing
- **PLAS.5230** (https://www.uml.edu/catalog/courses/PLAS/5230)
  Screw Design Principles
- **PLAS.5250** (https://www.uml.edu/catalog/courses/PLAS/5250)
  Synthetic Fibers: Processing, Structure, and Properties
- **PLAS.5260** (https://www.uml.edu/catalog/courses/PLAS/5260)
Nanoscale Plastics Processing

- **PLAS.5500**
  (https://www.uml.edu/catalog/courses/PLAS/5500)
  Processing with Elastomers

- **PLAS.5510**
  (https://www.uml.edu/catalog/courses/PLAS/5510)
  Computer Aided Extrusion Die Design

- **PLAS.5520**
  (https://www.uml.edu/catalog/courses/PLAS/5520)
  Machine Design

- **PLAS.5850**
  (https://www.uml.edu/catalog/courses/PLAS/5850)
  Computer Aided Engineering and Design I

- **PLAS.5880**
  (https://www.uml.edu/catalog/courses/PLAS/5880)
  Injection Molding

- **PLAS.6780**
  (https://www.uml.edu/catalog/courses/PLAS/6780)
  New Developments in Polymer Manufacturing.
PLAS.5000 Advanced Project In Plastics I (Formerly 26.500) - Credits: 0-1
A laboratory course for advanced projects in the areas of plastics materials, design, processing, elastomers, coatings, adhesives, or medical plastics.

PLAS.5010 Advanced Project In Plastics II (Formerly 26.501) - Credits: 3
Continuation of 26.500.

PLAS.5020 Medical Device Development Regulation (Formerly 26.602 and PLAS.6020) - Credits: 3
Comprehensive and in-depth analysis of US medical device diagnostics development and approval requirements. Detailed analysis of quality assurance issues and regulatory reforms implemented under the Food and Drug Administration. Provides a step-by-step guide through the Center for Devices and Radiological Health (CDRH) investigational device exemptions, premarket approval, 510 (k) application process, and product development protocol and review processes.

PLAS.5060 Polymer Structure Properties & Applications (Formerly 26.506) - Credits: 3
Relationships between polymer structure (chemical composition, molecular weight and flexibility, intermolecular order and bonding, supramolecular structure) and practical properties (processability, mechanical, acoustic, thermal, electrical, optical, and chemical) and applications.

PLAS.5090 Plastics Processing Theory I (Formerly 26.509) - Credits: 3
Principles of Rheology and continuum mechanics involved in the processing of plastics, and their applications in plastics process engineering including flows in standard geometries and extrusion applications.

PLAS.5110 Polymer Blends (Formerly 26.511) - Credits: 3
Physical, mechanical, and thermal properties, preparation, and testing of polymer blends, alloys, and multiphase systems. Thermodynamic theories and experimental determination of miscibility of polymer blends. Structure property relationships for multiphase systems and interpenetrating networks.

PLAS.5120 Foams (Formerly 26.512) - Credits: 3
This course covers the fundamentals of polymer foaming, processing methods, recent technologies, foam characteristics, and applications. Fundamentals cover the cell nucleation and growth mechanisms in foaming and the role of thermodynamics and kinetics. Batch foaming, extrusion foaming, foam injection molding, and bead foaming are discussed as the common processing methods. The characteristics and performance of polymeric foams, process-structure-property relationships, and the relevant applications in various industries also are presented.

PLAS.5130 New Plastics Materials (Formerly 26.513) - Credits: 3
Critical examination of the new plastics appearing in the research literature and being field-tested for commercialization in the plastics industry.

PLAS.5140 Statistics for Six Sigma (Formerly 26.514) - Credits: 3
A review of statistical techniques for Six Sigma with Applications specifically designed for the plastics processing industry. Those completing the course should be at the Six Sigma green belt level or better.

PLAS.5150 Lean Plastics Manufacturing (Formerly 26.515) - Credits: 3
Methods of analysis and operation of plastics manufacturing facilities. Topics include: performance measurement, inventory control, forecasting, production planning, scheduling, resource management, supply chains, various technologies for improved productivity.

PLAS.5180 Plastics Product Design (Formerly 26.518) - Credits: 3
This course reviews the theoretical principles and the engineering practice associated with the development of new plastic products. The course focuses on design practices for products that will be produced by conventional and advanced injection molding processes. Topics include design methodology, plastic materials selection, design for manufacturing, computer aided engineering, mechanical behavior of plastics, structural design of plastic parts, prototyping techniques, experimental stress analysis, and assembly techniques for plastic parts.

PLAS.5230 Screw Design Principles (Last Term 2007 Spring)(Formerly 26.523) - Credits: 3
Energy balances, energy efficiency for extrusion and injection molding, application of energy equation (conduction, convection, viscous dissipation), equations of state, melt
conveying in simple and compound screws, screw scale up, plastication.

**PLAS.5240 Process Analysis Instrument and Control**  
(Formerly 26.524) - Credits: 3


**PLAS.5250 Synthetic Fibers: Processing-Structure-Properties**  
(Formerly 26.525) - Credits: 3

An introduction to processing-structure-properties of fibers and its significance to modern advanced materials. This course covers both traditional and emerging fiber spinning methods (ex. solution spinning, melt extrusion, gel-spinning, and electrospinning), post-processing techniques (ex. yarns, weaving), and the resulting multi-scale structures and properties. The unique physical and chemical properties of fibers and its application as past and emerging advanced materials will be discussed.

**PLAS.5280 Plastics Information Data Bases**  
(Formerly 26.528) - Credits: 1

Review of procedures for literature searching, databases, etc.

**PLAS.5300 Selected Topics**  
(Formerly 26.530) - Credits: 1-3

Topics in various fields of Plastics Engineering. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary Plastics Engineering.

**PLAS.5320 Adhesives and Adhesion**  
(Formerly 26.532) - Credits: 3

Adhesive joining of engineering materials. Surface chemistry, theories of adhesion and cohesion, joint design, surface preparation, commercial adhesives, Rheology, equipment, testing, service life, and reliability.

**PLAS.5330 Green Coatings Science and Technology I**  
(Formerly 26.533) - Credits: 3

This course reviews the basic principles of design and formulation of water-borne, high-solids and powder resins used for the development of solvent-less "green" coatings and the use of bio-derived resins, mostly based on soybean oil and other renewable raw materials. The mechanisms and methods of curing and of polymerization for polymers used as coatings will also be covered. The basic principles of formulation of coatings will be introduced. Permission of instructor for Plastics Engineering Undergraduates seeking to take course as technical elective.

**PLAS.5340 Coatings Science and Technology II**  
(Formerly 26.534) - Credits: 3

A continuation of 26.533. This graduate course reviews the basic principles of design and formulation of waterborne, high-solids, powder resins that meet current manufacturing regulations. Rheology of polymer and pigment dispersion, and their application to coatings, inks and adhesives will be included here.

**PLAS.5350 Rubber Technology**  
(Formerly 26.535) - Credits: 3

Polymerization and compounding of the commercial elastomers. Properties and test methods. Leading applications and methods of processing.

**PLAS.5360 Rheology of Polymers**  
(Formerly 26.536) - Credits: 3

Rheology of polymer melts, solutions, latexes, and pigment dispersions, and their application to coatings and adhesives.

**PLAS.5370 Business Law for Engineers**  
(Formerly 26.537) - Credits: 3

Business legal issues engineers encounter in practice, including contractual, products liability, and intellectual property issues. Business torts relating to product design, manufacturing and inadequate warning defects. Unreasonably dangerous products and strict liability.

**PLAS.5400 Commercial Development of Plastics**  
(Formerly 26.540) - Credits: 3

The concepts of industrial marketing will be reviewed for research, pricing strategies, and product planning for market segmentation, place (distribution)-promotional activities. Topics will include creating a demand, selling, and servicing base resins and additives.

**PLAS.5410 Computer Applications in Plastics**  
(Formerly 26.541) - Credits: 3

Problem solving in plastics engineering has been dramatically influenced by the computer and innovative software packages.
This graduate course will focus on the application and development of software packages for engineering analyses of plastics processes. Specially, the course will cover the basic CAD programs, Pro/ENGINEER, SOLIDWORKS, followed by basic Pre-and-Post processor software, FEMAP, meshing program HYPERMESH, FEMLAB multiphysics, and MATHEMATICA.

**PLAS.5420 Colloidal Nanoscience and Nanoscale Engineering (Formerly 10.542/26.542) - Credits: 3**

This course will cover the fundamentals of nanoscale colloidal processes, intermolecular forces and electrostatic phenomena at interfaces, boundary tensions and films at interfaces, electrostatic and London forces in disperse systems, interactions and self-assembly of polymer colloids, nanoparticles, surfactants and biomolecules. Applications include microfluidics; lab-on-a-chip; nano-biocolloids, vesicles, colloidosomes, polymersomes and polymer hydrogel microcapsules for drug delivery and nanostructured materials and devices.

**PLAS.5440 Advanced Plastics Materials (Formerly 26.544) - Credits: 3**

This course reviews the historical developments of polymeric material systems, commodity, engineering, biodegradable, and high performance thermoplastics. Topics include their synthesis, structure, properties, and applications and there is also an overview of typical additives that are used to modify the properties of plastics. Knowledge of general and/or organic chemistry is recommended as a prerequisite for this course.

**PLAS.5450 Additives for Polymer Materials (Formerly 26.545) - Credits: 3**

Additives incorporated into polymers to modify processing and end-use properties: reinforcements, plasticizers, stabilizers, flame retardants, colorants, biostats, blowing agents, anti-stats, impact modifiers, and processing aids.

**PLAS.5470 Materials for Renewable Energy and Sustainability (Formerly 26.547) - Credits: 3**

This course reviews the selection and design of materials for use in energy generation and conservation applications. Both traditional and renewable technologies for energy generation are reviewed, and the differences in materials needs for generation, storage and transmission highlighted. Particular emphasis is placed on organic and polymeric materials technological challenges in solar, wind and hydro/geothermal energy and future transportation fuel production. The concept of life cycle assessment is introduced for the optimization of systems from a materials science perspective. The impacts of global economics, ethics and efficiency are also addressed. The course approaches sustainability as an open-ended, complex engineering problem and introduces students to the broad range of career opportunities for materials engineers in renewable energy.

**PLAS.5480 Analytical and Numerical Methods in Plastics Processing (Formerly 26.548) - Credits: 3**

This course covers the use of analytical and numerical methods related to engineering. Topics include ordinary differential equations, linear second order differential equations, matrices, vectors, linear systems of equations, partial differential equations. Use of numerical methods to differential equations, linear algebra, regression, interpolation, data analysis, and partial differential equations.

**PLAS.5490 Product Design for Elastomers (Formerly 26.549) - Credits: 3**

This course covers the basics of thermoset and thermoplastic elastomer product design. Topics include mechanical behavior, large deformation structural analysis, design for manufacturability, performance limitations, and end use applications for elastomers and assembly considerations.

**PLAS.5500 Processing with Elastomers (Formerly 26.550) - Credits: 3**

This course covers the basics of elastomer processing. Topics include mixing, Rheology, extrusion, injection molding, compressing molding, and curing as it applies to elastomers.

**PLAS.5510 Extrusion Die Design (Formerly 26.551) - Credits: 3**

This is a project-oriented course which utilizes current CAE programs to design extruder dies. This course will study the basic principles of extrusion die design and apply these principles in designing extrusion dies. A review of the extrusion process and the flow behavior of various polymers will be studied.

**PLAS.5520 Machine Design (Formerly 26.552) - Credits: 3**

Hydraulics, machine logic, drives, pumps, motors, heaters, barrel and screw combinations, mechanical design. Hydraulic and electrical control circuits development. A semester project is required.

**PLAS.5530 Medical Device Design I (Formerly 26.553) - Credits: 3**
A systematic approach to inventing new medical devices. The class details the process of validating medical needs including market assessment and the evaluation of existing technologies; basics of regulatory (FDA) and reimbursement planning; brainstorming and early prototyping for concept creation. Course format includes expert guest lecturers and interactive practical discussions with faculty. Students will prepare a medical device proposal and presentation.

PLAS.5540 Medical Device Design II (Formerly 26.554) - Credits: 3

This course focuses on how to take a medical device invention forward from early concept to technology translation and implementation planning. Topics include technology research & development; patent strategies; techniques for analyzing intellectual property; advanced planning for reimbursement and FDA approval; choosing translation strategies (licensing vs. start-up); ethical issues including conflict of interest; fundraising approaches and cash requirements; essentials of writing a business or research plan; strategies for assembling a development team. Students will prepare a final medical device proposal and presentation.

PLAS.5550 Medical Device Processing - Credits: 3

Critical analysis of current methods of medical device manufacturing, focusing on processing and performance considerations. Includes discussion of different production methods, material selection considerations, biocompatibility, leachables and extractables, device sterilization, and sterile packaging.

PLAS.5630 Current Topics in Plastics Materials I (Formerly 26.563) - Credits: 1

Individual research and presentation in the field of plastics materials.

PLAS.5640 Current Topics in Plastics Materials II (Formerly 26.564) - Credits: 1

Individual research and presentation in the field of plastics materials.

PLAS.5650 Thermosets (Formerly 26.565) - Credits: 3

Provides an in-depth review of the major families of engineering thermosetting resins: phenolics, aminos, polyesters, epoxies, silicones, and various polyurethanes systems. Emphasis is on the basic chemistry, inherent physical properties and processability, and the effect of polymer modifiers (additives) on the functional properties of molding compounds.

Typical market sectors served and related processing/fabrication technologies used in reinforced plastics/composites are reviewed.

PLAS.5660 Polymer Materials Systems Solution (Formerly 26.566) - Credits: 3

This course investigates the selection processes to be followed in screening material candidates, and specifying a material of record. Emphasis is placed on prioritizing performance requirements, contrasting potential candidates, reviewing processing demands, and post-fabrication schemes. The course will be based on actual case studies.

PLAS.5680 Dynamic Mechanical Properties II (Formerly 26.568) - Credits: 3

Practical review of theoretical concepts of rheological measurements with practical applications of experimental techniques. Emphasis will be on the viscoelastic properties of polymer solutions, melts, and solids with correlation with theoretical dynamic mechanical behavior.

PLAS.5690 Current Topics in Plastics Design I (Formerly 26.569) - Credits: 1

Individual research and presentation in the field of plastics design.

PLAS.5700 Current Topics in Plastics Processing I (Formerly 26.570) - Credits: 1

Individual research and presentation in the field of plastics processing.

PLAS.5710 Plastics Processing Engineering Laboratory I (Formerly 26.571) - Credits: 1

Laboratory study of the interaction between process variables and materials in extrusion, injection molding, blow molding, thermoforming, compounding and mixing.

PLAS.5720 Advanced Plastics Processing Engineering Laboratory (Formerly 26.572) - Credits: 1

PLAS.5730 Graduate Polymer Laboratory - Credits: 3

This course provides in-coming graduate students hands-on experience with plastics processing and characterization techniques. Students formed parts of products using multiple extrusion processes, injection molding, blow molding, and thermoforming. These products then are characterized for their mechanical, thermal, and other characteristics using standard test methods. A heavy emphasis also is placed on reporting the
results in a professional manner.

PLAS.5740 Advance Physical Properties Lab  
(Formerly 26.574) - Credits: 1
Measurement of mechanical properties in tension, compression, shear, and flexure; dielectric constant and dissipation factor; thermal behavior under stress; melt rheology.

PLAS.5750 Biomaterials in Medical Applications  
(Formerly 26.575) - Credits: 3
A comprehensive study of the history, current and future rents within biomedical devices and their applications. Students will be introduced to research techniques used to analyze the different classes of biomaterials. An overview of typical host reactions such as inflammatory response and their evaluation will be touched upon.

PLAS.5760 Advanced Mold Design  
(Formerly 26.576) - Credits: 3
This course provides an integrated approach to mold engineering which includes the interrelationships of polymeric materials, engineering principles, processing, and plastics product design. Major topics include cost estimation, mold layout and feed system design, cooling systems, structural design considerations, and ejector system design. Analytical treatment of the subject matter is given based on the relevant rheology, thermodynamics, heat transfer, fluid flow and strength of materials.

PLAS.5770 Plastics Process Engineering I  
(Formerly 26.377/577) - Credits: 3
The first course in a two semester sequence to study the fundamental principles of polymer processing, i.e., the conversion of the polymeric materials into useful articles. The course will first study the properties of polymers (bulk and rheological and thermal properties) and why they are important to understanding polymer processing. This course will emphasize the fundamental principles of the extrusion process and examine the correlation between elements of the extruder, polymer properties, and processing variables and why they all must be considered when studying and understanding a plastics processing technique.

PLAS.5780 Advanced Plastics Processing  
(Formerly 26.578) - Credits: 3
This course reviews the common plastics manufacturing processes, including extrusion, injection molding, blow molding, thermoforming, and rotational molding. After the review, the course focus shifts to the impacts of screw design and processing parameters on the conveyance, melting, devolatilization, and mixing with single screws and compounding with twin screw extruders. This course also includes an overview of die designs, multi-shot and gas assist injection molding, film stretching and methods for heating and cooling in plastics processing.

PLAS.5790 Problems In Biomaterials/Directed Study  
(Formerly 26.579) - Credits: 3
Selection of a current biomaterial problem of interest by the individual student, examination of pertinent literature to determine present knowledge in the area, formulation of an approach to resolve or clarify the issues involved, and (time permitting) work towards the solution of the selected problem.

PLAS.5820 Current Topics in Plastics Design II  
(Formerly 26.582) - Credits: 1
Individual research and presentation in the field of plastics product or tooling design.

PLAS.5830 Advanced Research Methodology  
(Formerly 26.583) - Credits: 3
A systematic evaluation of the techniques used in efficient research and development. Experimental data are analyzed and plotted using a mathematical approach. Creative thinking, problem solving, and student presentation of data are stressed. Extensive reading of research papers, analysis of such, and defense of the analysis required.

PLAS.5850 Computer Aided Engineering I  
(Formerly 26.585) - Credits: 3
This course provides a fundamental approach to computer-aided engineering for plastics processing. Emphasis is upon the theory and techniques of computer aided engineering as applied to plastics processing problems, allowing students to understand the various assumptions and methods used to create the programs.

PLAS.5880 Injection Molding  
(Last Term 2008 Spring)  
(Formerly 26.588) - Credits: 3
An individual research project, term paper and presentation are required.

**PLAS.5890 Polymer Nanocomposites (Formerly 22.570/26.589) - Credits: 3**

This course deals with the preparation, characterization, behavior and properties of polymer nanocomposites, with an emphasis on the most commercially relevant systems to date, as well as new developments in the field. The major preparation routes to these materials are discussed, with an emphasis on the importance not only of dispersion but of true thermodynamic compatibility in these systems. From there, the focus shifts to describe the consequences of nanocomposite structure in terms of both molecular behavior and macroscopic properties, as informed by the most up-to-date research literature available. Case studies of specific systems will serve as opportunities to gain deeper understanding, and the safety issues surrounding nanoparticle handling will also be presented. Finally, current research by invited lecturers working in the field will be presented as time permits.

**PLAS.5900 Survey of Intellectual Property (Formerly 26.590) - Credits: 3**

A review of patents, trademarks, copyrights and their application for protection of technology in the plastics industry. Other topics to be considered will be employee rights/non-competition agreements, foreign protection, and technology licensing. (in the Plastics Industry)

**PLAS.5910 Industrial Thesis Development I (Formerly 26.591) - Credits: 1-9**

Enables graduate students to work part-time to compliment academic studies with practical industrial experience and acquire/enhance expertise in their research as well as thesis investigation.

**PLAS.5940 Additive Manufacturing Engineering Fundamentals - Credits: 3**

Critical analysis of current methods of additive manufacturing. Materials selection, processing-structure-property relationships, testing, relationship to transport phenomena and/or reaction kinetics.

**PLAS.5950 Thermoplastic Elastomers (Formerly 26.595) - Credits: 3**

A comprehensive review of thermoplastic elastomer (TPE) technology. Physical and chemical nature of the various classes of TPE’s will be considered with emphasis on mechanical and rheological properties relevant to engineering applications.

**PLAS.5960 Plastics, Elastomers and Additives from Renewable Resources (Formerly 26.596) - Credits: 3**

This course will provide and introduction to plastics, elastomers and additives obtained from renewable resources. Processes that involve conversion (chemically/enzymatically) of naturally occurring precursors (monomers) obtained from renewable resources to plastics and elastomers will be reviewed. Brief discussion of processing, degradation and recycling of these materials will also be included.

**PLAS.5970 Plastics & Environment (Formerly 26.597) - Credits: 3**

This course investigates the waste management solutions for different types of plastics. Both traditional and emerging recycling methods will be highlighted. Accumulation of plastic waste in the natural environment and the toxicity of plastics as well as their additives will be discussed. Further, analysis methods and instrumentation to characterize recycled plastics, and the differences in virgin polymers and recycled polymers will be introduced. Potential degradable, biodegradable or biobased alternatives will be reviewed along with the concepts of life cycle assessment and Green Chemistry for designing the most sustainable plastic materials.

**PLAS.5990 Rapid Prototyping - Credits: 3**

Survey of the rapidly expanding technology field of rapid prototyping. Technologies to be considered include stereolithography, laminated object manufacturing, selective laser sintering, fused deposition modeling, and solid ground curing.

**PLAS.6010 Graduate Industrial Coop Education I (Formerly 26.601) - Credits: 1-3**

Graduate students interested in developing a practical industrial experience component to complement their academic training may register for this course with advisor’s approval. This credit is not applicable to the mandated degree credit hours.

**PLAS.6060 Plastics Manufacturing Systems Engineering (Formerly 26.606) - Credits: 3**

The course provides guidance about plastics manufacturing as an integrated system with broadly applicable analysis in three areas: 1) machinery, 2) controls, and 3) operations. The machinery topics include heating/cooling, hydraulics/pneumatics, electric drives, and sensors. The controls topics include signal conditioning, data acquisition, machine controllers, and related control laws. The operations topics include process characterization, process optimization,
quality control, and automation. The course is developed to support plastics processing engineers and others involved with plastics manufacturing who are performing process development, research, and machine design.

**PLAS.6070 Supply Chain Management for Engineers** (Formerly 26.607) - Credits: 3

This course focuses on design, development, and planning supply chain networks while examining the product’s life cycle with an emphasis on the manufacturing processes. Throughout the course, global supply chain management, supply chain drivers, distribution networks, network design under uncertainty, supply-demand cycle, demand forecasting, inventory management, supply chain performance, end-of-life, cradle-grave and cradle-cradle products, along with supply chain decision-making topics will be covered. These topics will be demonstrated with the implementation of examples, and case studies.

**PLAS.6100 Plastics Industry Development** (Formerly 26.610) - Credits: 3

The goals of this course are numerous. In the large sense, the primary focus of this course will be to review many of the major technological developments and discoveries that have helped make the plastics industry what it is today. Having a thorough understanding of how these developments were implemented commercially can help us implement modern day technologies in a more efficient and productive manner.

**PLAS.6110 Coloration of Engineering Thermoplastics** - Credits: 3

A comprehensive approach to all elements of Color Technology focused on needs for future plastics engineers. The course includes theory of color vision, instrumental color measurement and tolerancing, chemistry and processes of commercial dyes and pigments, their testing in polymers, failure modes and elements of industrial color matching. Special attention will be given to weatherability of color formulations.

**PLAS.6180 Structural Product Design** (Formerly 26.618) - Credits: 3

Design of plastic and composite products to meet structural requirements including strength, stiffness, impact, fatigue, and creep while remaining low weight, low cost, and easy to manufacture. The course will include an overview of structural properties of polymeric materials as well as application of finite element analysis to homework and project assignments.

**PLAS.6420 Characterization of Polymers and Plastics** (Formerly 26.642) - Credits: 3

This course provides an in-depth review of the various means by which important properties of polymers and plastics are determined. Lectures will cover analysis of composition and structure (including deformation techniques) as well as measurements of common physical, mechanical, thermal, barrier, fire and optical properties. Coverage will include both the fundamental basis for the techniques and their practical applications, strengths and weaknesses. Time and resources allowing, selected techniques will be demonstrated in the lab as well.

**PLAS.6500 Nanoscale Transport Phenomena for Manufacturing Nanodevices** (Formerly 26.650) - Credits: 3

An interdisciplinary course taught by faculty from the Chemical, Mechanical and Plastics Engineering Department, who have special knowledge in nanoscale fluid mechanics and heat transfer. The course on nanoscale transport phenomena constitutes a bridge between existing fluid and heat transfer courses in multiple disciplines and emerging nanoscale science and engineering concepts to reflect the forefront of nanomanufacturing. The course is designed to incorporate recent advances in manufacturing polymer based nanodevices. Key issues of the implementation and maintenance cost for fabrication will be addressed. Hands-on laboratory experiments will be performed to complement the lectures with the ultimate goal of designing and building a complete nanodevice at the end of the course. The course will prepare graduates for employment focused on designing and manufacturing nano/microfluidic systems, lab on ship devices, electronic devices, medical devices and other emerging technologies.

**PLAS.6750 Biomaterials II** (Formerly 26.675) - Credits: 3

The degradation of biomaterials in the biological environment for applications such as sutures, orthopedic implants, dental implants, etc. will be reviewed. Students will analyze issues unique to the field of implants, devices and biomaterials. While reviewing new products and standards, the prospective and possibilities of biomaterials will be studied.

**PLAS.6780 New Developments in Polymer Manufacturing** - Credits: 3

This course explores advanced concepts and new developments in polymer manufacturing. It is designed for students with prior courses and/or experience in polymer processing.

**PLAS.6820 Physical Polymer Science** - Credits: 3
Comprehensive course covering physical polymer science and engineering. The role of molecular conformation and configuration in determining the physical behavior of polymers. The amorphous and crystalline states of polymers; polymer/polymer phase diagrams; glass-rubber transition and polymer viscoelastic behavior.

PLAS.7410 Master's Thesis - Plastics Engineering (Formerly 26.741) - Credits: 1
Individual research projects in plastics.

PLAS.7430 Masters Thesis Plastics Engineering (Formerly 26.743) - Credits: 3
Individual research projects in plastics.

PLAS.7460 Master's Thesis - Plastics Engineering (Formerly 26.746) - Credits: 6
Individual research projects in plastics.

PLAS.7490 M S Grad Res Plastics (Formerly 26.749) - Credits: 9
Individual research projects in plastics.

PLAS.7510 Doctoral Thesis Research (Formerly 26.751) - Credits: 1
Individual research projects in plastics.

PLAS.7520 Doctoral Thesis Research (Formerly 26.752) - Credits: 2
Individual research projects in plastics.

PLAS.7530 Doctoral Dissertation/Plastics Engineering (Formerly 26.753) - Credits: 3
Individual research projects in plastics.

PLAS.7560 Doctoral Dissertation/Plastics Engineering (Formerly 26.756) - Credits: 6
Individual research projects in plastics.

PLAS.7590 Doctoral Dissertation/Plastics Engineering (Formerly 26.759) - Credits: 9
Individual research projects in plastics.

PLAS.7630 Continued Graduate Research (Formerly 26.763) - Credits: 3
Individual research projects in plastics.

PLAS.7660 Continued Graduate Research (Formerly 26.766) - Credits: 6
Individual research projects in plastics.

PLAS.7690 Continued Graduate Research (Formerly 26.769) - Credits: 9
Individual research projects in plastics.

PLAS.7CPT Curricular Practical Training for Engineering Doctoral Candidates - Credits: 1
Curricular Practical Training (CPT) is a training program for doctoral students in Engineering. Participation in CPT acknowledges that this an integral part of an established curriculum and directly related to the major area of study or thesis.