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Doctoral Degree Requirements

Doctoral Research

In addition to the other requirements of the University, a candidate for a doctoral degree must complete an acceptable dissertation. The dissertation must satisfy the following criteria:

1. It should demonstrate the candidate's intellectual competence and maturity in the field of concentration;
2. It should make an original and valid contribution to knowledge; and
3. It should be an individual achievement and the product of independent research.

Although doctoral dissertations may result from a project involving collaboration of several scholars, the individual contribution of each doctoral candidate must be substantial, clearly identifiable, and presented separately. The Committee will judge the completed dissertation in terms of the candidate's ability to review and make critical use of the literature; to formulate a problem, develop appropriate methodology, and work systematically toward a solution; and to summarize the material or data and draw conclusions from them. The writing should be of publishable quality.

Dissertation Committee

After a student has chosen an area of research and a research supervisor, 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.


Dissertation Credits

If the graduate student requires the use of University resources to continue his or her dissertation but has completed the required number of credits for doctoral research, he or she may sign up for 3, 6, or 9 credits of Continuing Graduate Research (see General Policies).

Graduate students who have completed all the requirements except the writing and defense of the dissertation and who do not need to use university resources must register for Continued Matriculation (CM.601 (https://www.uml.edu/catalog/courses/CM/601).201) and pay a fee each semester until they graduate.

Note: International students on F-1 or J-1 visas must be registered for a minimum of nine credits each semester. Contact the International Students and Scholars Office for more information.

Dissertation Preparation

Every graduate student who completes a dissertation is required to bear the cost of binding two copies of the manuscript for the University's files. Copywriting is optional and available for an additional fee.

Dissertation Defense

Two weeks prior to the dissertation defense, announcements of the defense, listing the graduate student's name, dissertation title, and place and time of the defense, must be submitted to the chairperson of the department, the college dean, the Registrar's Office and posted and distributed throughout the university. The defense is open to the public.

Doctoral Degree Requirements

The doctoral degree is conferred upon graduate students who have met all the requirements listed below:
1. The student must successfully complete the graduate courses in the major field, including the GPA requirement, and the number of course and dissertation credits required by the particular program.

2. If indicated, the language requirement specified by the major department must be satisfactorily completed.

3. A qualifying examination, oral and/or written, conducted by the major department, must be passed before any work is begun on the dissertation. If the student fails the qualifying examination he or she may, at the discretion of the department, be permitted a second and final opportunity. At this point, having completed steps 1 through 3, the student is admitted to candidacy for the doctorate.

4. A dissertation based upon the results of original research, and which is satisfactory to the Dissertation Committee of the major department, must be completed.

5. A final oral dissertation defense conducted by the Dissertation Committee, based primarily upon, but not necessarily limited to, the contents of the candidate’s dissertation must be passed. The examination cannot be scheduled until all members of the Dissertation Committee have had seven working days in which to read the dissertation. The oral examination is to be conducted by the Dissertation Committee, whose membership may be augmented by the non-voting faculty. In order to pass the defense, the candidate may not receive more than one dissenting vote from the members of the Dissertation Committee.

6. All financial obligations (tuition, fees, and expenses) must be satisfied as evidenced by the completion and submission of a Graduate Degree Clearance form to the Registrar’s Office.

**Procedure for Opting Out with a Master’s Degree**

Students accepted into a doctoral program who elect to instead obtain the master’s degree and leave the university must follow the following procedure:

1. The student must file an Academic Petition requesting to be changed from the doctorate to the master’s degree program.

2. The student must complete all required courses for the master’s degree, compile a minimum 3.0 grade point average, successfully defend his/her thesis, and complete the clearance process at the Registrar’s Office.

3. All graduate courses (and undergraduate course work used for graduate credit), whether taken for the original doctoral program or for the master’s degree, will be included in the grade point average and listed on the student’s graduate transcript.

**Master’s Degree Requirements**

**Advising**

**General Requirements for the Master's Degree**

**Research Option for the Master's Degree**

**Research Project**

**Thesis**

**Thesis Committee**

**Thesis Preparation**

**Thesis Defense**

**Students Continuing on to a Doctoral Program**

**Advising**

An entering graduate student should meet with the departmental graduate coordinator as soon as possible after arrival on campus. The coordinator will:

1. Help design and then approve the student’s complete program leading to the master’s degree.

2. Recommend course credits from within and outside the University for transfer into the student’s degree program.

3. Monitor the student’s progress toward the degree, which
must be completed within a five-year time period in most programs (See Time for Limit for Degree Completion).

**General Requirements for the Master’s Degree**

To be recommended for a masters degree, a candidate must satisfy all requirements of the University and the specific requirements of the department in which he or she is enrolled. The requirements of the University are listed below, and the specific requirements established by the various departments may be found in the section describing the particular programs.

A candidate for the master’s degree must complete the following within five years of matriculation in order to receive the degree: (Note: Master’s degrees which require 45 or more credits have a limit of six years.)

1. A course of study designed by the department in which he or she is enrolled and approved by the University. The course of study must have a minimum of 30 credit hours of graduate work including, where applicable, a thesis or project in the student’s chosen field.
2. A student must successfully pass an oral or written examination on his or her complete master's program if required by the department.
3. Satisfactory grades in all subjects offered for the degree must be earned (See Academic Standing).
4. All financial obligations, including tuition, fees, and expenses, must be satisfied as evidenced by completion and submission of a signed Graduate Degree Clearance form to the Registrar’s Office.

**Research Option for the Master’s Degree**

If required by the program, a student must complete a master’s project or a thesis. The proposal must be approved by the department in which the student is enrolled and the final project or thesis must be of graduate level quality.

**Project**

The project must consist of a scholarly investigation, such as a review, report, synthesis, design or experiments in the student’s field resulting in a comprehensive written document. Usually, if a student chooses the project option, he or she is required to take additional course credits. Each project is awarded only three to four credits and is intended to be completed within the time limit of one semester. If the work for a project is not completed by the end of the semester, the instructor will give the student an Incomplete which is to be treated the same as an incomplete for a regular course.

**Thesis**

The requirements for a thesis are much more extensive, including the completion of acceptable research and its defense before a thesis committee. The completed thesis must conform to the format specified in the "Thesis Guide (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)" which is available in the Registrar’s Office. The time required for completion may vary; if a student has not completed the thesis by the end of the semester, but is making satisfactory progress, he or she is given the grade of "PR". If the student requires the use of university resources to continue thesis research, but has completed the required number of credits for the master’s thesis, he or she may sign up for 3, 6, or 9 credits of Continuing Graduate Research (see Course Descriptions). However, if the student is not using University resources, but is in the process of writing the thesis, he or she may register for Continuing Matriculation for the semester(s) during which the work is completed. Continuing Matriculation is available to international students only under special circumstances. International students should contact the International Student Office (https://www.uml.edu/ISSO/default.aspx) for more information and to make sure they comply with visa and immigration regulations.

Upon successful completion of the thesis, the grade of "S" will be awarded for the all semesters in which the student is registered for thesis research. Only the Registrar’s Office can issue this grade.

**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 responsibilities of the Thesis Committee shall be to:

1. Approve the research topic.
2. Supervise the progress of the thesis.
3. Read, evaluate and approve or disapprove of the written thesis.
4. Hear, evaluate and approve or disapprove of the oral defense of the thesis.
5. Report the completion of all thesis requirements to the
Thesis Preparation

Every graduate student who completes a thesis is required to bear the cost of binding two copies of the manuscript for the University's files. Copy writing is optional and available for an additional fee.

Thesis Defense

Two weeks prior to the thesis defense, announcements of the defense listing the candidate's name, thesis title, and place and time of the defense, must be submitted to the chairperson of the department, the college dean, and the Registrar’s Office, and posted and distributed throughout the University. The defense is open to the public.

For Students Continuing on to a Doctoral Program

Students accepted into a master’s degree program who decide to continue on for the doctorate but want to first complete their master’s degree must adhere to the following procedure.

1. The student must complete all required courses, compile a 3.0 grade point average, and successfully defend his/her thesis, if required.
2. The student must complete the Registrar’s Office clearance process for the master’s degree.
3. A student is prohibited from enrolling in doctoral research until he or she has completed the clearance process for the master’s degree.
4. The student must then apply to the doctoral program by completing the standard Graduate Admissions application process.
5. Official admission into a doctoral program and receipt of a letter of acceptance are contingent upon completion of the clearance process for the master’s degree.

This online academic catalog provides the latest information on all graduate areas of study and degree programs at the University of Massachusetts Lowell and supersedes all previous versions of the catalog.

View the full list of master’s, doctoral and certificate programs or navigate by college or school.

Manning School of Business

School of Education (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Francis College of Engineering

College of Fine Arts, Humanities & Social Sciences

Zuckerberg College of Health Sciences

Kennedy College of Sciences

UMass System Graduate Programs

Gainful Employment Information (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

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/), (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.

- Conventional Application
- Application Deadline
- empty
  (https://stage.uml.edu/Catalog/Graduate/Admissions/#ApplicationDeadline)
- Types of Admission
- empty
  (https://stage.uml.edu/Catalog/Graduate/Admissions/#TypesofAdmission)
- Status as a Graduate Certificate Candidate
  (https://stage.uml.edu/Catalog/Graduate/Admissions/#GraduateCertificate)

- Acceptance of Foreign or American Master’s Degree Toward Doctoral Requirement
- Transfer Credit
- Graduate Equivalency Credit

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, IELTS, Duolingo. 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 may, 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 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
Financial Information

University-related costs include tuition and mandatory fees. Please contact The Solution Center for more tuition and fee information (https://www.uml.edu/thesolutioncenter/bill/tuition-fees/Graduate/in-state.aspx).

- New England Regional Program
- Health Insurance
- Veterans
- Residency Classification
- Overdue Accounts
- Payment Plans
- University Charges

New England Regional Student Program

Massachusetts and the university participate in a reciprocal program in which qualified and legal residents of other New England states may attend graduate school in an approved program at the University of Massachusetts Lowell and pay 150 percent of the Massachusetts in-state tuition charges. (All other applicable fees apply.) Applicants are considered for unique and distinctive graduate level studies not available in their home state university system. Full details regarding eligible programs are available from the New England Board of Higher Education, 45 Temple Place, Boston, Massachusetts 02111 (617-357-9620), or at the University Graduate Admissions (https://www.uml.edu/Grad/default.aspx) office (www.uml.edu/grad (https://www.uml.edu/Grad/default.aspx)). See the tuition costs for the New England Regional Program.

*UMass Lowell also participates in the Proximity Allowance of the New England Regional Program. This program allows New Hampshire residents from selected towns within a 20 mile radius of UMass Lowell to be eligible for a tuition discount for most majors. Please visit www.uml.edu/admissions/proximity (http://www.uml.edu/Grad/Costs/default.aspx) for details.

Health Insurance

Mandatory on-campus (accident) insurance is charged to all graduate students. All graduate students enrolled in 9 or more credit hours will be charged for health insurance as required by state law. Graduate students may waive student health insurance charges if they maintain comparable insurance coverage and complete an insurance waiver form by the required deadline. Forms are available in the Office of Graduate Admissions and Accounts Receivable Office, Dugan Hall, UMass Lowell South. Family health insurance plans are also available with options for coverage of spouses and/or spouses and dependent children.

International Students: As authorized under the insurance laws for higher education students in Massachusetts (section 275 of Chapter 151 of the Acts of 1996), the University of Massachusetts Lowell requires that all international students must enroll in the University's Student Health Insurance Plan.

Veterans

The Veterans Administration has approved the University of Massachusetts Lowell for undergraduate study. Visit the Office of Veterans Services (https://www.uml.edu/student-services/Veterans/default.aspx) for more information.

RESIDENCY CLASSIFICATION

Rules for Determination of Domicile

University tuition rates are established on the basis of official state residency as determined by a student’s true "domicile." "Domicile" is defined as a person’s true, fixed and permanent home and place of habitation where he or she intends to remain permanently or for an indefinite time. Massachusetts residency for tuition purposes is not acquired by mere physical presence in Massachusetts while a person is carrying on a course of study at the University. A student’s residency status is based on a determination of one’s domicile at the time of entry or re-entry to the University. A student may apply to be reclassified at any time and must provide detailed documentation to support the claim that he or she met the requirements for Massachusetts residency for tuition purposes at the time of his or her entry as a student. One notable exception is made for students who marry Massachusetts residents while enrolled in a course of studies. The complete set of rules are attached to the application for reclassification (https://www.uml.edu/Enrollment/Residency/Classification-Reclassification.aspx).

Payment of Bills

Graduate students will be permitted to attend classes and to utilize university facilities only after they have cleared all their financial obligations to the university. Financial obligations include indebtedness for library and parking fines, rental payments and repayment of emergency loans. All bills are payable in advance by check or money order and are due as
specified on the student invoice. Major credit cards are also accepted. All payments of fees and tuition should be made payable directly to the University of Massachusetts Lowell. A student in debt to the university at the end of any semester or summer session is not permitted to register again at the university until his or her indebtedness has been discharged. In addition, student transcripts and diplomas will not be released unless all indebtedness has been discharged.

Pay My Bill
(https://www.uml.edu/thesolutioncenter/bill/default.aspx)

Overdue Accounts

Should it be necessary to utilize the services of a collection agency or attorney for an overdue student account, the student will be liable for any and all legal fees, commissions, and associated service charges.

Payment Plans

The University of Massachusetts Lowell offers a low-cost, interest-free payment option. This plan allows students to budget the annual cost of tuition and fees over a ten month period. Visit the Solution Center (https://www.uml.edu/thesolutioncenter/bill/eBill/payment-options.aspx) for more information on payment options.

University Charges

University-related costs include tuition and mandatory fees. Please contact the Solution Center for more information on tuition and fees.

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

(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 graduate student aid contact visit the Solution Center at www.uml.edu/thesolutioncenter (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/step-parents of undergraduate dependent students. Interest rate is fixed and repayment begins 45-60 days after the second disbursement. Refer to the Direct Loan web site (http://www.ed.gov/offices/OSFAP/DirectLoan/index.html) 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/Forms.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.

ASSISTANSHIPS

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/Grad/Accepted-Students/coordinators.aspx) or chairperson (see www.uml.edu/Grad/coordinators.aspx) for a list. 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. No teaching/research assistantship may be awarded to a graduate student with incompletes, F’s, or U’s on his or her transcript.

2. No teaching/research assistantship may be awarded to a graduate student who fails to maintain good academic
3. No University-funded teaching/research assistantship may be 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/Grad/Accepted-Students/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/catalog-AY21/pdf/Graduate.pdf)
- Language Arts & Literacy (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
- Mathematics & Science Education (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Doctor of Philosophy in Engineering (Ph.D.)

- Chemical Engineering
- Civil Engineering
- Computer Engineering
- Electrical Engineering
- Energy Engineering
- Mechanical Engineering
- Mechanical Engineering/Chemical Engineering
- Mechanical Engineering/Civil & Environmental Engineering
- Mechanical Engineering/Energy Engineering
- Mechanical Engineering/Manufacturing
- Plastics Engineering

Doctor of Nursing Practice (DNP)

- Nursing

Doctor of Philosophy (Ph.D.)

- Applied Psychology and Preventative Science
- Applied Biology (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
  Biomedical Science;
  Developmental & Evolutionary Biology;
  Quantitative Biology & Biophysics; and
  Cellular & Molecular Biology
- Biomedical Engineering & Biotechnology
- Business Administration
  Finance Management
- Business Administration Technology
- Computer Engineering
- Electrical Engineering
- Energy Engineering
- Mechanical Engineering
- Mechanical Engineering/Civil & Environmental Engineering
- Mechanical Engineering/Energy Engineering
- Mechanical Engineering/Manufacturing
- Plastics Engineering
- Chemistry
- Biochemistry
- Environmental Studies
- Green
Chemistry
- Computer Science
- Bio/Chemical Informatics
- Computational Mathematics
- Criminology and Criminal Justice
- Crime, Criminals & Community
- Global Perspectives on Crime & Justice
- Victims, Crime & Justice
- Global Studies
- Security & Human Rights
- Socio-Economic Development
- Comparative Cultures
- Marine Sciences & Technology
- Nursing
- Pharmaceutical Science
- Physics
- Applied Mechanics
- Energy Engineering
- Atmospheric Sciences
- Radiological Sciences
- Polymer Science
- Polymer Science/Plastics Engineering

Doctor of Physical Therapy (DPT)
- Physical Therapy

Doctor of Science
- Public Health
- Epidemiology

Master's Programs Offered
Listed by Degree Earned
- Master of Arts
- 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 Arts (MA)
- Community Social Psychology

Master of Science (M.S.)
- Criminal Justice
- History
- Peace & Conflict Resolution
- Security Studies

Master of Business Administration (MBA)
- General Business
- Accounting
- Business Analytics
- Entrepreneurship
- Finance
- Healthcare
- Information Technology
- International Business
- Managerial Leadership
- Marketing

Master of Education (M.Ed.)
- Curriculum & Instruction
- Autism Studies
- Science Education, beyond initial
- Math Education, beyond initial
- Educational Administration
- Higher Education
- Reading & Language

Master of Music (MM)
- Music Education
- Community Music
- Sound Recording Technology

Master of Public Administration (MPA)
- Public Administration
- 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
• Autism Studies
• Biological Sciences Bioinformatics Biotechnology Education, Communication and Outreach Option (This program does NOT lead to teaching licensure)
• Biomedical Engineering & Biotechnology Biomedical & Biotechnology (PSM)
• Business Analytics
• Chemistry Chemistry & Polymer Science, Pharmaceutical Biochemistry (PSM)
• Clinical Laboratory Sciences Clinical Lab Science (PSM)
• Computer Science Bio/Chemical Informatics Software Entrepreneurship - Not Accepting new applications Entrepreneurship (PSM) - Not Accepting new applications
• Co-op Option in Engineering (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
• Engineering Management
• Entrepreneurship
• Environmental Studies Atmospheric Sciences Environmental Sciences (PSM) Environmental Engineering Sciences Environmental Geoscience (PSM)
• Finance
• Health Information Management Health Informatics Health Management
• Information Technology

• Marine Sciences & Technology Coast & Ocean Admin. Science/Technology (PSM)
• Mathematics Applied & Computational Mathematics Industrial Mathematics (PSM) Mathematics for Teachers Probability & Statistics
• Nursing Adult / Gerontological Nursing Family Health Nursing
• Pharmaceutical Science
• Physics
• Public Health
• Radiological Science & Protection Radiological Science and Protection (PSM) Medical Physics
• Security Studies CBRNE Security Critical Infrastructure Protection Cybersecurity

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

• Chemical Engineering Leadership
• Civil Engineering Leadership Environmental Geotechnical Structural Transportation
• Computer Engineering Leadership
• Electrical Engineering Leadership Optics
• Energy Engineering Leadership Nuclear Solar
• Mechanical Engineering Leadership
• Plastics Engineering Leadership Coatings & Adhesives Fibers & Composites Synthetic Fibers

Education Specialist (EdS)

• Administration, Planning & Policy (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
• Curriculum & Instruction (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf) Education of Diverse Populations
• Reading & Language (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
About Graduate Certificates

Most graduate certificate are comprised of four courses designed to provide specific knowledge and expertise vital to today’s changing and complex needs in the workplace. In most cases courses may be applied toward a degree program.

Requirements to Complete a Graduate Certificate

The courses to complete the certificate must be completed within a five year period with a minimum 3.0 grade point average, and with no more than 3 credits below B. Courses completed for one certificate may not be used for another certificate. Courses may not be transferred into a graduate certificate; however, approved course substitutions are allowed.

Certificate Application Process

Individuals must complete a simplified application and provide an official undergraduate transcript indicating that a baccalaureate degree has been awarded. GRE’s are not required. NOTE: If your bachelor’s degree is from outside of the U.S., you may be required to take the TOEFL examination.

See the university’s requirements for graduate admission.

Graduate Certificates Offered

- Additive Manufacturing (AM) in Radio Frequency (RF) & Microwave (MW) Applications
  (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
- Applied Statistics
- 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
  (https://www.uml.edu/Catalog/Graduate/Health-Environment/Clinical-Lab-Nutritional-Sci/Certificate-Program.aspx)
- 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
  (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
- Evaluation and Assessment
  (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
- 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
- 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
- Nutritional Sciences
  (https://www.uml.edu/Catalog/Graduate/Health-Environment/Clinical-Lab-Nutritional-Sci/Certificate-Program.aspx)
The Professional Science Master's (PSM) is an innovative, non-thesis degree option designed for students to pursue advanced training in science, health or engineering while simultaneously developing professional leadership skills highly valued by employers. PSM programs typically consist of 8 core courses in science, health or engineering, three professional courses in leadership, communication and project management, a paid internship or professional development project and a reflective seminar. PSM programs have been developed in concert with industry in response to employer demands for specific skills and knowledge above and beyond the core science curriculum.

In contrast to typical masters degrees, which require a thesis as a step toward preparation for an academic career, PSM programs are designed as terminal degrees that prepare candidates to compete in the global market. In essence, PSM programs are the MBAs of the 21st century. The National PSM Association offers networking and professional workshops to promote continued career development for PSM alumni across the country.

What differentiates the PSM from the core Master's degree?

What PSM programs are available at UMass Lowell?

Graduates earn a masters degree in science with a PSM Option in the fields indicated below.

**Biological Sciences**
(http://www.uml.edu/Catalog/Graduate/Sciences/Biology/Default.aspx)
- Applied Biotechnology
- Environmental Biotechnology
- Biosafety
- Project Management in Life Sciences

**Biomedical Engineering and Biotechnology**
Applications for this program have been suspended.

**Chemistry**
(http://www.uml.edu/Catalog/Graduate/Sciences/Chemistry/Default.aspx)
- Chemistry and Polymer Science
- Pharmaceutical Biochemistry

**Clinical Laboratory Sciences**
Applications for this program have been suspended.
empty
(http://www.uml.edu/Catalog/Graduate/Sciences/Chemistry/Default.aspx)

empty
(http://www.uml.edu/Catalog/Graduate/Sciences/Chemistry/Default.aspx)
Environmental Sciences
(http://www.uml.edu/Catalog/Graduate/Sciences/Environmentalscience/Default.aspx)

- Atmospheric Sciences
- Geosciences

Marine Sciences
(http://www.uml.edu/Catalog/Graduate/Sciences/Marine/Default.aspx)

- Coastal and Ocean Administration, Science and Technology

Mathematics - Applications for this program have been suspended.

- Industrial Mathematics

Physics
(http://www.uml.edu/Catalog/Graduate/Sciences/Physics/Default.aspx)

- Radiological Sciences

Professional Leadership - Applications for this program have been suspended.

Work Environment - Applications for these program have been suspended.

- Cleaner Production & Pollution Prevention
- Environmental Epidemiology
- Ergonomics and Safety
- Occupational & Environmental Hygiene

For more information regarding PSM programs at UMass Lowell contact William Smith (mailto:william_smith@uml.edu).

Recommended PSM Science Courses:

Students should consult with faculty advisers to determine best course choice for their career advancement needs. All PSM students should include at least 1 course (basic or enhanced) that incorporates communication into their curriculum.

Learning Outcomes Assessment Policy

In keeping with the University's commitment to excellent educational experiences and high-quality programs for its students, and consistent with practices at other institutions within the state and nationally, UMass Lowell routinely engages in the assessment of student learning at the course, program, institution and systems levels. The learning outcomes assessment process may include a variety of methods such as standardized tests, student surveys and focus groups, campus developed instruments, and a review of student will be protected. In circumstances beyond the individual course level, the identity of the student will be protected. The student's name, grade or other identifying information will be removed before the student work is reviewed. Selected student work may be subject to review by a limited cohort of higher educational personnel, primarily faculty. Assessment of student learning is undertaken primarily for the purpose of improving student learning, curriculum development, instructional improvement, and enhancing student academic success. Assessment activities will have absolutely no effect on a student's grade, academic standing, ability to transfer, or ability to be graduated. UMass Lowell will take all necessary steps to ensure the confidentiality of all student records and student work reviewed through this process in accordance with FERPA regulation.

UMass System Graduate Programs

UMass Lowell offers two intercampus programs drawing on the strengths of the whole UMass System.

- Marine Science
- Biomedical Engineering & Biotechnology Program

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 Bachelors to Masters 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 (https://www.uml.edu/Academics/undergraduate-programs/bachelors-masters.aspx) 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 credits is not accepted for graduate certificates. The Bachelors 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 Master’s 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 applied to the University’s Bachelor’s to Master’s Program.

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.

Graduate Programs

UMass Lowell offers more than three dozen master’s programs, including Education Specialist (Ed.S.) post-graduate programs. Many of our programs have non-thesis options. If you’re not ready to matriculate into a full program, consider our certificate programs. If you are looking for a doctoral program, we offer more than two dozen in a wide range of disciplines.

Online & Professional Studies Programs

UMass Lowell offers a number of graduate degrees and certificates and part-time undergraduate degrees and certificates entirely online, or as a mix of online and on-campus courses through its Division of Graduate, Online & Professional Studies. By making the courses available online - during the evening and on weekends - the University makes it easier for busy professionals to fit education into their lives.
General Regulations for Graduate Students

Each University student is subject to two sets of academic regulations - those of the University as a whole, which are cited in this section, and the academic rules of the college and program in which he or she is enrolled. The academic rules of colleges and programs are listed in sections devoted to college programs.

In registering for courses, each student assumes full responsibility for knowledge of and compliance with the definitions, regulations, and procedures for the University, as set forth in this publication. Moreover, in accepting admission to the University, each student assumes responsibility for knowledge of and compliance with the definitions, regulations, and procedures of the University pertaining to his or her student status as set forth in the appropriate UML publications.

Students who have questions about the interpretation or application of University academic policy should consult the dean of their college or the Vice Provost for Graduate Education.

Graduate Policies

- Academic Integrity
- Academic Standing
- Acceptance of Master’s Degree Toward Doctoral Requirements
- Commencement
- Course Credit
- Course Descriptions
- Degree Completion: Doctoral Degree
- Degree Completion: Master’s Degree
- Dissertation and Thesis Guide
- Equal & Fair Treatment
- Grading Policies
- Graduate Clearance
- Graduate Grade Appeal Process
- Learning Outcomes Assessment
- Registration & Enrollment
- Right of Access to Student Records
- Statue of Limitations
- Transcripts
- Transfer Credits
- University Appeals Process Regarding Academic (Non-misconduct) Issues
- University Disciplinary Procedures
- Veterans Benefits and Transition
- Withdraw from a Course or the University

Academic Integrity Policy

UNIVERSITY OF MASSACHUSETTS LOWELL POLICY AND PROCEDURES RELATING TO STUDENT ACADEMIC INTEGRITY AND MISCONDUCT

I. Statement of Principles: The University has a responsibility to promote academic honesty and integrity and to develop procedures to deal effectively with instances of academic dishonesty. Students are responsible for the honest completion and representation of their work, for the appropriate citation of sources, and for respect of others academic endeavors. Academic dishonesty is prohibited in all programs of the university.

II. Academic Misconduct Subject to Disciplinary Action:

(1) Academic misconduct is an act in which a student:

(a) Seeks to claim credit for the work or efforts of another without authorization or citation;
(b) Uses unauthorized materials or fabricated data in any academic exercise;
(c) Forges or falsifies academic documents or records;
(d) Intentionally impedes or damages the academic work of others;
(e) Engages in conduct aimed at making false representation of a student’s academic performance; or
(f) Assists other students in any of these acts.

(2) Examples of academic misconduct include, but are not limited to: cheating on an examination; collaborating with others in work to be presented, contrary to the stated rules of the course; submitting a paper or assignment as one’s own work when a part or all of the paper or assignment is the work of another; submitting a paper or assignment that contains ideas or research of others without appropriately identifying the sources of those ideas; getting unauthorized access to examinations or course materials; submitting, without the permission of the current instructor, work previously presented in another course; tampering with the laboratory experiment or computer program of another student; knowingly and intentionally assisting another student in any of the above, including assistance in an arrangement whereby any work, classroom performance, examination or
other activity is submitted or performed by a person other than the student under whose name the work is submitted or performed.

III. Possible Disciplinary Sanctions:

(1) The following are the disciplinary sanctions that may be imposed by an instructor for academic misconduct:

(a) An oral or written notice of misconduct;
(b) An assignment to repeat the work, to be graded on its merits;
(c) A lower or failing grade on the particular assignment or test;
(d) A lower grade in the course;
(e) A failing grade in the course;

In addition, an instructor or the Academic Dean may recommend the following sanctions:

(f) A non-deletable failing grade in the course;
(g) Suspension from the University; (h) Expulsion from the University.

Sanctions f  h are imposed by the Office of the Provost.

(2) One or more of the disciplinary sanctions listed above may be imposed for an incident of academic misconduct.

IV. Definitions

As used herein:

(1) Office of the Provost means the Provost, Vice Provost or a designee.
(2) Days means academic calendar days and excludes Saturdays, Sundays, legal holidays and days upon which the university is closed.
(3) Academic Dean means the Academic Dean or designee for the college in which the subject course is taught.
(4) Instructor refers to the Instructor of Record.
(5) Minor Disciplinary Sanction means a disciplinary sanction, identified in paragraph III (1) (a)-(c) and imposed, for academic misconduct, upon a student by an instructor.
(6) Major Disciplinary Sanction means a disciplinary sanction, identified in paragraph III (1) (f)-(h) and imposed, for academic misconduct, upon a student by the Office of the Provost or the Academic Integrity Appeals Board upon the recommendation of the instructor or the Academic Dean or imposed at the discretion of the Office of the Provost.
(7) Notice to the student, whenever required herein, shall be e-mailed to the students official student.uml.edu e-mail address or mailed to the student by regular first class United States mail at his or her current address as maintained by the university.

V. Imposition of Disciplinary Sanctions by the Instructor:

(1) Where an instructor concludes that a student enrolled in one of his or her courses has engaged in academic misconduct, the instructor may impose one or more of the following disciplinary sanctions, as listed under paragraph III, subsections (a) through (e):

(a) An oral or written notice of misconduct;
(b) An assignment to repeat the work, to be graded on its merits;
(c) A lower or failing grade on the particular assignment or test;
(d) A lower grade in the course;
(e) A failing grade in the course.

(2) When possible, prior to imposing a minor sanction, the instructor shall notify the student that the instructor believes an act of academic misconduct has occurred, that a sanction may be imposed, and that a Notification of Academic Dishonesty Form will be filed with the Office of the Provost.

(3) Upon the imposition of a minor sanction under this section, the instructor shall notify the Office of the Provost. Notification to the Office of the Provost shall occur within 10 days, using the Notification of Academic Dishonesty Form (https://powerforms.docusign.net/0687535d-2f15-49db-b1e5-1190d3448cb7?env=na2), and shall include identification of the student, a description of the misconduct and a specification of the sanction imposed.

(4) Within 10 days following receipt of such notice, the Office of the Provost shall provide notice of the imposed discipline to the student, the instructor and to the Academic Dean. Notification to the student shall include a statement of the misconduct, specification of the sanction imposed, a statement indicating the students right to an appeal before the Academic Dean and a link to the policy and procedures set forth herein.

(5) A student who receives notice of a disciplinary sanction imposed under this section has the right to a hearing before the Academic Dean to contest the determination that academic misconduct occurred or the disciplinary sanction imposed or both. If the student desires such a hearing, he or she must file a written request with the Office of the Provost and the Academic Dean within 10 days of receipt of notice from the Office of the Provost.

(6) In the event that the student does not file a written request for an appeal within 10 days, the Office of the Provost shall review the matter with respect to the subject student and may, at his or her discretion, uphold the recommended sanction or impose a major sanction. In any event, the Office of the Provost shall, within a reasonable time, provide notice of the outcome to the student, the instructor and to the Academic Dean.

VI. Recommendation of Major Disciplinary Sanction by the
Instructor:

(1) Where an instructor concludes that a student enrolled in one of his or her courses has engaged in academic misconduct in the course, the instructor for that course may recommend one or more of the following disciplinary sanctions:

   (f) A non-deletable failing grade in the course;
   (g) Suspension from the University
   (h) Expulsion from the university.

(2) When possible, prior to the recommendation of a major sanction, the instructor shall notify the student that the instructor believes an act of academic misconduct has occurred, that a major sanction is being recommended, and that a Notification of Academic Dishonesty Form will be filed with the Office of the Provost.

(3) Upon the recommendation of a major sanction under this section, the instructor shall notify the Office of the Provost using the Notification of Academic Dishonesty Form (https://powerforms.docusign.net/0687535d-2f15-49db-b1e5-1190d3448cb7?env=na2). Notification to the Office of the Provost shall occur with 10 days and shall include identification of the student, a description of the misconduct and a specification of the sanction recommended.

(4) Within 10 days following receipt of such notice, the Office of the Provost shall provide notice of the recommended discipline to the student, the instructor, and the Academic Dean. Notification to the student shall include a statement of the misconduct, specification of the sanction recommended, a statement indicating the students right to an appeal before the Academic Dean and a copy of the policy and procedures set forth herein.

(5) A student who receives notice of a disciplinary sanction recommended under this section has the right to a hearing before the Academic Dean to contest the determination that academic misconduct occurred or the disciplinary sanction recommended or both. If the student desires such a hearing, he or she must file a written request with the Office of the Provost and the Academic Dean within 10 days of receipt of notice from the Office of the Provost.

(6) In the event that the student does not file a written request for an appeal within 10 days, the Office of the Provost shall review the matter and may, at its or her discretion, impose or modify the sanction recommended. In any event, the Office of the Provost shall, within a reasonable time, provide notice of the outcome to the student, the instructor, and to the Academic Dean.

VII. Appeal to the Academic Dean: When an appeal to the Academic Dean is commenced in accordance with the provisions set forth in Paragraphs V(5) or VI(5), the Academic Dean shall proceed in accordance with this section to consider one or more of the disciplinary sanctions listed in paragraph IV, subsections (1) (a) through (h).

(1) Conference With Student: The Academic Dean shall offer to discuss the matter with the student. The purpose of this discussion is to permit the Academic Dean to review with the student the charges levied against him or her and to afford the student an opportunity to respond.

(2) Conference With Instructor: The Academic Dean shall attempt to discuss the matter with any involved instructor. This discussion may occur either before or after the conference with the student. It should include consultation with the instructor on the facts underlying the alleged academic misconduct and on the appropriateness of the imposed or recommended sanction.

(3) Determination that No Academic Misconduct Occurred: If, as a result of discussions under subsections (1) and (2), the Academic Dean determines that academic misconduct did not in fact occur or that the disciplinary sanction is not appropriate under the circumstances, the Academic Dean shall notify the instructor and the Office of the Provost. The Office of the Provost shall promptly thereafter notify the student and take appropriate action with respect to the student records.

(4) If, as a result of discussions under subsections (1) and (2), the Academic Dean determines that academic misconduct did occur and that one or more of the disciplinary sanctions listed under paragraph III, subsections (1) (a) through (h) is appropriate, the Academic Dean shall prepare and forward to the Office of the Provost, within 10 days, a written Finding of Misconduct which shall include identification of the student, a description of the alleged misconduct, a summary of evidence, findings of fact and a specification of the disciplinary sanction imposed.

VIII. Appeal to the Office of the Provost

The decision reached by the Academic Dean may be appealed to the Provost Office of the Provost if the student believes that he or she did not receive due process.

Grounds for Appeal of Due Process

An appeal to the Office of the Provost shall be limited to a review of supporting documents and the process and outcome of the Academic Dean or designee for one or more of the following grounds:

Bias by the Instructor, Academic Dean, or designee substantially influenced the outcome of the process to the detriment of the student.

New, relevant information has come to light that was not available at the time of the hearing by the Academic Dean.

Unusual procedures were followed or the procedures outlined herein were not followed, to the detriment of the student.
If the student desires such a hearing, he or she must file a written request with the Office of the Provost and the Academic Dean within 10 days of receipt of notice from the Office of the Provost. The request must be based upon the Grounds for Appeal listed above.

(2) When an appeal to the Office of the Provost is commenced in accordance with this paragraph, the Office of the Provost shall review the matter with respect to the student and may, at his or her discretion, uphold, vacate or modify the discipline imposed or direct such appeal to be heard by the Academic Integrity Appeals Board. In any event, the Office of the Provost shall, within a reasonable time, provide notice of the outcome to the student, instructor, and to the Academic Dean.

(3) In the event that the student does not file a written request for an appeal within 10 days, the Office of the Provost shall review the matter with respect to the student and may, at his or her discretion, uphold or modify the discipline imposed. In any event, the Office of the Provost shall, within a reasonable time, provide notice of the outcome to the student, instructor and to the Academic Dean.

IX. Role of the Academic Integrity Appeals Board:

(1) The Academic Integrity Appeals Board is an ad hoc committee appointed by the Office of the Provost and consists of a minimum of three faculty members chosen by the Office of the Provost with no two members selected from the same College; the board shall not include a faculty member from within the department initiating charges of academic dishonesty. The Board is chaired by the Office of the Provost who shall vote only in the case of a tie. [Or One member shall serve as Chair at the direction of the Office of the Provost. The Chair shall vote only in the case of a tie.]

When an appeal is directed to the Academic Integrity Appeals Board by the Office of the Provost in accordance with the provisions set forth in Paragraphs VIII, the Academic Integrity Appeals Board shall schedule the hearing, within a reasonable time period, at a time that is mutually agreed upon by the student, Office of the Provost and members of the Academic Integrity Appeals Board.

(2) Reasonably in advance of the hearing, the Academic Integrity Appeals Board shall obtain from the Academic Dean, in writing, a full explanation of the facts upon which the determination of misconduct was based and shall provide to the student a copy of the policy and procedures set forth herein.

(3) The hearing before the Academic Integrity Appeals Board shall be conducted in accordance with the following requirements:

(a) The Academic Integrity Appeals Board shall consider relevant evidence including documentary evidence and testimony of the instructor, student, Chair and/or Dean where appropriate.

(b) The student shall have the right to be heard and to present relevant evidence, including documentary evidence and the testimony of witnesses, in his or her own behalf.

(c) The Academic Integrity Appeals Board shall maintain a record of the hearing including any and all pleadings and documentary evidence presented.

(d) The Academic Integrity Appeals Board shall prepare written findings of fact and a written statement of its decision based upon the record of the hearing.

(e) The Academic Integrity Appeals Board may find academic misconduct and impose a sanction of suspension or expulsion only if the proof of such misconduct is clear and convincing. In other cases, a finding of misconduct must be based on a preponderance of the credible evidence.

(f) The Academic Integrity Appeals Board may impose a disciplinary sanction that differs from the recommendation of the Academic Dean.

(g) The instructor or Academic Dean may be witnesses at the hearing conducted by the Academic Integrity Appeals Board, but shall not have responsibility for conducting the hearing.

(4) Determination that No Academic Misconduct Occurred: If, after the hearing, the Academic Integrity Appeals Board determines that there is insufficient evidence that academic misconduct occurred or that no disciplinary sanction is appropriate under the circumstances, the Academic Integrity Appeals Board shall notify the instructor, the Academic Dean and the Office of the Provost. The Office of the Provost shall promptly thereafter notify the student and take appropriate action with respect to the student records.

(5) Process Following Determination by the Academic Integrity Appeals Board that Academic Misconduct Occurred:

(a) If, after the hearing, the Academic Integrity Appeals Board determines that academic misconduct did occur and that one or more of the disciplinary sanctions listed under paragraph III, subsections (1) (a) through (h) is appropriate, the Academic Integrity Appeals Board shall prepare and forward to the Office of the Provost, within 10 days, a written Finding of Misconduct which shall include identification of the student, a description of the misconduct and a specification of the disciplinary sanction to be imposed.

(b) Within 10 days following receipt of the written Finding of Misconduct from the Academic Integrity Appeals Board, the Office of the Provost shall provide written notice of the imposed discipline to the instructor, the Academic Dean and
the student.

Academic Standing

- Warning Notice
- Probation
- Academic Dismissal and Reinstatement
- Graduate Fresh Start
- Spring 2020 Academic Standing

GPA Minimum

No more than 6 course credits of grades below a B may be counted toward the master’s degree; no more than 9 credits of the same grades may be counted toward the doctorate. No graduate degree will be awarded to any student whose overall cumulative grade point average falls below 3.0.

Academic Standing

The university will temporarily suspend our student Academic Standing status process. Designations of Warning, Probation, or Dismissal will not appear on transcripts for Spring or Summer 2020. Students will maintain their spring/summer 2020 academic standing through the Fall of 2020.

Warning Notice

Any graduate student whose semester grade point average (GPA) falls below 3.0 will automatically receive a warning notice which will also be sent to the graduate coordinator, and filed with the student’s record in the Registrar’s Office. The student will be strongly advised to meet with the graduate coordinator or his/her designee within 30 days of receipt of the warning notice and develop an academic plan to bring his or her GPA to a level above 3.0.

Probation

Any graduate student whose semester GPA falls below 3.0 for a second time, will automatically receive a letter of probation from the Vice Provost for Graduate Education. Copies of the letter will be sent to the graduate coordinator, chairperson, college dean, and also placed on file with the student’s record in the Registrar’s Office. Within 30 days, the department graduate committee, chaired by the graduate coordinator or his/her designee, will meet with the student and decide whether to recommend loss of degree candidacy. Such a decision or other course of action will be fully documented in writing with copies sent to the chairperson, and college dean. A recommendation of loss of degree candidacy and dismissal are subject to the approval of the college dean.

Academic Dismissal and Reinstatement

Any student whose semester GPA falls below 3.0 for a third time, and whose cumulative GPA is below 3.0, will automatically be dismissed from his or her graduate program and the University. Reinstatement will be considered if the student provides a detailed justification and academic plan concerning how he or she will correct this academic deficiency. The plan must be attached to a Graduate Academic Petition and approved by the graduate coordinator, chairperson, the college dean, and the Vice Provost for Graduate Education or his/her designee. If any of the above individuals disapproves of the reinstatement, the dismissal will remain in effect and no subsequent appeals will be considered.

Independent of the warning/probation/dismissal system, the dean of the college where the student’s degree program resides may at any time examine the performance of any student not meeting the academic standard expected of graduate students within that college and recommend to the appropriate graduate committee a course of action including dismissal.

For the procedure for formal adjudication of any academic issues (non-misconduct) which may arise, please see University Appeals Process Regarding Academic (non-misconduct) Issues of Graduate Students.

Graduate Fresh Start

Master and Doctoral degree candidates and non-degree students who have been absent from the University for four years or longer may be readmitted under the program Graduate Fresh Start. If admitted into a degree granting program, under the terms of Graduate Fresh Start, a returning graduate student will be treated as if s/he were a new student. A maximum of two courses (six credits) at the 500 level or higher completed during earlier periods of enrollment with grades of "B" or better may, with the approval of the degree granting department, be transferred into the degree program. These courses must be transferred via an academic petition and will be accepted toward graduation but not included in the cumulative grade point average (GPA). Thesis and dissertation research credits are ineligible for transfer. Courses completed during earlier periods of enrollment with grades below "B" are not eligible for transfer. A student may be readmitted under the Graduate Fresh Start program only once at the graduate level.

Students who wish to be considered for the Graduate Fresh Start Program must follow the normal procedures for admission to the University and file a Graduate Fresh Start Contract (https://www.uml.edu/docs/graduatefreshstart16_tcm18-229435.pdf) (pdf). Academic Petitions for transfer credits must be approved by the appropriate graduate coordinator and/or department chair of the degree granting department, and must be filed with the University Registrar. In addition, the student must submit a personal statement which addresses personal...
and professional growth during the period of time in which the student was absent from the University which supports the students potential for academic success. If admitted, credits and GPA start at zero. Transfer courses may count towards the degree, but are not included in the GPA.

All courses taken and grades achieved during earlier periods of enrollment will appear on the transcript along with a notation that they are not included in the cumulative grade point average. Once this change is made to the academic record, the change can NOT be reversed.

Spring 2020 Academic Standing

The university will temporarily suspend our student academic standing status process. Designations of "Warning", "Probation", or "Dismissal" will not appear on transcripts for Spring 2020. Students will maintain their Spring 2020 academic standing through the Fall of 2020. The university will determine students who have earned a place on the dean's list based on their calculated letter-grade GPA for Spring 2020.

Acceptance of Foreign or American Master's Degree toward Doctoral Requirements

Students accepted into a doctoral program who hold a master's degree in the same or a closely related discipline from a U.S. or foreign academic institution will have their transcripts and supporting documentation reviewed by the department graduate committee.

The committee may choose one of the following actions:

1. Approve all coursework and thesis for the master's degree up to the total number of credits granted by the University of Massachusetts Lowell department for its master's degree, and thereby require the student to complete only "beyond the master's" course/thesis credits for the doctorate.

2. Accept the U.S. or foreign master's degree, but because of deficiencies in the student's master's program, require a limited number of graduate courses to be added to the total credits required for doctoral degree completion "beyond the master's".

3. Require that a student with a U.S. or foreign master's degree obtain a University of Massachusetts Lowell master's degree before proceeding to the doctorate.

All coursework for U.S. or foreign master's degrees considered for approval by the department must be at a grade level of B or better. Official, documented verification of the degree awarded must also be provided.

Commencement

CommencementConferring of DegreesAcademic HonorsReplacement Diploma

Commencement

Graduation exercises are held once a year at the end of the spring semester. Students who have completed degree requirements during spring semester or the previous summer term or fall semester are permitted to attend commencement exercises, and their names are listed in the commencement booklet. Attending commencement exercises is not compulsory. An individual who wishes to receive a diploma by mail must notify his/her college dean and file a corrected address through student self service if he or she anticipates moving from a previously reported permanent address.

Conferring of Degrees

- In May for students completing degree requirements during the spring semester.
- In late August for students completing degree requirements during the summer term.
- In February for students completing degree requirements during the fall semester.

Individuals who wish to submit verification of degree completion to employers or to graduate schools during the period between the end of their final grading period and the awarding of diplomas may obtain a letter of completion from the Registrars Office.

Academic Honors

Due to the many fields and diversity of study at UMass Lowell, academic honors for graduate students are discipline-based and vary within respective colleges. Honors for graduate students are not listed on transcripts.

Replacement Diploma

Replacement diplomas may be ordered through Registrar's Office for an additional fee.

Registration and Enrollment Policies
Continuous Registration

In order to maintain continuity of enrollment, a matriculated student must register each fall and spring until the program of study is complete and the degree has been earned. A graduate student who plans to receive his/her graduate degree in the summer term (awarded in August) must register during the previous summer session in order to maintain continuous matriculation.

If for any reason a student is not registered for a course (because of a leave of absence or because the thesis or dissertation has been successfully defended, but the final manuscript has not been submitted to the library), the student must register for CONT.6010 (Continued Matriculation) in order to maintain continuous registration. Since students are not allowed to register if they have outstanding financial obligations to the university, it will be necessary for them to clear their financial record in order to register for Continued Matriculation.

Master’s students may only register for two semesters of Continued Matriculation. Doctoral candidates may register for up to three semesters. Exceptions to the this rule may be granted with approval of the academic department (Graduate Coordinator/Department Chair) and college dean. Students completing a thesis or dissertation must also have the approval of their thesis/dissertation advisor. Exceptions must be requested via a Graduate Academic Petition. If an exception is not granted, the student will be withdrawn from the University and need to reapply. If a student reapplyes and is readmitted, the rules regarding the Statute of Limitations restart.

Continued Matriculation does not entitle a student to any use of university facilities, services or resources, but only maintains an active record and provides for appropriate mailings. Students who are engaged in academic work necessary to complete their thesis or dissertation, participate in a required full time internship or curricular practical training, or otherwise engage in or make use of University facilities or other resources must register for a minimum of 1 credit. (Note: Specific internship/CPT requirements will vary by department and students may be required to register for 3, 6, or 9 credits depending upon their program of study.)

The rules regarding the Statute of Limitations for the completion of master’s and doctoral degrees still apply to students registered for Continued Matriculation.

All international students on F-1 or J-1 visas must register as full-time students (9 credits) each semester until their degree requirements are completed. Any variance from this policy must be approved by the International Student and Scholars Office.

A student who fails to maintain continuous matriculation loses the status of a degree candidate and must reapply to the Graduate Admissions Office (https://www.uml.edu/Grad/default.aspx) (www.uml.edu/grad (https://www.uml.edu/Grad/default.aspx)) for readmission and for renewal of candidacy.

Dropping Classes and Refund Policy

Graduate students may drop courses during the first ten days of classes and receive a refund. No refund will be given after these time periods. To formally withdraw from a course during this period, or thereafter, the student must drop the course through SiS (https://www.uml.edu/Enrollment/SiS/default.aspx) self service (www.uml.edu/enrollment/isis/default.aspx (https://www.uml.edu/Enrollment/SiS/default.aspx)). If the student fails to officially drop a course, he or she will remain enrolled and be required to pay for tuition and fees. In addition, if the student does not drop a course and does not attend classes, he or she will receive an "F" on the official transcript.

Changes in Registration

Courses may be added or dropped through self-service in SiS (https://www.uml.edu/Enrollment/SiS/default.aspx) (www.uml.edu/enrollment/isis/default.aspx (https://www.uml.edu/Enrollment/SiS/default.aspx)). Students who wish to add a course during the sixth through 10th day of classes will need a permission number from the instructor of the course. Permission numbers are not needed to drop a course. In addition, students may change from audit to credit or from credit to audit during this period. Courses dropped during the first 10 academic days will not appear on the student’s permanent record. No new courses may be added and no course may be changed from audit to credit after the tenth academic day. Thereafter, a student wishing to drop courses must do so by the date indicated in the Graduate Academic Calendar (http://www.uml.edu/Registrar/Calendars/default.aspx (https://www.uml.edu/Registrar/Calendars/default.aspx)).

No refund of tuition and fees is allowed after the tenth day of the semester. The grades for courses dropped after the tenth day will appear as W on the student’s record.

Change of Program

A graduate student wishing to change departments or transfer to a doctoral program upon completion of his or her master’s degree must follow the steps listed below:

1. No transfers will be considered until the student has been
in the original department in which he or she was accepted for at least one semester.

2. All sections of a new application sheet must be completed.

3. If so desired, the student may request that all test scores, letters of recommendation, etc., in his or her original file be used as part of his or her new application package.

4. The student must specify on the application form when his or her master's degree will be completed and when he or she will actually begin doctoral studies (for students applying to a doctoral program).

5. A check made payable to University of Massachusetts Lowell to cover the application fee must be included, or payment must be made by credit card when applying online.

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.

During the summer term students are classified as full-time when they are registered for a minimum of 9 credits which may combine courses/credits from the different sessions within the summer term. Students who enroll in only one of the accelerated summer session (summer I or summer II) may be considered by the institution as the equivalent to full-time for the specific time period of that session only when registered for a minimum of 6 credits. This is for enrollment purposes only. Please note: Financial aid, veterans benefits or other types of aid define 9 credits for full-time study.

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.

Course Designations

- Course Numbering System
- Continuing Graduate Research
- Course Prefixes
- Audit

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 given semester is nine credits.
Course

Numbering System and Designation:

- **4000-4999** - Undergraduate courses usually designed for juniors or seniors; no more than six credits may be taken for graduate credit with the permission of the graduate coordinator.
- **5000-5999** - Courses for graduate credit, but which may be taken by advanced undergraduates with the advisor’s permission.
- **6000-6999** - Graduate courses which are open only to graduate students.
- **7000-7999** - Seminars, special topic courses, projects, or thesis research for advanced candidates in master’s and doctoral degree programs.

Each course offering is designated by a four letter prefix and a four-digit course number (e.g., BIOL.5290).

Continuing Graduate Research

Once a student has completed the required number of credits for master’s or doctoral thesis/dissertation research with grades of PR or S (see summary of degree credit requirements), he or she will not be allowed to sign up for additional thesis/dissertation research credits. Instead, if required for teaching/research assistantships or immigration/visa purposes, the student may enroll in 3, 6, or 9 credits of Continuing Graduate Research designated _ _763, 766, or 769_ _ _ where the first two blanks represent the departmental designation, 3, 6, and 9 indicate the respective number of credits, and the last three blanks are the standard numbers which code to a particular faculty member in the department.

The two digit college prefix identifies a college department and/or special area. The three-digit course number identifies the course level.

Course Prefixes

Each college department and/or special subject area has been assigned an identifying two digit number within the numerical ranges specified as follows:

- **Education** - EDUC
- **Engineering** - CHEN, CIVE, EECE, ETEC, ENVE &MECH, MTEC, ENGY, ENGN, PLAS
- **Health** - PUBH &AREO, HSCI, NURS, DPTH, NUTR, HSCI, MLSC, EXER
- **Humanities/Social Sciences, Fine Arts** - AMST, LGST, ENGL, HIST, CRIM, PHIL, POLI, PSYS, ASP, SOCI, ECON, WLFT, WLGE, WLIT, WLAR, WLKH, WLCH, WLPO, WLAN, WLSI, WLSP, WLLA, ARHI, FAHS &ARTS, MUTH, MUAP MUED, MUHI, MUPF, MUEN,MUBU, MUSR, AEST
- **Management** - ACCT, FINA, MKTG, POMS, MIST, ENTR, MGMT, BUSI
- **Science and Math** - BIOL, LIFE, CHEM, ATMO, ENVI, GEOL, INFO, COMP, MATH, MSIT, PHYS, POLY, RADI
- **Biomedical Engineering** - BMBT
- **Marine Science** - im

Audit

A graduate student may, upon approval of the advisor and the instructor, register for a course on an audit basis, but must pay the full amount of tuition and fees. An audit student is not required to take tests or the final examination. A change in registration from audit to credit or credit to audit must be done during the add/drop period. Under no circumstances can a course taken for audit be given credit at a later date.

Equal and Fair Treatment

Under federal and state laws, all students are protected from discrimination based on race, color, religion, national origin, disability, gender, (including sexual harassment), age, sexual orientation, marital or veteran status. If you feel that you have been discriminated against based upon any one of these areas, you must contact Equal Opportunity and Outreach (EOO). These protections also include retaliation for filing complaints of discrimination. Concerns regarding course offerings, instructor and student attitudes should also be directed to EOO staff at 978-934-3565.

Students are responsible for adhering to the polices of the University regarding equal and fair treatment.

Graduate Grading Policies

Grading System

-Spring 2020 Grading Scheme
Grade Exclusion
Grades for Projects, Theses/Dissertations and Seminars
Incompletes
Course Listing on the Graduate Transcript
Audited Courses
Grade Appeal Process

Grading System

The grading system uses grades:

- **A+(4.0)**, **A(4.0)**, **A-(3.7)**
- **B+(3.3)**, **B(3.0)**, **B-(2.7)**
- **C+(2.3)**, **C(2.0)**
- **F(0.0)**
- **FX (0.0)** Failed due to Academic Misconduct (May not be replaced or deleted)

The following special grades are also used:

- **INC** (Incomplete)
- **S** (Satisfactory, B or better)
- **U** (Unsatisfactory) for projects, theses/dissertations, and seminars only
- **AU** (Audit)
- **W** (Withdrawal from a course or from the University)
- **X** (Withdrawal because of illness or personal emergency)
- **Y** (University withdrawal for non-academic reasons)
- **PR** (In Progress for theses or dissertations)
- **NC** (No Credit for theses or dissertations where no progress has been made)

A student registering for research will do so each semester up to the total number recommended. No graduate degree will be awarded to a student whose cumulative average for course work in his or her program is below 3.0. Some programs may require a higher grade point average for graduation. The cumulative grade point average is computed from all graduate level courses taken for a grade at the University of Massachusetts Lowell.

**SPRING 2020 GRADING SCHEME**

Faculty Senate passed a spring 2020 grading scheme on March 25, 2020:

For Spring 2020, any grade of F will be converted to NC and not factored into the students GPA. Students may submit requests to change their grading scheme to Pass-No Credit option from the last day of classes, May 1, 2020 through May 15, 2020. Requests for change of grading scheme may only be made by the student. A new form will be created for this purpose, and will be made available by the start of the advising period. Pass-No Credit courses earn credits when the grade of P is assigned, but these credits are not qualitatively weighted and hence do not affect a students academic average. Requests for changes of grading scheme will be approved by the deans office of the students home college, regardless of which college offers the course in question.

Students may present a grade of P in a prerequisite course taken in Spring 2020 to satisfy the enrollment requirement for a postrequirement course that normally requires a specific minimum letter grade in the prerequisite with departmental approval.

Where a programs professional accreditation requires students to be evaluated with a letter grade, no requests for P/NC grading schemes will be granted.

A course with a Pass/No Credit election cannot be applied to the Universitys Bachelors to Masters Program.

There are no changes to the current transfer credit policy, and letter grades are required for transfer consideration.

Changes of grading scheme are final.

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<thead>
<tr>
<th>Letter Grades Are Factored Into Your GPA</th>
<th>Earned Credits</th>
<th>P/NC Grades Are Not Factored Into Your GPA</th>
<th>Earned Credits</th>
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</table>

*Based on a typical 3-credit course.

Grade Exclusion

A request may be submitted to omit a specific course (grade and credits) from the GPA for matriculated students. Such a request must be presented on an Academic Petition, provide detailed justification for the specific action, and certify that the action has been approved by a majority of the departmental graduate committee. Only one grade exclusion in total, including a grade for a repeated course, will be permitted for each degree sought by the student as recommended by the departmental graduate committee. However, the official transcript will list grades for all undergraduate and graduate courses taken at the University with the notation that the grade and credits are excluded from the GPA. Once a grade exclusion has been processed it may not be reversed. Additionally, grade substitutions are not permitted.
Grades for Projects, Theses/Dissertations and Seminars

Spring 2020 Grading Scheme
- Students may NOT elect Pass/NC for thesis and dissertations.

- Students may elect Pass/NC for projects and seminars graded S or U.

  - **Projects** (Enrollment Restricted to Matriculated Graduate Students):
    - Only one of three grade designations will be allowed for projects:
      - S for projects completed at a satisfactory level
      - U for unsatisfactory completion of a project (no credit toward degree requirements)
      - INC Incomplete

  - **Theses/Dissertations** (Enrollment Restricted to Matriculated Graduate Students):
    - PR will be given for thesis/dissertation research if the student has made satisfactory progress during the semester.
    - NC will be given if the student has made no progress during the semester on thesis/dissertation research.
    - U Unsatisfactory (no credit toward degree requirements)

After successful defense of the thesis/dissertation, a grade of "S" (Satisfactory) will be given for all semesters of the thesis/dissertation research. Only the Registrar's Office can issue this grade.

- **Seminars**
  - S - Satisfactory
  - U - Unsatisfactory (no credit toward degree requirements)
  - INC - Incomplete

Under no circumstances will letter grades (A, B+, etc.) be allowed for projects, theses/dissertations, or seminars.

Incompletes

If, because of unusual circumstances, a student is unable to meet all the requirements of the course by the end of a semester, the grade of Incomplete (INC) may be given.

Responsibility for making arrangements with an instructor to complete all outstanding coursework rests entirely with the student, who must complete all outstanding coursework by the date listed on the Graduate Academic Calendar ([https://www.uml.edu/Registrar/Calendars/default.aspx](https://www.uml.edu/Registrar/Calendars/default.aspx)). Under no circumstances will a student be allowed to graduate with incomplete(s) on his or her transcript.

Prior to completion of the missing work, the incomplete will not be computed into the grade point average (GPA). If the student completes the missing work within the specified period, the instructor must evaluate the work and turn in a grade change form to the Registrar’s Office before the deadline for instructors to submit final grades for incomplete courses as specified on the Graduate Academic Calendar ([https://www.uml.edu/Registrar/Calendars/default.aspx](https://www.uml.edu/Registrar/Calendars/default.aspx)). However, if the student does not complete the missing work by the specified date and no grade change form is submitted by the instructor, the student’s grade will automatically change to a grade of "F" and be computed into the GPA.

Course Listing on the Graduate Transcript

All graduate courses for which a student registers (including repeated courses) are listed on the transcript and are used to calculate the student’s grade point average whether or not they are taken to fulfill degree requirements. In addition, undergraduate courses which a student takes to fulfill prerequisite requirements before or during matriculation in a graduate program, or courses taken for personal enrichment, will also be listed on the transcript.

Audited Courses

A graduate student may, upon approval of the advisor and the instructor, register for a course on an audit basis, but must pay the full amount of tuition and fees. An audit student is not required to take tests or the final examination. A change in registration from audit to credit or credit to audit must be done during the add/drop period. Under no circumstances can a course taken for audit be given credit at a later date.

Graduate Clearance

To apply for Graduation, graduate students must fill out a Declaration of Intent to Graduate (DIG) form and have it approved by their Graduate Coordinator and (if applicable), Thesis/Dissertation Advisor.

The Registrar’s Office will verify number of credits, final grades, GPA requirements an if applicable submission of
thesis/dissertation prior to awarding the degree.

Additional Requirements for Students Completing a Thesis or Dissertation

All students who are completing a thesis or dissertation must also submit one clean copy (NOT the original) of the signature page for the thesis or dissertation. The signature page must be signed and dated by the thesis/dissertation advisor and all committee members. Copies of the Thesis or Dissertation must be submitted to the Library for binding and microfilming by the deadline date. In addition, doctoral students are required to complete the "Survey of Earned Doctorates" online, you will be emailed the information when your submit your DIG form.

Graduate Grade Appeal Process for Students

The instructor of the class is the primary authority with respect to a student's proficiency and final grade in that course. A student who believes that his or her final grade reflects an erroneous, capricious, arbitrary, or prejudiced academic evaluation may appeal the grade. The academic judgment used in determining the merits of the grade to be awarded shall not be reviewable. This process does not apply to cases of academic dishonesty, which are adjudicated through the "academic dishonesty process."

1. The student may file an appeal of his or her complaint, in writing, to the instructor within 30 days after a final grade is posted to the student's record. The instructor must respond within 14 days of receiving the appeal.

2. If the student remains dissatisfied by the decision of the instructor under step (1), he or she may, within 14 days after formal receipt of the instructor’s final decision, appeal, in writing, to the chairperson of the program (or the Dean of the College if the instructor is the chairperson) in which the course or other exercise or activity is offered. The chairperson must respond within 14 days of receiving the appeal. The decision may be: (a) that the appeal be dismissed; (b) if the student provides demonstrable evidence of an erroneous, arbitrary, capricious, or prejudiced academic evaluation, then the chairperson will recommend appropriate remedies that a grade be changed or the student be allowed an opportunity to retake an examination or other exercise; or (c) that another appropriate remedy be administered.

3. If no satisfactory resolution is reached in step (2) then the student or the instructor may appeal, in writing, to the Dean of the College within 14 days after formal receipt of the chairperson’s final decision.

4. The Dean, after discussion with the appropriate parties, may resolve the grievance by agreement or render a decision within 21 days of receipt of the written appeal. The decision may be: (a) that the appeal be dismissed; (b) if the student provides demonstrable evidence of an erroneous, arbitrary, capricious, or prejudiced academic evaluation, then the Dean will recommend appropriate remedies that a grade be changed or the student be allowed an opportunity to retake an examination or other exercise; or (c) that another appropriate remedy be administered.

5. The decision of the Dean is final and not subject to additional appeal by either student or instructor. The appeals process ends at this step.

6. The Department chair or his/her designee is responsible for keeping a record of the appeal on file in accordance with University Records Retention Policy.

Right of Access to Student Records

Access
University Student Records
Release of Student Records
Release Exclusions
Additional Information

Access

The Family Educational Rights and Privacy Act of 1974 (FERPA) grants any student currently in attendance, or any former student, the right of access to inspect or review his or her educational files, records, or data. Students who wish to inspect their records must file a Right of Access form with the office or department in which the desired record is kept. Right of Access forms are available in the Office of Student Services or through student self service. Wherever practicable, within ten days of receipt of the Right of Access form, the office or department will notify the student as to the date, time, and location when the desired record will be available for inspection. If a student believes that circumstances effectively prevent inspecting and reviewing the records at the designated
date, time and location, he or she may request alternative inspection arrangements or copies of the records instead, subject to a fee for copies. The Dean of Students or the Deans designee will consider the request.

University Student Records

The University maintains the following general records on students:

**Admission File** - Admissions Office  
(https://www.uml.edu/Grad/default.aspx) - www.uml.edu/grad

**Permanent Academic Records** - Registrar’s Office  
(https://www.uml.edu/Registrar/default.aspx) - www.uml.edu/registrar

**Financial Aid Records** - Financial Aid Office  

**Health Records** - Health Services Office -  
www.uml.edu/student-services/health/

**Account and Payment Records** - Student Financial Services Office  
(https://www.uml.edu/thesolutioncenter/bill/tuition-fees/default.aspx) - www.uml.edu/Tuition-fees/

**Campus Conduct Records** - Dean of Students Office -  
www.uml.edu/student-services/Dean/

The file of each student must contain a record of all non-University affiliated individuals or organizations requesting access to information in the file, plus statements that specify the legitimate educational purposes for which access was requested.

Except as otherwise permitted under FERPA, information or records concerning individual students may not be released to any individual or agency without the students written permission. Any request for such information received without such written permission will not be honored and will be returned with a request for a written release from the student.

**Release of Student Records**

FERPA allows release of a students education records without the students written permission under certain circumstances, including the following:

1. To personnel of the University, i.e., faculty, administrators,
or staff for legitimate educational purposes only.
2. To officials of other institutions in which the student seeks admission or intends to enroll, provided that the student is notified of the release.
3. To federal or state officials in connection with the audit and evaluation of programs funded by federal or state governments, with the enforcement of legal requirements that relate to such programs, or in connection with the students application for or receipt of financial aid.
4. To accrediting organizations in order to carry out their accrediting functions.
5. To parents who claim the student as a dependent on their IRS statement.
6. In connection with an emergency, to appropriate persons if revealing such information is necessary to protect the health or safety of the student or other persons.
7. In response pursuant to a validly issued subpoena, subject to advance notification of the student unless such notice is prohibited by court order.
8. As otherwise permitted under or consistent with FERPA.

The following data are considered informational in nature and may be released without the permission of the student, at the discretion of the University: students name, major, acknowledgement of a student’s participation in officially recognized activities and sports, weight and height of members of athletic teams, date(s) of attendance; degrees, certificates, awards received; the most recent previous educational agency or institution attended by the student and appointment as a Resident Assistant or Community Development Assistant. For graduate students who are teaching credit courses, work department, office address, and employments category are also defined as directory information.

**Release Exclusions**

Any student who wishes to have some or all of his or her directory information excluded from release by the University without prior permission must complete the appropriate selections available thru student self service  
(https://www.uml.edu/Enrollment/SiS/default.aspx))

**Additional Information**

Any student who believes that his or her records are inaccurate
or misleading may request a hearing with the Dean of Students to discuss the contents of such records and whether or not they need to be changed. Additional information on procedures or policies relating to University compliance with the Family Rights and Privacy Act can be obtained from the Office of Student Services or the Registrar’s Office.

Statute of Limitations (Time Limit for Degree Completion)

A graduate degree, at either the master’s or doctoral level, implies a significant mastery of a discipline within a specified time period. A well designed curriculum is not a mere collection of classes that add up to a set number of credits. It is, rather, a coherent selection of courses with an overall educational achievement that is greater than the sum of its parts. However, this coherence is lost if the program is completed over a long time span.

Master’s degree requirements must be completed within a five-year period from the semester of admission. For those master’s programs requiring 45 or more credits, the time limit is six years.

The doctoral degree must be completed within an eight-year period beginning with the semester of admission as fully matriculated or matriculated with conditions.

A student may obtain an extension of one year by filing an Academic Petition (https://www.uml.edu/docs/petition_grad_tcm18-87176.pdf) (http://www.uml.edu/docs/petition_grad_tcm18-3545.pdf) signed by his or her coordinator, department chair, and college dean, and which is then submitted to the Registrar’s Office.

Time Extension Appeal Procedure

In exceptional cases, an additional extension may be granted by the Graduate Policy and Affairs Committee (GPAC). In this case, the student must submit an Academic Petition (https://www.uml.edu/docs/petition_grad_tcm18-87176.pdf)(http://www.uml.edu/docs/petition_grad_tcm18-3545.pdf), a letter of explanation accompanied by a detailed schedule for degree completion, and a letter from the student’s coordinator or thesis advisor in support of the request.

Transcripts

In order to obtain a transcript, a student may print an unofficial transcript or order an official copy through self-service in SIS (https://www.uml.edu/Enrollment/SiS/default.aspx) (https://www.uml.edu/enrollment/sis/ (https://www.uml.edu/Enrollment/SiS/default.aspx)). If SIS is not available, a transcript may be ordered by filling out a Transcript Request Form (https://www.uml.edu/docs/transcriptrequest_tcm18-3516.pdf) and submitting it to the University of Massachusetts Lowell Registrar’s Office at 883 Broadway Street, Lowell, MA 01854.

Course Listing on the Graduate Transcript

All graduate courses for which a student registers (including repeated courses) are listed on the transcript and are used to calculate the student’s grade point average whether or not they are taken to fulfill degree requirements. In addition, undergraduate courses which a student takes to fulfill prerequisite requirements before or during matriculation in a graduate program, or courses taken for personal enrichment, will also be listed on the transcript.

Transfer Credit

- Spring 2020 Grading Scheme- There are no changes to the current transfer credit policy, and letter grades are required for transfer consideration.

The following are minimal guidelines for transfer of credit. Individual departments are free to impose more stringent requirements. Only courses completed elsewhere within five years prior to the date of admission to a graduate degree program at the University of Massachusetts Lowell may be considered by the faculty of the department for transfer in accordance with the following regulations.

1. A maximum total of 12 graduate credits earned with a grade of B or better taken at another accredited institution may be transferred to a master’s degree program (see individual programs for further restrictions, if any). A maximum of 24 credits with a grade of B or better may be transferred to a doctoral program.

2. Grades of C or better for courses taken at UMass Lowell when the student held non-degree status may also be transferred (by Academic Petition) into a degree program. However, the 6 and 9 credits with grades below a B (graduation limit) for master’s and doctoral degrees, respectively, (see Retention Policy) and calculation of the
cumulative grade point average based on all graduate courses taken at the University (see Academic Grades) remain in effect.

3. An official transcript and description of the course(s) must be submitted with the written request.

4. The courses presented must be from an accredited U.S. or Canadian institution authorized to grant graduate degrees.

5. The courses presented for a master’s degree must not have been used in earning another master’s degree.

6. The courses presented must be appropriate to the degree program for which the applicant is applying.

7. The courses presented must be graduate level.

8. Transfer credit may not be granted for research seminars, clinical courses, practica, internships, or special projects.

9. Transfer credit from another U.S. or Canadian institution must not exceed equivalent course credit (typically 3) at UMass Lowell, and will be based on UMass Lowell’s standard of 37.5 semester contact hours being equal to 3 credits. One and two course credit transfers will also be considered providing they are proportional to the 37.5 semester contact hour standard.

10. Students who wish to transfer credit must file (within the first semester of matriculation) the Academic Petition form available from the Registrars Office.

11. With the approval of the department, a maximum of 6 credits of 4000 level courses taken at the University of Massachusetts Lowell with grades of C or better, not used for the baccalaureate degree, may be considered for transfer and counted toward the graduate degree.

University Appeals Process Regarding Academic (Non-Grade Appeal and Non-Misconduct) Issues

The underlying purpose of the University’s appeals procedure is to guarantee due process and to protect the rights of both students and faculty in graduate programs.

The following procedure provides a mechanism for formal adjudication of any academic issues (non-misconduct and not related to grade appeal) which may arise. (For information regarding the process for grade appeals, see the Graduate Grade Appeal Process.)

Responsibility for initiation of each of the steps belongs to the appellant.

Step 1. If an informal discussion between the student and the instructor or individual with whom the student has a conflict does not resolve the issue, the resolution of an academic appeal of a student should begin within the department. The first step in the resolution of a problem or disagreement should be a discussion between the instructor, the student, and his/her faculty advisor or the coordinator of the program.

Step 2. If the matter cannot be resolved after such a discussion, a formal appeal, in writing and containing the pertinent facts, should be presented by the student to the chairperson/head of the department within two months of the occurrence that precipitated the appeal. Any appeal made outside this time period shall not be considered by any University body. The chairperson of the department will appoint committee composed of faculty members in the department. Within seven working days, this committee shall convene and discuss the appeal with the student and the instructor, coordinator, or individual with whom the student has a conflict. The student may be accompanied by his or her advisor or a faculty representative during the discussion of the appeal. The committee, by a majority vote after deliberations with only members of the committee present, shall render a decision within five working days and notify the appropriate parties in writing with the rationale for the decision included in the notification.

Step 3. If the decision of the departmental committee is not satisfactory to all parties, the appeal may be forwarded to the College Dean within two weeks of the decision of the departmental committee. The Dean will appoint a college committee composed of area coordinators of all graduate programs within the college or a suitable committee of faculty. The committee will be chaired by the college dean, or his/her designee. Within seven working days, the committee shall convene and discuss the appeal with the student. At this level the student may request to be present at the committee meetings, that discussions or proceedings be tape recorded, and that a transcript be prepared from the tape. The request for a recording must be made at the time the appeal is made to the college committee. The college committee shall render a decision by majority vote after deliberations with only members of the college committee present within five working days and notify the appropriate parties in writing with the rationale for the decision included in the notification.
Step 4. If the decision of the college committee is not satisfactory to all parties, the appeal may be forwarded to the Graduate Policy and Affairs Committee (GPAC) within ten working days after the decision of the college committee. The committee shall convene within 10 working days after the GPAC chairperson has received a written request for a hearing from the appellant, and discuss the appeal with the student and faculty advisor or representative. A request for recording and preparing a transcript of the discussions with the student present may be made at the time of appeal. The committee shall render a written decision within five working days and notify the appropriate parties. The decision of the Graduate Policy and Affairs Committee shall be final, and the information accumulated during the appeal procedure shall be forwarded to the Provost to be kept on file. If any decision involving the awarding of a degree is made and the official deadline for graduation exercises has passed during the appeal, the degree date will reflect the initiation of the appeal.

The above time periods define working days as days when classes are in session for the fall and spring semesters. Efforts will be made to honor the same time periods during intercession and June - August although some flexibility must be accepted by the appellant because of potential difficulties in assembling committee members during these periods.

The GPAC chairperson may modify the Step 4 hearing time framework at his/her discretion to coincide with regularly scheduled GPAC meetings. In either of the above cases, the appellant must be notified in writing by the hearing officer (along with an explanation) of any modification of the hearing time schedule. The chairperson may recommend that final voting/discussion of Step 4 cases be done in Executive Session with only committee members present.

Non-Academic Misconduct

Improper conduct or behavior of graduate students is subject to the University of Massachusetts Lowell Student Conduct Code and Judicial Process (https://www.uml.edu/student-services/Student-Conduct/default.aspx). Copies of this document may be obtained from the Dean of Students Office.

Withdrawal Policies

Withdrawal from a Course
Withdrawal from the University

Withdrawal from a Course

A student finding it necessary to withdraw from a course must do so within the time specified in the graduate academic calendar (https://www.uml.edu/Registrar/Calendars/default.aspx). The student's permanent record will indicate a grade of W for the course(s) from which he or she has withdrawn unless the withdrawal has taken place within the first 10 class days of the semester during which no record will be kept. (See Dropping Classes and Refund Policy in this Catalog for information on dropping a course.)

Withdrawal from the University

A student who wishes to withdraw from the University must submit his/her request in writing to the Registrar’s Office. This procedure ensures that the student’s academic and financial obligations are cleared before leaving the University. If a student officially withdraws from the University by the withdrawal date indicated in the graduate academic calendar, the permanent record will indicate a grade of W. If the student fails to follow the official withdrawal procedure and does not withdraw in good standing, the student will not be permitted readmission to a graduate program at the University except under extenuating circumstances.

Withdrawal from courses may have implications for degree progress, veterans benefits, health insurance, financial aid, and immigration status. Students are advised to consult their academic advisor as well as officials in appropriate offices prior to withdrawing from class. Instructors are required to submit a last known date of attendance or academic activity for students who receive a grade of For other non-passing grades. Students who cease attending without officially withdrawing may affect their Financial Aid.

All previous application materials will remain on file for a two year period. At any time during this period, a student who has
offically withdrawn may request readmission by completing and submitting only the cover page of the graduate application and paying the application fee. After two years, a student must file a new, complete application and submit the appropriate fee to the Graduate Admissions Office (https://www.uml.edu/Grad/default.aspx) (www.uml.edu/grad (https://www.uml.edu/Grad/default.aspx)) in order to be readmitted.

Veteran and Military Policies

- Veterans Benefits and Transition Policy
- Military Connected Student Policy

Veterans Benefits and Transition Policy

In compliance with the Veterans Benefits and Transition Act of 2018, section 3679 of title 38, United States Code, the University of Massachusetts Lowell

- will permit any covered individual to attend or participate in the course of education during the period beginning on the date of which the individual provides to the university a certificate of eligibility for entitlement to educational assistance under Chapter 31 or 33 (a certificate of eligibility can also include a Statement of Benefits obtained from the Department of Veterans Affairs (VA) website eBenefits, or a VAF 28-1905 form for Chapter 31 authorization purposes) and ending on the earlier of the following dates: The date on which payment from VA is made to the university 90 days after the date the university certified tuition and fees following the receipt of the certificate of eligibility.
- will not impose any penalty, including the assessment of late fees, the denial of access to classes, libraries, or other institutional facilities, or the requirement that a covered individual borrow additional funds, on any covered individual because of the individuals inability to meet his or her financial obligations to the institution, when the delay is due to the delayed disbursement funding from VA under Chapter 31 or 33.

The statute allows the University of Massachusetts Lowell require covered individuals to take the following actions:

- Submit a certificate of eligibility for entitlement to educational assistance no later than the first day of a course of education.
- Submit a written request to use entitlement. Students must complete the online Veterans Services Certification Request form (https://www.uml.edu/student-services/Veterans/Forms.aspx) through the universitys Office of Veterans Services.
- Provide additional information necessary to the proper certification of enrollment by the university (for example, official transcripts from all previously attended institutions.)
- Pay for the amount that is the difference between the amount of the students financial obligation and the amount of the VA education benefit disbursement. The university may assess a financial hold or late fee if timely payment is not made in the following cases: The covered individual will receive less than 100% tuition reimbursement based on the certificate of eligibility or written request of entitlement provided by the covered individual, or The covered individual incurs charges for housing, meal plans, or other fees or charges that are not eligible for payment by the Veterans Administration.

Note: A covered individual is any individual who is entitled to educational assistance under Chapter 31, Vocational Rehabilitation and Employment, or Chapter 33, Post 9/11 GI Bill.

Military-connected Student Policy

Accommodations for Temporary Short-Term Military Assignments

Students serving in the United States Air Force, Army, Marine Corps, Navy, or Coast Guard, including Active-Duty, Reservists, and National Guard members shall receive academic accommodations for short-term military assignments including Federal or Commonwealth Activation, Unit Training Assemblies (UTAs or "Drill Weekends"), Advanced Individual Training (AIT), Professional Military Education (PME) courses, Temporary Duty Travel (TDY), Temporary Additional Duty (TAD), Temporary Duty Under Instruction (TDI), or other military short-term assignments. Activated students shall provide a copy of military orders, or an advance copy of informal notice, to the Office of Veterans Services as soon as
they are provided by the military unit. The Office of Veterans Services will notify the appropriate Deans office who will then inform the students professors and instructors. The Office of Veterans Services will assist with administrative processes to support the student (i.e., connect with financial aid, registrars office, and other resources as required). In such cases, students have the following options:

- The student may request to drop his or her course(s) and may request a back-out and removal of charges if the request to drop the course(s) is granted when submitting documentation up to and including the last day of classes for the semester.
- If more than half of the semester has been completed and at least one graded assignment has been submitted*: the student may request an Incomplete (INC)* or, *as determined by the instructor, assign an appropriate final grade or credit to a student who has satisfactorily completed a substantial amount of coursework and demonstrated sufficient mastery of course material.

Students who withdraw due to military service obligations may return to the University and request re-enrollment in subsequent terms without penalty if they meet academic requirements for their matriculated program. Military-connected students shall not be academically penalized for their military service or that of their family members.

* Note: Any course work already completed in the term withdrawn from will be forfeited. Students who elect this option will have to repeat courses they withdraw from to get credit for those courses. Students who elect to take an incomplete or receive the grade earned will not receive a refund for tuition and fees.

Students taking Online Courses

Unresolved Complaints

A. OUT-OF-STATE STUDENTS

Out-of-state students residing in NC-SARA (National Council for State Authorization Reciprocity Agreement) states which include all states except California whose complaints are not resolved through the UMass Lowell Institutional Complaint Process can submit complaints to the Massachusetts Department of Higher Education through the SARA Student Complaint Form (https://www.mass.edu/foradmin/sara/complaints.asp).

For more information, contact:

Alexander Nally, Assistant General Counsel
Massachusetts Department of Higher Education
One Ashburton Place, Room 1401
Boston, MA 02108
617-994-6910
SARAInquiries@dhe.mass.edu
(mailto:SARAInquiries@dhe.mass.edu)
www.mass.edu/sara
(https://www.mass.edu/foradmin/sara/home.asp)

B. MASSACHUSETTS RESIDENTS AND ONLINE STUDENTS IN NON-SARA STATES AND TERRITORIES
After you have exhausted the complaint procedures made available by UMass Lowell, located above, if you have a complaint or concern that has not been resolved by UMass Lowell, you may file a general complaint with the Massachusetts Department of Higher Education (DHE) by using the general complaint form (https://www.mass.edu/forstufam/complaints/complaints.asp). The DHE general complaint form should be used by students who are located in:

- Massachusetts
- Non-SARA Member States or Territories (e.g., California, Guam, etc.)

**Online students with non-academic complaints:** If you have a non-academic complaint that you would like to bring to our attention, please use the non-academic complaint form (https://uml.tfaforms.net/218611) to provide us with a brief description of the issue.
Kennedy College of Sciences

The UMass Lowell Kennedy College of Sciences fosters critical and creative thinking for future solutions to environmental, economic and human problems, while helping students to develop the capacity to respond to a changing world.

A wide range of ongoing research and project opportunities exist within the various degree programs, and interdisciplinary study is emphasized. Graduates of these programs are heavily recruited both regionally and nationally by industry and governmental agencies.

Faculty in the Kennedy College of Sciences (https://www.uml.edu/Sciences/faculty-list.aspx)

NOTE: links to department catalog section at bottom of this page.

Graduate Programs Offered

Master of Science (MS) - degree awarded in the following fields:
- Bioinformatics Science
- Biotechnology Option
- Education, Communication and Outreach Option (This program does NOT lead to teaching licensure)
- Chemistry
- Computer Science
- Environmental Studies
- Atmospheric Sciences (Concentration)
- Marine Sciences and Technology
- Professional Science Master’s Option (Coastal and Ocean Administration, Science and Technology)
- Mathematics
- Applied Mathematics Option
- Mathematics for Teachers Option
- Probability and Statistics Option
- Scientific Computing Option
- Professional Science Master’s Option (Industrial Mathematics)
- Physics
- Optical Sciences Option
- Radiological Sciences and Protection

Doctor of Philosophy (PH.D.) - degree awarded in the following fields:
- Chemistry
  - Biochemistry Option
  - Environmental Studies Option
  - Green Chemistry Option
- Computer Science
  - Bio/Cheminformatics Option
  - Mathematical Science Option
- Marine Sciences and Technology
- Physics
  - Applied Mechanics Option
  - Atmospheric Sciences Option
  - Energy Engineering Option
  - Radiological Sciences Option
- Polymer Science
- Polymer Science/Plastics Engineering Option

Links to Department Sections in This Graduate Academic Catalog:
- Biological Sciences
- Chemistry
- Computer Science
- Environmental, Earth &Atmospheric Sciences
- Marine Sciences and Technology
- Mathematical Science
- Physics &Applied Physics
- Radiological Sciences and Protection
Department of Biological Sciences

The following degree programs are available:

- **Doctor of Philosophy in Applied Biology**
  (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
  Biomedical Science, Developmental & Evolutionary Biology, Quantitative Biology & Biophysics, Cellular & Molecular Biology
- **Doctor of Philosophy in Biomedical Engineering and Biotechnology** (Interdisciplinary)
- **Doctor of Philosophy in Chemistry Biochemistry Option**
  (see full description in Chemistry section) (Interdisciplinary)
- **Doctor of Philosophy in Marine Science and Technology**
  (Interdisciplinary)
- **Master of Science in Marine Science and Technology**
  (Interdisciplinary)
- **Master of Science in Biological Sciences**
- **Bioinformatics Option**
- **Biotechnology Option**
- **Education, Communication and Outreach Option**
  (This program does NOT lead to teaching licensure).
- **Graduate Certificates**
  - Biotechnology and Bioprocessing
  - Environmental Biotechnology
  - Molecular and Cellular Biotechnology

Facilities

The Departmental research and teaching instrumentation includes an array of centrifuges (ultraspeed, superspeed, microfuges), electrophoresis equipment (preps and analytical for proteins and nucleic acids, sequencing, isoelectric focusing, pulsed-field), PCR thermal cyclers, HPLC perfusion and other chromatography equipment; UV-visible and fluorescence spectrophotometers, scintillation spectrometers, various microscopes (transmission EM, fluorescence, confocal, inverted phase), microinjection apparatus, flow cytometer, Coulter counter, speed vac, electroporator, microtiter plate reader, fermenters, laminar-flow hoods, and numerous incubators, baths, and ovens for cell growth and temperature-controlled reactions. The facilities include dark rooms, X-ray facility, temperature-controlled plant and animal cell culture incubation chambers and walk-in rooms, and animal quarters. Labs and offices have Internet access and extensive computer facilities such as computerized image processing and microdensitometry.

A new bioinformatic computational lab containing 20 new Dell and PC computers and several iMac stations has recently been opened within the department. Highly specialized equipment in the Center for Advanced Materials in the Chemistry Department, such as transmission and scanning electron microscopes, scanning tunneling-atomic force microscope, secondary ion mass spectrophotometers, and X-ray diffractometers, are available for faculty and student research.

Faculty Research Interests

The graduate faculty in the Department of Biological Sciences are actively engaged in research in the following areas: bioinformatics, biochemistry, molecular biology, cell biology, immunology, neurobiology, developmental biology, tumor cell biology, biogeochemistry, and applied environmental microbiology.

Degree Requirements

A minimum of 30 semester hours of graduate level work is required for the Master of Science degree in Biological Sciences (Note: the Education, Communication and Outreach Option requires 33 credits. The student has a choice of three paths to degree completion in the general Biology degree: Bioinformatics, Biotechnology and Education, Communication and Outreach options: thesis, project, or non-thesis).

Minimal core requirements for all options include 1 semester (3 credits) of Professional Communication in Science and Technology BIOL.6040 (https://www.uml.edu/catalog/courses/BIOL/6040), a graduate colloquium - BIOL.6010 (https://www.uml.edu/catalog/courses/BIOL/6010) (1 credit) and a minimum of 12 credits of formal course work selected from departmental electives (exclusive of thesis, project, problems, or other directed studies).

The remaining credits may be satisfied by additional electives within the department (thesis, project, problems, or more course work), by transfer credit for approved graduate level biological sciences courses taken at other accredited institutions (9 credit maximum), or by graduate courses taken in related disciplines within the University (e.g., bioinformatics, chemistry, environmental sciences, chemical engineering, radiological sciences; 8 credit maximum). There is no formal language requirement.

Students whose professional goals are to continue on for the Ph.D. degree, or who plan to seek employment in academic or industrial research laboratories as technicians or junior scientists are strongly advised to choose the thesis or project option in order to successfully compete for such positions. Students in the non-thesis option should endeavor to select...
courses with accompanying laboratories whenever possible.

Thesis:

In choosing to complete a thesis, the student concentrates on an in-depth, independent, scholarly investigation of a contemporary biological problem. Credit is allowed for 6-12 semester hours of M.S. Thesis Research. After consulting with the research advisor, the student selects two additional faculty members (one of whom must be from within the Department) to serve as members of the Thesis Committee. The student presents to the Committee a proposal of intended research and obtains the Committee’s approval of the research topic. After completing the written thesis, the student gives an oral presentation of his results to the Thesis Committee.

Project:

The project track is designed for independent laboratory investigations of a more limited nature than completing a thesis. Generally, a project is completed in one or two semesters and credit is given for 3 or 6 semester hours of M.S. Project (no more than 6 credits will be allowed).

Non-Thesis:

This track offers course work in breadth and depth, and may be of special interest to secondary school science teachers and individuals already employed in academic, hospital, or industrial laboratories. The course work only track may be completed during the day on a full-time basis or in late-afternoon or evening sessions on a part-time basis. However, since not all day courses are available in the evening sessions, a part-time student’s progress toward the M.S. degree will depend not only on his/her available time and abilities, but also on the scheduling of electives. In some instances, with the consent of a faculty member, an evening student may elect to complete a thesis or project.

Professional Experience:

Credit (BIOL-5000; 3cr) may be requested by individuals who present satisfactory evidence (in the form of a written statement from their current supervisor) of engaging in at least one year of full-time experience in secondary school science teaching, or in an academic, hospital, or industrial laboratory setting.

Professional Communication in Science and Technology

Each student is required to complete one semester of Professional Communication in Science and Technology (BIOL.6040; 3 credits) in Biology.

Master of Science in Biological Sciences - General

The 31 credit program, with the widest flexibility in course selection, allows students to choose a focus of cellular, organismal, ecological, evolutionary, molecular, or physiological biology. Depending on their career goals, students may choose either course work, the project option or the research option. All MS candidates are expected to show sufficient knowledge and skills to pursue independent and creative research.

- Degree Pathway (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Master of Science in Biological Sciences - Bioinformatics Option

The 30 credit option in Bioinformatics prepares students for industry positions in bioinformatics and computational biology by providing interdisciplinary coursework in Biology and other science disciplines which emphasize the biologically-informed analysis and interpretation of biological data. Thus students gain the skills necessary for the analysis of biological datasets, and the opportunity to engage in research experiences that require the application and development of computational analysis to solve biological problems. This option is focused on bioinformatics through a biologically informed lens.

Students completing the Bioinformatics option complete 30 credits: 3 Department of Biological Sciences Bioinformatics course (Course Electives), any 1 related interdisciplinary elective that includes relevant complementary courses from Computer Science, Mathematics, and Chemistry, and up to 4 Biological Sciences electives depending on if the student takes MS Project or Thesis credit.

- Degree Pathway (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Master of Science in Biological Sciences - Biotechnology Option

This option is more structured than the M.S. in Biological Sciences program described above. The core curriculum offers extensive hands-on experience in current techniques and instrumentation. Field trips and seminars afford students an opportunity for interaction with the biotechnology industry. Students are encouraged to conduct research in one of the recognized areas of biotechnology or to present an innovative application of technology or engineering principles to a biological problem of economic interest. The nature and extent of the investigation will determine its degree credit value. Those who enter the program having already completed some of the core courses, or who already have extensive laboratory experience, may consult with an advisor to design a course of study appropriate to their needs. A variety of biotechnology-related electives are available.
Master of Science in Biological Sciences: Education, Communication and Outreach Option

This 33 credit program allows students to gain expertise in the biological sciences, while also taking appropriate coursework in education, psychology, and business that is tailored to their desired career. Students have the opportunity to diversify their coursework into other departments that are relevant for their career paths, without compromising the scientific rigor or their education and training.

Graduates of the Master of Science in Biological Sciences: Education, Communication and Outreach option will be prepared to:

- Communicate biological and related scientific concepts to the public, students and/or their colleagues.
- Effectively communicate using evidence-based approaches, i.e., using active learning, eliciting misconceptions, and supporting constructivist learning.
- Support science-informed decision-making for experts in other areas.
- Interpret, analyze and evaluate evidence-based education research.
- Apply knowledge of biological sciences to the understanding of peer-reviewed research.

II. Doctor of Philosophy Degree Program (Ph.D. in Chemistry-Biochemistry Option)

The Department of Biological Sciences and the Department of Chemistry have developed a program in Biochemistry which results in the award of a Ph.D. in Chemistry. For a full discussion of program requirements, see the section on biochemistry in the Chemistry Department.

III. Doctor of Philosophy Degree Program in Biomedical Engineering & Biotechnology

The department of Biological Sciences offers a Doctorate in Biomedical Engineering and Biotechnology. For a full description of the program, see the five-campus program.

IV. Doctor of Philosophy in Marine Science and Technology (Interdisciplinary)

An interdisciplinary program is offered through the UMass Intercampus Graduate School (IGS). Students graduating with a M.S. or Ph.D. degree from IGS receive a joint degree from the University of Massachusetts Amherst, Boston, Dartmouth, and Lowell. The degree programs are fundamentally grounded in a broad, integrated, interdisciplinary approach to the study of marine sciences and technology. Students located at the four participating campuses are required to complete "core" courses selected from the natural and social sciences to equip them for interdisciplinary studies and research before focusing upon an area of concentration. For a full description of the program, see Marine Science and Technology.

Bachelor's-Master's Program

Outstanding undergraduates may pursue an accelerated course of study leading to the BS and MS degrees in Biological Sciences.

- How to apply and program information

Graduate Certificates in Biological Sciences

- Biotechnology and Bioprocessing
- Environmental Biotechnology
- Molecular and Cellular Biotechnology

Admission Criteria:

Prospective students will be required to complete a simplified application and provide their undergraduate transcript.
indicating that they hold a baccalaureate degree in a relevant natural science or engineering field. Applicants with degrees from institutions outside the USA are encouraged to have their credentials evaluated by one of the local evaluation companies. A minimum undergraduate GPA of 3.0 (4 point scale) is preferred. Close attention will be paid to grades in relevant science and engineering courses. GREs are not required.

Please note that a Graduate Certificate, while below a full Masters degree, is not a remedial graduate program. Students must demonstrate the ability to complete graduate level work to be accepted into a graduate certificate program. As such, if an applicant was denied acceptance into a graduate degree program due to academic deficiencies, then acceptance into the certificate program is unlikely.

Requirements for Completion of Certificate:

- Students must complete all certificate requirements (core and electives).
- The program must be completed within five years.
- Students must have a minimum grade point average of 3.0 with not more than one course with a grade below ?B (note a B- is considered below a B).
- All other University requirements apply, including deadlines and fees.

Transferability:

Courses may not be applied to a certificate if already applied to another certificate and vice versa. However, credits earned towards a certificate may be applied to a Masters or Doctoral degree program in an appropriate discipline. Note that acceptance into a Graduate Degree Program is separate from acceptance into a Graduate Certificate Program.

Biotechnology and Bioprocessing

Biological Sciences and Chemical &Nuclear Engineering departments (Interdisciplinary)

Seongkyu Yoon, Ph.D., 978-934-4741, 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:

- CHEN.5350
  (https://www.uml.edu/catalog/courses/CHEN/5350) Principles of Cell and Microbe Cultivation (3 credits)
- CHEN.5450
  (https://www.uml.edu/catalog/courses/CHEN/5450) Isolation and Purification of Biotech Products (3 credits)

Plus Two Electives from the following:

- CHEN.5550
  (https://www.uml.edu/catalog/courses/CHEN/5550) Biopharmaceutical Regulatory Compliance (3 credits)
- CHEN.5380
  (https://www.uml.edu/catalog/courses/CHEN/5380) Advanced Separations in Biotechnology (3 credits)
- CHEN.5860
  (https://www.uml.edu/catalog/courses/CHEN/5860) Biotechnology Processing Projects Laboratory (3 credits)
- CHEN.5480
  (https://www.uml.edu/catalog/courses/CHEN/5480) Engineering Process Analytics
- CHEN.5500
  (https://www.uml.edu/catalog/courses/CHEN/5500) Biomedical Applications of Nanotechnology
- A technical elective with the approval of the Coordinator (3 credits)

Environmental Biotechnology

Biological Sciences, Chemistry, Civil &Environmental Engineering departments (Interdisciplinary)

Rick Hochberg, Ph.D. (mailto:rick_hochberg@uml.edu), 978-934-2885

Environmental biotechnology refers to the application of biological technologies to monitor, understand, and remediate environmental problems. This certificate combines courses that explore the ecological impact of anthropogenic environmental change with courses that provide training in current biological technologies that can be brought to bear on environmental problems. Recent advances in biotechnology are providing new avenues for investigating biologically mediated environmental processes, many of which were inaccessible using traditional approaches. New biological technologies are being developed
to mitigate environmental problems. These include the biological remediation of pollutants, biological treatment of wastewater and drinking water, source tracking of microbial pathogens, and mitigation of toxic algal blooms. As environmental resources are increasingly strained and new biological technologies with the potential to improve our environment become available, the demand for professionals with training in environmental biotechnology will continue to increase.

**Required Courses** (choose two):

- BIOL.5230
  - Biology of Global Change
- CIVE.5780
  - Biological Wastewater Treatment

**Elective courses** (choose six to eight credits):

- CHEM.5800
  - Advanced Analytical Biochemistry
- CHEM.5140
  - Advanced Analytical Chemistry
- CHEM.5260
  - Chromatography
- CIVE.5670
  - Environmental Aquatic Chemistry
- CIVE.5680
  - Environmental Fate and Transport
- CIVE.5950
  - Hazardous Waste Site Remediation
- BIOL.5670
  - Recombinant DNA Techniques
- BIO.5690L
  - Recombinant DNA Techniques Laboratory

Total: 12-14 credits

**Molecular & Cellular Biotechnology**

Biological Sciences and Chemical Engineering departments (Interdisciplinary)

**Contact:** Rich Hochberg, Ph.D.
(mailto:rick_hochberg@uml.edu), 978-934-2885

The Graduate Certificate in Molecular and Cellular Biotechnology provides students with training in this growing field. Over the years, an ever-increasing demand for manipulation of DNA and analysis in cultured cells in most aspects of funded research has created a growing need in the job market.

Certificate Program: The Certificate consists of five courses, with four core courses and one related elective (14 credits total).

All students must hold a baccalaureate degree in a relevant natural science or engineering field; at least one year of college-level biology, genetics and biochemistry also is required.

**Required Courses:** (4 courses, 11 credits)

- BIOL.5670
  - Molecular Biology Lecture (3 credits)
- BIOL.5690L
  - Molecular Biology Lab (2 credits)
- BIOL.5420
  - Cell Biology (3 credits) OR BIOL.4600
  - Stem Cell Biology (3 credits)*
- Cell Culture (BIOL.5760)
  - (3 credits) +

* Students may take both Cell Biology and Stem cell Biology, in which case one will count towards the core and the other as the elective.
+ Either Cell Biology or Stem Cell Biology can be used to satisfy the pre-requisite for Cell Culture.

**Elective courses** (students choose one 3 credit course from the...
following list):

- **BIOL.5190**
  (https://www.uml.edu/catalog/courses/BIOL/5190) Biochemistry I*

- **BIOL.5410**
  (https://www.uml.edu/catalog/courses/BIOL/5410) Topics in Cell Biology

- **BIOL.5420**
  (https://www.uml.edu/catalog/courses/BIOL/5420) Cell Biology (if not taken as core)

- **BIOL.5600**
  (https://www.uml.edu/catalog/courses/BIOL/5600) Stem Cell Biology (if not taken as core)

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

- **CHEN.5450**
  (https://www.uml.edu/catalog/courses/CHEN/5450) Isolation & Purification

*Biochemistry I is a pre-requisite for Molecular Biology and Cell Biology, but still may be used to satisfy the certificate requirements.
BIOL.5000 Professional Experience (Formerly 81.500) - Credits: 3

3 Credits will be given to individuals who present evidence of having at least one full year of current experience in an academic, hospital, or industrial laboratory setting, or in secondary school science teaching.

BIOL.5050L Bioinformatics - Credits: 4

There is a growing need for bioinformaticians in research and industry as datasets are getting bigger and more complex, making computational methods necessary for analysis. This hands-on course introduces principles, databases, software, and programming for the analysis and interpretation of molecular datasets. Emphasis is on practical assignments using computational approaches from a biologist’s perspective. Topics include genome assembly, variant detection, comparative genomics and transcriptomics, metagenomics, as well as data retrieval form databases and basic programming using Bash and R. A term project and computer-based exercises are designed to showcase the capabilities and limitations of bioinformatics tools used in genome research, as well as to develop skills in coding literacy.

BIOL.5062 Bioinformatic Tools in Sequence Analysis - Credits: 3

This hands-on course introduces databases, approaches, and software for the analysis and interpretation of molecular sequences. Practical assignments and a term project emphasize the application of computational approaches from a biologist’s perspective. Topics include genome assembly, transcriptomic analysis, and data retrieval from databases using both graphical user interfaces and basic computer programming using Bash and R. The class assignments are all computer-based exercises that are designed to showcase the capabilities and limitations of bioinformatics research and tools used in sequence analysis, as well as to develop skills in coding literacy.

BIOL.5062L Bioinformatic Tools in Sequence Analysis Lab - Credits: 1

This lab accompanies the Bioinformatic Tools in Sequence Analysis lecture, with hands-on practical assignments to achieve a firmer understanding of bioinformatics tools and principles. Assignments and a term project emphasize the application of computational approaches from a biologist’s perspective. Topics include genome assembly, transcriptomic analysis, and data retrieval from databases using both graphical user interfaces and basic computer programming using Bash and R. The class assignments are all computer-based exercises that are designed to showcase the capabilities and limitations of bioinformatics research and tools used in sequence analysis, as well as to develop skills in coding literacy.

BIOL.5072 Data Science for Biologists - Credits: 3

Like many other areas of science and business, biology is increasingly defined by increasing amounts of available data. The ability to analyze, visualize, and make inferences from this data will become increasingly valuable for future biologists. Data science can be defined as the intersection between computer science, applied statistics, and knowledge of the application domain—in this case, biology. In this class we will apply methods such as generalized linear models, multi-level models, unsupervised learning, and basic neural networks to biological problems. Hands-on activities using Python will give students experience with steps of data science project, including simulating, exploring, visualizing, drawing conclusions with statistics, and creating a reproducible analysis.

BIOL.5072L Data Science for Biologists - Credits: 1

Like many other areas of science and business, biology is increasingly defined by increasing amounts of available data. The ability to analyze, visualize, and make inferences from this data will become increasingly valuable for future biologists. Data science can be defined as the intersection between computer science, applied statistics, and knowledge of the application domain—in this case, biology. In this class we will apply methods such as generalized linear models, multi-level models, unsupervised learning, and basic neural networks to biological problems. Hands-on activities using Python will give students experience with steps of data science project, including simulating, exploring, visualizing, drawing conclusions with statistics, and creating a reproducible analysis.

BIOL.5080 Cell Biology for Teachers (Formerly 81.508) - Credits: 3

This online course will examine the structure and function of cells and the regulation of cellular processes characteristics of living organisms. Students will explore the complexity of the eukaryotic cell and gain an understanding of the mechanisms of cellular control and regulation. Course activities will make connections to state frameworks and national standards, and lead to the development of grade-appropriate curriculum materials for use in the elementary and middle school classroom. Class activities will include discussions, quizzes, lesson plans, web reviews, current events, and a final project.

BIOL.5090 Photobiology (Formerly 81.509) - Credits: 3

Biological process involving light in plants and animals. Topics include mechanisms of light absorption, energy transduction, light reactions in photosynthesis, functions of color in flowering plants, visual systems and structural and pigment coloration in animals, pigmentation in animals affecting camouflage and reproductive strategies. In addition, the
genetics involved in responses to light such as photoperiods, circadian rhythms, and seasonal cycles will be covered.

BIOL.5170 Vertebrate Animals in Biological Research (Formerly 81.517) - Credits: 3

Vertebrate Animals in Biological Research: History, Protocols, Regulations and Techniques is a lecture, discussion, and techniques based course to cover the principles of vertebrate animal research in biology. This course covers topics ranging from the history of animal research, ethics, regulations, institutional compliance, experimental design, research techniques, disease models, and animal welfare during research. The course will involve literature review and discussions regarding all topics being covered as well as the creation of an IACUC protocol. The protocol will then be reviewed in a mock IACUC meeting. There will also be hands on portions involving research techniques using training analogues and familiarization with animal research tools.

BIOL.5190 Biochemistry I (Formerly 81.519) - Credits: 3

Primarily for M.S. students in biological sciences. Lecture and text assignments on the subjects of protein, carbohydrate, lipid, enzyme and membrane biochemistry will be supplemented with research journal readings.

BIOL.5200 Biochemistry II (Formerly 81.520) - Credits: 3

This course will focus on protein dynamics where students will gain facility with thermodynamics of protein folding/misfolding, catalysis, kinetics and binding equilibria as they apply to proteins and other molecules in biological systems. The central theme of this course is that living systems can be understood in terms of the fundamental principles defining the structure and energetics of biological molecules. Attention will be given to quantitative aspects of enzyme kinetics and molecular binding. Examples of how these principles apply to the understanding and treatment of human disease will be discussed.

BIOL.5210L Biochemistry Techniques (Formerly 81.521) - Credits: 2

Biochemistry Required of M.S. students in them Biotechnology Option. Emphasis on common techniques and instrumentation employed in modern research laboratories.

BIOL.5230 Biology of Global Change (Formerly 81.523) - Credits: 3

BIOL.5260 Evolutionary Biology (Formerly 81.526) -

Credits: 3

Lectures deal with the patterns and processes of biological evolution. Covers the history of evolutionary thought, the evidence for evolution, the generation and maintenance of population-level variation, natural selection, adaptation, sexual selection, speciation, phylogenetics, molecular evolution, the fossil record and extinctions. In addition to lecture and textbook material, the course surveys classic and contemporary primary literature from evolutionary biology. A written paper and/or seminar presentation will be required.

BIOL.5280 Molecular Biotechnology: Recombinant Protein Production (Formerly 81.528) - Credits: 3

Proteins are major targets of Pharmaceuticals, and are themselves increasingly used as therapeuticals. However both basic research and the pharmaceutical industry depends on availability of purified proteins that are often difficult to isolate from native sources. In this lecture course, students will learn basic and advanced theoretical background in expression and purification of recombinant proteins. It will cover a variety of expression systems, including prokaryotic and eukaryotic cells. The course will also address traditional and new methods in recombinant protein purification. Furthermore, students will be introduced to some downstream applications such as crystallization screens and biochemical/biophysical studies. Student will choose a term project for oral and written presentation.

BIOL.5290 Recombinant Protein Production Techniques (Formerly 81.429 & 81.529) - Credits: 4

This course introduces students to the principles and practice of recombinant protein expression and purification’s. Proteins are major targets of pharmaceuticals, and are themselves increasingly used as therapeuticals. However both basic research and pharmaceutical industry depends on availability of purified proteins that are often difficult to isolate from native sources. This course will provide both didactic and laboratory instruction. It is comprised of a series of lecture and laboratory exercises, with an emphasis on practical techniques and hands-on experience of recombinant protein purification. The course will cover a variety of expression systems, including prokaryotic and eukaryotic cells, and address traditional and new methods in protein purification.

BIOL.5300 Cancer Genomics - Credits: 3

Cancer is usually the result of genetic alterations acquired over a lifetime that enable a tumor to grow and spread. As a result, each tumor is unique and involves a complex combination of mutations--a part of the reason that cancers can be so hard to treat. To better understand the characteristics of these diseases and discover appropriate treatments, institutions have
Comprehensively profiled the genomic changes across thousands of people’s tumors. That data is available for anyone with the right skills to analyze. In this class, we will delve into the world of the genomics of cancer, as a way to learn how cancers develop, how molecular profiling technologies generate data about these cancers, and how bioinformatics approaches can harness these data to gain insight and discover treatment.

**BIOL.5320 Genomics (Formerly 81.532) - Credits: 3**

This course surveys the field of genomics, examining current technologies and their biological applications. Lectures cover genome organization, genome sequencing and annotation, functional genomics, evolutionary genomics, transcriptomics, proteomics and the role of bioinformatics in organizing and interpreting genomic data. Students will be expected to submit written papers and to make oral presentations.

**BIOL.5340L Genomics Laboratory (Formerly 81.534) - Credits: 1**

A series of molecular laboratory and computer-based bioinformatics exercises providing practical experience in the collection and analysis of genomic-level data.

**BIOL.5360 Behavioral Ecology - Credits: 3**

Animals learn songs, practice agriculture, and craft tools. They build elaborate structures without a blueprint and migrate across the globe without a map. This course explores the mechanistic and evolutionary causes of animal behavior. A combination of lectures, discussions, and animal demos will introduce students to major themes in the field, while emphasizing experiments and ecological context as fundamental to the study of behavior. Students will discuss historic debates and emerging research on the evolution of exaggerated sexual ornaments and defensive structures, sensory bias, heritability of behavior, reciprocity & kinship, and the emergence of animal societies. By the end of the course, students will be able to interpret the behaviors of animals in the evolutionary framework.

**BIOL.5370 Biology and Evolution of Arthropoda (Formerly 81.537) - Credits: 3**

A detailed examination of phylum Arthropoda from developmental, ecological, genetic, morphological and paleontological perspectives. Specific topics include arthropod origins and relationships to proto-arthropods, the evolution of segmentation, and current perspectives on relationships within the phylum.

**BIOL.5380 Advanced Genetic Analysis - Credits: 3**

This course explores fundamental concepts in classical and molecular genetics. We will examine how studies in genetic model organisms (including budding yeast, Drosophila, and C. elegans) have yielded remarkable insight into a host of biological mechanisms, including cell-signaling pathways, animal development, and gene regulation. Special emphasis will be placed on how geneticists design and interpret their studies. The semester will cover strategies ranging from the classical (screens, selection, complementation, and conditional mutants) to the modern approaches enabled by the genomic revolution (genetic engineering, gene misexpression, and genome-wide association studies).

**BIOL.5390L Biology and Evolution of Arthropoda (Formerly 81.539) - Credits: 1**

An exploration of protoarthropod and arthropod diversity using live and preserved specimens of the major taxa including Tardigrada, Onychophora, Chelicerata, Crustacea, Myriapoda and Hexapoda. Students will learn to collect, dissect, identify, handle and care for live specimens.

**BIOL.5400 Advances in Plant Biology (Formerly 81.540) - Credits: 3**

Topics covered are similar to those considered in 81.440. However, students are required to complete a more in-depth review of a current research topic in plant biology and will conduct additional reading and writing assignments.

**BIOL.5420 Advanced Cell Biology (Formerly 81.542) - Credits: 3**

This is an advanced course in cell biology. In this course we will examine different areas of eukaryotic cell biology including: membrane structure and function, cell adhesion, intercellular communication, signal transduction, chemotaxis, receptor-mediated endocytosis and intracellular trafficking. Mechanisms underlying relevant human diseases will also be discussed. Upon completion of the course the student will have a strong understanding of cell biology, develop critical thinking processes, proficiency in scientific reading and how to communicate material succinctly.

**BIOL.5470 Evolution in Context for Teachers (Formerly 81.547) - Credits: 3**

This course empowers life science teachers of all levels with the skills and knowledge to more effectively foster student understanding of evolution by natural selection. By exploring evolution in multiple contexts, the Darwinian framework for how life evolved (and continues to evolve) are presented in an interactive and engaging manner. Teachers learn to use virtual resources to enhance their students learning while digging deep into the most profound and interesting science
conducted in the last 100 years. Evolution in context makes the science of evolution come alive in a real and relevant manner. From the historical and scientific to the environmental and political, teachers will learn about evolution in ways they never imagined.

BIOL.5480 Form Feeds Function in Vertebrate Evolution - Credits: 4

This course will provide you with a solid comparative knowledge of how vertebrates including humans have evolved, focusing on how anatomy (form) feeds function (physiology, biomechanics) in movement biology (cardiorespiratory, sensing, locomotion, feeding). It is only by understanding our evolutionary history that you understand e.g. how vertebrates became Olympian movers, how humans became bipedal, why we use parts of the ancestral jaw to hear, and how we avoid choking when we swallow. Such knowledge is important for medical and veterinary school, but will also support you in biomedical and biotechnology fields as well as in various general science disciplines. This course emphasizes modes of thought, including the differences between evidence and inference, and between correlation and causality.

BIOL.5490L Biology of Muscle - Credits: 4

This course takes integrative approaches to exploring architecture, physiology and mechanics of vertebrate skeletal muscle as the main driver of movements in organisms including humans. Combining presentations and discussions of important publications with simple experiments and report-writing, the course hones a specialist-level understanding of how the organ structure is constructed, how cell-level phenomena govern contraction, how the nervous system controls muscle function, how muscle contractions are constrained by physics, and how muscle as an organ structure is able to mitigate those constraints. We will also build and use actuators inspired by muscle function.

BIOL.5550 Entomology - Credits: 3

This course explores the diversity, evolution, and behavior of insects. Insects are pollinators, undertakers, and parasites. They are master architects, and the inventors of flight and biomechanics. Their societies can tower over elephants or fit in the palm of your hand. Plagues of locusts have shaped human agriculture. Their evolutionary history that you understand e.g. how vertebrates became Olympian movers, how humans became bipedal, why we use parts of the ancestral jaw to hear, and how we avoid choking when we swallow. Such knowledge is important for medical and veterinary school, but will also support you in biomedical and biotechnology fields as well as in various general science disciplines. This course emphasizes modes of thought, including the differences between evidence and inference, and between correlation and causality.

BIOL.5550L Entomology Lab - Credits: 1

This laboratory focuses on insect classification, development and behavior. Students will travel to local field sites to study and collect insects. Each student will curate a professional insect collection and develop a working knowledge of insect taxonomy through dissection and comparison of preserved specimens, including economically and medically important insects. Students will also rear a variety of social and solitary insects under experimental conditions and report their results. Labs on behavior will focus on insect communication, parental care, eusociality, and orientation.

BIOL.5570 Metazoan Parasitology (formerly 81.557) - Credits: 3

An introduction to the diversity of metazoans (animals) that parasitize humans, livestock, other animals (both vertebrate and invertebrate), and plants. Lectures emphasize the morphology, form and function, physiology, systematics, evolution, lifecycles and pathogenesis of several major parasitic groups.

BIOL.5590L Metazoan Parasitology Laboratory (formerly 81.559) - Credits: 1

The purpose of the laboratory is to provide students an opportunity to identify and work with a variety of parasites that we discuss in lecture. We will work with preserved specimens, slide material, necropsies, and live specimens. Students will learn how to identify parasites and appreciate where they live in the vertebrate body.

BIOL.5600 Stem Cell Biology (formerly 81.560) - Credits: 3

The molecular and genetic characteristics of stem cells and their developmental potential will be explored. Lectures and readings will cover the development of embryonic, fetal and adult stem cells, and will examine their use in treating human disorders receiving widespread attention, including neurodegenerative diseases, heart disease, spinal cord injury and leukemia. The ethical, legal and social implications of stem cell research will also be discussed. Additional library investigation and a term paper or seminar will be required.

BIOL.5620 Cardiovascular Physiology (formerly 81.562) - Credits: 3

This course will focus on human cardiovascular physiology in normal and diseased states. The objective of Cardiovascular Physiology is to reinforce the concept that the cardiovascular system can be understood in terms fundamental biophysical and cellular physiological principles. Quantitative aspects will be reinforced with problem sets in the accompanying lab course 81.563. Key concepts in the course will be placed in a medical context showing the underlying
physiological concepts that lead to disease states such as: altered blood pressure heart failure, valvular disease and arrhythmias.

**BIOL.5630L Cardiovascular Physiology Lab (Formerly 81.563) - Credits: 1**

Cardiovascular Physiology Lab is designed to supplement Cardiovascular Physiology 81.562. The objective of the course is to teach cardiovascular system function using problems sets as well as clinical and pathophysiological examples.

**BIOL.5670 Molecular Biology (Formerly 81.567) - Credits: 3**

A study of the principles and specialized techniques of cloning, purifying, and manipulating recombinant DNA molecules.

**BIOL.5690L Molecular Techniques (Formerly 81.569) - Credits: 4**

Laboratory experiments and independent projects designed to illustrate current techniques and instrumentation used in genetic engineering. Included are restriction mapping, cloning, plasmid purification, blot hybridization, and DNA sequencing. Students are introduced to computer software utilized for DNA sequence analysis and manipulation.

**BIOL.5720 Virology (Formerly 81.572) - Credits: 3**

A study of bacterial, animal, and plant viruses, including viral structure, modes of replication, biochemistry of the infected cell, genetic properties, and viral oncogenesis. Emphasis is on virus-cell interaction at the molecular level.

**BIOL.5760 Cell Culture (Formerly 81.576) - Credits: 4**

A series of lecture and laboratory exercises that will focus on the in vitro culture and analysis of multiple cell type commonly used in biomedical research laboratories. The lecture component will review methodologies used to establish immortalized cell lines, medium component for specific cell types, and techniques for genetically manipulating and analyzing cell lines. The laboratory exercises will emphasize the mastery of sterile techniques used to grow both established cell line and primary cultures, and molecular tools used for introducing recombinant genes and for analyzing cell growth and differentiation.

**BIOL.5800 Developmental Biology (Formerly 81.580) - Credits: 3**

An in depth discussion of contemporary topics related to reproduction and embryogenesis. Lecture material is supplemented with reading assignments in a recently published textbook and current literature taken from research journals. Emphasis is on the dynamic nature of the interactions between developing cells as well as the events that occur during fertilization, implantation and the development of the mammalian embryo which lead to birth. Students examine how studies with nonmammalian model systems such as Drosophila and Xenopus have enhanced our knowledge of mammalian development. Among the topics discussed are the role of adhesion molecules, HOX genes, apoptosis, hypomethylation of genes, axis formation and hormonal control of differentiation. Class participation is expected. Critical scientific reading and thinking is encouraged by having students present to the class published original research papers on topics of current interest in the field of developmental biology.

**BIOL.5810L Developmental Biology Lab - Credits: 1**

This course provides hands on experience in current methods and model systems used to investigate questions in developmental biology. Students will be exposed to a wide variety of embryonic systems, including intensively studied genetic model systems (e.g. C. elegans, zebrafish, mouse) and others with well-established experimental attributes (e.g. chick, sea urchin). Analytical and experimental techniques used to explore invertebrate and vertebrate development include embryological manipulation, molecular and cell biology approaches. Conceptual topics include cell specification and differentiation, pattern formation, morphogenesis, and comparative embryology. This lab supplements the Developmental Biology lecture (BIOL.5800).

**BIOL.5820 Cancer Biology (Formerly 81.582) - Credits: 3**

A study of the genes and proteins implicated in the cause of human cancer and discussion of the complex behaviors of cancer cells that differ from their normal counterparts in human tissue. Lectures and original research papers will be used.

**BIOL.5840 Comparative Vertebrate Embryology - Credits: 3**

A comparative study of vertebrate embryological development focusing on the morphological development (e.g., Differentiation of tissues, organs, and systems) of vertebrates. Evolutionary relationships of the classes of vertebrates will be investigated through their anatomy. This course builds on concepts taught in Developmental Biology, providing more detailed analysis of tissue development in a comparative context.

**BIOL.5860 Experimental Design and Analysis in Life**
Science - Credits: 3

Through discussion of practical issues arising in biology research, reading of the literature and performing applied exercises students will move principles of sound experimental design, analysis and presentation from their "recognition vocabulary" to their "active vocabulary". The objective is for students successfully completing this course to be able to serve as a statistical consultant for researchers (including themselves) wishing to conduct experiments requiring moderately complex statistical designs.

BIOL.5880 Structural Biology (Formerly 81.588) - Credits: 3

Structural basis of the molecular biology of cells and the regulation of cellular processes will be discussed. This course will cover the fundamental knowledge about protein, nucleic acid and membrane structure in relation to central systems in biology. Topics to be discussed include structural enzymology, macromolecular assemblies for replication, transcription, translation, membrane proteins, signal transduction, cell motility and transport, cell-cell interactions, the immune system, and virus structure. Students will choose a recently published primary research article for an oral presentation, and will lead a class discussion on that topic.

BIOL.5890 Practical Protein Crystallography (Formerly 81.589 & 81.489) - Credits: 4

This course provides grounding in the principles and practice of protein x-ray crystallography. The course will be unique in format and provide both didactic and laboratory instruction. It is comprised of a series of lecture and laboratory exercises, with an emphasis on practical techniques and hands-on experience of modern protein crystallography. The course will cover the fundamental knowledge about x-ray physics, instrumentation and geometrical diffraction, protein crystallization, macromolecular data collection and processing, phase estimation and improvement, model building and refinement, and model assessment. Student will also be given a recently published structural paper for writing a report on the subject.

BIOL.5892 Crystallography and Structural Bioinformatics - Credits: 3

This course provides grounding in the principles and practice of protein x-ray crystallography, with some applications in structural bioinformatics and drug discovery. This course is comprised of a series of lecture with an emphasis on practical methodologies of modern protein crystallography and structural bioinformatics. The course will cover the fundamental knowledge about x-ray physics, instrumentation and geometrical diffraction, protein crystallization, macromolecular data collection and processing, phase estimation and improvement, model building and assessment, and some exploration of bioinformatics tools employed in molecular docking and virtual screening.

BIOL.5894L Crystallography and Structural Bioinformatics Lab - Credits: 1

This lab course provides grounding in the principles and practice e-ray crystallography, with some applications in structural bioinformatics and drug discovery. It covers topics correlated with the co-requisite lecture course BIOL.5892.

BIOL.5940 Immunology II, Current Topics - Credits: 3

This course will focus on recent advances in the field of immunology including the study of immune development and activation, response to infection, vaccines, immunoregulation, cancer immunotherapy, and immune dysfunction. Expanding upon the foundational immunologic concepts covered in BIOL.4930/BIOL.5930, students will gain knowledge of the innate and adaptive immune system at the structural, molecular, cellular, and functional levels. The objectives of Advanced Topics in Immunology are to gain a comprehensive and practical understanding of current immunological principles in research and clinical/applied sciences, learn to critically read and evaluate scientific literature, learn to interpret data, and design experiments that rigorously test hypotheses.

BIOL.5945 Host-Pathogen Interactions - Credits: 3

This transdisciplinary course will examine the interface between pathogens and their hosts at multiple levels. We will begin with molecular and cellular interactions between host and pathogen species and will expand to include ecological patterns, behavioral biology, and host-pathogen co-evolution. Following an introduction to infectious disease, microbiology, and immunology, we will critically read and evaluate scientific literature. The objectives of Host-Pathogen Interactions are to gain a comprehensive and practical understanding of host-pathogen dynamics, patterns of disease ecology, and host-pathogen co-evolution. Students will learn to critically read and evaluate scientific literature, interpret data, and design experiments.

BIOL.6030 Graduate Colloquium Biology (Formerly 81.603) - Credits: 1

Presentations of current topics by visiting scientists and staff. Required of all graduate students.

BIOL.6040 Professional Communication in Science and Technology (Formerly 81.604) - Credits: 3
The course instructs students in developing effective writing and speaking skills required for preparation of publishable scientific manuscripts and presentations. The importance of clear, concise writing style and delivery of presentations to both research, scientists and non-scientists is emphasized. Guest speakers discuss commercialization of technology, intellectual property, and electronic literature searches/citation. Experimental design, statistical analyses, research grant preparation, and poster presentations are also reviewed. Outside readings are used to critically evaluate contemporary issues related to disclosure, conflict of interest, publishing ethics, biosecurity, and electronic science collaborations/team research.

**BIOL.6050 Graduate Proposal Writing Seminar - Credits: 1**

The primary purpose of this course is to enable students to apply their broad biological sciences perspectives and intellectual skills to solve complex problems and to catalyze new discoveries. To achieve these goals, students will gain effective skills in preparing professional proposals. Key concepts in the course highlight hypothesis formation and proposal development. This approach will help bridge-the-gap between classroom-based and research-based curriculum components of the Applied Biology PhD program. Exposure to the diverse range of specialties represented by students studying in the biological sciences field will enrich and diversify student knowledge.

**BIOL.6060 Applied Biology I - Credits: 1**

This is the first in a two-semester sequence of courses that will introduce students to the range of research topics being addressed at UMass Lowell as well as to professional applications of Biology. Applied Biology is at the forefront of scientific research and technological development and underpins a number of growing industries. This course will provide an opportunity for students to learn about key areas in Applied Biology including Microbiology, Biochemistry, Biotechnology, Genetics, Evolution, and Healthcare. To achieve these objectives this course will be divided into three topic blocks (4-5 weeks each) where a faculty member will provide a didactic overview of that topic, and will then bring in guest lecturers who will use half the class time.

**BIOL.6070 Applied Biology II - Credits: 1**

This is the second course in a two-semester sequence of courses that will introduce students to the range of research topics being addressed at UMass Lowell as well as to professional applications of Biology. Applied Biology is at the forefront of scientific research and technological development and underpins a number of growing industries. This course will provide an opportunity for students to learn about key areas in Applied Biology including Microbiology, Biochemistry, Biotechnology, Genetics, Evolution, and Healthcare. To achieve these objectives this course will be divided into three topic blocks (4-5 weeks each) where a faculty member will provide a didactic overview of that topic, and will then bring in guest lecturers who will use half the class time.

**BIOL.6660 Selected Topics in Molecular and Cellular Biology (Formerly 81.666) - Credits: 3**

Topics will focus on the central dogma of molecular Biology (DNA to RNA to protein) and how they relate to the structure and function of the cell. Course material will be taken directly from the current, primary literature with emphasis on student presentations and discussion. Multidisciplinary groups will select topics of interest to present to the class, and topics will vary by semester depending on student interests. Student groups will be expected to organize presentations into background and discussion sections and will lead class discussions.

**BIOL.7070 Internship Biology (Formerly 81.707) - Credits: 1**

Internship or co-op.

**BIOL.7100 Supervised Instruction in Undergraduate Biology Education - Credits: 1-3**

Graduate students will assist with the preparation of course materials, teaching and/or grading in selected courses offered by the Department of Biological Sciences. Students will be expected to work well independently, while also working under the supervision of a faculty mentor. Through these activities, the student will learn about materials used, as well as teaching and learning techniques implemented in undergraduate biology education. Required for the MS in Biological Sciences option: Education, Communication, and Outreach.

**BIOL.7210 Special Problems In Biology (Formerly 81.721) - Credits: 1-3**

**BIOL.7310L M.S. Project in Biology (Formerly 81.731) - Credits: 1-9**

**BIOL.7430 Master’s Thesis - Biology (Formerly 81.743) - Credits: 1-9**

**BIOL.7530 PhD Dissertation Biological Sciences (Formerly 81.753) - Credits: 1-9**

**BIOL.7590 PhD Dissertation Biochemistry (Formerly 81.759) - Credits: 1-9**
81.759) - Credits: 9
BIOL.7690 Continued Graduate Research (Formerly
81.769) - Credits: 9
Department of Chemistry

The following graduate programs are offered:

- **Doctor of Philosophy in Chemistry** Specializations include: Analytical, Inorganic, Organic, Physical Option in Biochemistry, Option in Environmental Studies, Option in Polymer Science or Polymer Science/Plastics Engineering
- **Master of Science in Chemistry** Specializations include: Analytical, Biochemical, Inorganic, Organic, Physical, Polymer Science
- **Master of Science in Chemistry - Professional Science Master’s (PSM) Options** Chemistry and Polymer Science, Pharmaceutical Biochemistry
- **Graduate Certificates** Chemistry

The Department of Chemistry at University of Massachusetts Lowell offers both the Master’s Degree in Chemistry and the Doctor of Philosophy Degree in Chemistry. The options and specializations allow interdisciplinary study and involve interaction between chemistry and other departments at the University of Massachusetts Lowell.

**Overall Departmental Entrance Requirements:**

1. A Bachelor’s Degree in Chemistry or a related discipline (which requires a solid base in Chemistry).
2. An Undergraduate GPA of 3.0 (or its equivalent).
3. A minimum combined score of 310 on the GRE. (A score of 315 for polymer science applicants).
4. English proficiency testing for International students whose native language is not English: TOEFL: a minimum score of 30 or IELTS: a minimum score of 6.0
5. 3 letters of recommendation
6. Students not meeting these requirements are invited to enroll in the Graduate Certificate Program and reapply.

**Master's Programs in Chemistry**

Specializations are offered in analytical, biochemistry, inorganic, organic, physical chemistry, and polymer science. This program provides opportunity for advanced study and research training in chemistry, both general and specialized. Provision also is made for the student to elect certain advanced subjects in related fields of mathematics, physics, and engineering.

The Department of Chemistry also offers two Professional Science Master’s Options in Chemistry (one in chemistry and polymer science and the other in pharmaceutical biochemistry) which have different requirements than those outlined below.

**Credit Requirements (Thesis Option)**

A minimum of 30 credits is required for the Master of Science degree in Chemistry, with 18 credits being earned in courses; and 12 credits earned in graduate research. Of the 18 course credit minimum, exclusive of research, a minimum of 15 credits must be taken in chemistry. The remaining course credits (3 or more) may be taken in chemistry or in related fields such as physics, mathematics, biology or engineering. Credit normally is not allowed for 400 level subjects in chemistry except for those designated in the catalog or approved by a student’s advisor. Each graduate program in chemistry must include at least three advanced subjects from three of the following areas: analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, physical chemistry, or polymer chemistry, unless such requirements have been met previously and approved by the department.

**Requirements**

**Specialization in Analytical Chemistry**

- **CHEM.5140 Advanced Analytical Chemistry**
- and two courses of the following:
  - [CHEM.5230 Organic Reaction Mechanism]
  - or **CHEM.5680 Structural Analysis**
  - **CHEM.5260 Chromatography**
  - **CHEM.5320 Advanced Physical Chemistry**
  - **CHEM.5500 Biochemistry I**
  - **CHEM.5430 Modern Inorganic Chemistry**
  - **CHEM.5800 Advanced Analytical Biochemistry**

**Specialization in Biochemistry**

- **CHEM.5500 Biochemistry**
- **CHEM.5510 Biochemistry II**

and any three courses of the following:

- **CHEM.5680 Structural Analysis**
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- CHEM.5140 Advanced Analytical Chemistry
- CHEM.5260 Chromatography
- CHEM.5230 Organic Reaction Mechanisms
- CHEM.5320 Advanced Physical Chemistry
- CHEM.5380 Biochemical Mechanisms
- CHEM.5600 Advanced Physical Biochemistry
- CHEM.5670 Advanced Computational Chemistry
- CHEM.5690 Advanced Biocheminformatics
- CHEM.5800 Advanced Analytical Biochemistry

Specialization in Inorganic Chemistry

- CHEM.5430 Modern Inorganic Chemistry
- CHEM.5320 Advanced Physical Chemistry
- CHEM.5230 Organic Reaction Mechanisms
and two courses of the following:

- CHEM.5140 Advanced Analytical Chemistry
- CHEM.5500 Biochemistry I
- CHEM.5510 Biochemistry II

Specialization in Organic Chemistry

- CHEM.5230 Organic Reactions, Mechanisms
- CHEM.5240 Organic Synthesis
- CHEM.5680 Structural Analysis
and at least two courses from the following:

- CHEM.5320 Advanced Physical Chemistry
- CHEM.5500 Biochemistry I
- CHEM.5430 Modern Inorganic Chemistry
- Specialization in Physical Chemistry
- CHEM.5310 Statistical Thermodynamics
- CHEM.5320 Advanced Physical Chemistry
- CHEM.5130 Spectroscopy
- CHEM.5230 Organic Reaction Mechanisms
- CHEM.5430 Modern Inorganic Chemistry
- CHEM.5400 Chemical Kinetics

Specialization in Polymer Science

Required: select from the following courses:

- POLY.5030 Advanced Polymer Science I
- POLY.5040 Advanced Polymer Science II
- POLY.5050 Polymer Preparation and Characterization
- POLY.5680 Structural Analysis
- CHEM.5680 Structural Analysis
- POLY.5530 Organic Chemistry of Macromolecules
- POLY.6070 Polymer Science Seminar
- POLY.7010 Graduate Research in Polymer Science
- POLY.5490 Physical Chemistry of Macromolecules
- CHEM.5230 Organic Reaction Mechanisms

Although the design of the academic program is the responsibility of the student’s advisory committee, the following listing provides recommended courses for program development.

First Semester Subjects

- POLY.5030 - Advanced Polymer Science I
- POLY.5050 - Polymer Preparation and Characterization
- CHEM.5680 - Structural Analysis
- POLY.5530 - Organic Chemistry of Macromolecules
- POLY.6070 - Polymer Science Seminar
- POLY.7010 - Graduate Research in Polymer Science
- POLY.5490 - Physical Chemistry of Macromolecules
- CHEM.5230 - Organic Reaction Mechanisms

Second Semester Subjects

- POLY.5040 - Advanced Polymer Science II
- POLY.5120 - Properties of Bulk Polymers
- POLY.6020 - Polymer Science Seminar
- POLY.7020 - Graduate Research in Polymer Science
- CHEM.6720 - Surface and Colloid Chemistry
- CHEM.5240 - Organic Synthesis
- PLAS.5230 - Plastics Processing Techniques

Seminar Requirement

Each semester the student is required to attend and participate in the chemistry seminar/colloquium program CHEM.6010,6020, 6030 and 6040. In addition, a master's candidate is required to present one seminar.

Thesis Advisory Committee

An advisory committee should be selected jointly by the student and advisor at the earliest possible opportunity. A minimum of three (3) faculty members are required for the master’s thesis committee. The student's advisor will serve as the chairperson of this advisory committee. The purpose of this
committee is twofold. First, it will be responsible for ascertaining that the student's research was conducted and presented in final form, in a professional and acceptable manner. Perhaps of more importance, the committee will serve in an advisory capacity during the course of the research project. In this spirit it is recommended that the student convene a meeting of the selected committee prior to starting his/her research. The purpose of this meeting is to informally present an outline of the proposed research project.

Non-Thesis Masters in Chemistry (NTMC)

This program provides opportunity for advanced study in chemistry that must include at least three of the following areas: analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, physical chemistry, or polymer chemistry.

Credit Requirements

The NTMC degree requires 30 credits (10 courses). The following NTMC requirements must be met:

1. A total of 18 course credits (CHEM or POLY prefix) must be taken within the Chemistry Department at University of Massachusetts Lowell.
2. The remaining credits may be satisfied by either additional CHEM or POLY courses or by transfer of up to 12 credits from a closely related program at a domestic university, including University of Massachusetts Lowell.

Note: Students who wish to pursue the NTMC degree who currently hold a B.S. or B.A. degree in chemistry or a related science, but do not have previous laboratory experience, may be required to take up to three undergraduate chemistry laboratory courses to ensure that they have sufficient laboratory skills upon completion of their NTMC degree.

Doctoral Programs in Chemistry

Doctor of Philosophy (Ph.D.) in Chemistry

Specializations:

- Analytical
- Organic
- Physical

Options:

- Ph.D. Option in Biochemistry
- Ph.D. Option in Environmental Studies

- Ph.D. Option in Polymer Science

Specializations

Analytical, Inorganic, Organic and Physical Chemistry

The doctoral program in chemistry is designed to provide students with a background in advanced course work and chemical laboratory techniques that will prepare them to carry out, under the guidance of experienced scientists, an original, independent investigation that will lead to an acceptable contribution to the body of contemporary knowledge.

Plan of Program

The doctoral degree normally requires four years of study beyond the bachelor's degree or a minimum of two to three years beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through a conference with the Advisory Committee (or with his or her temporary advisor). The initial part of the student's program, normally completed at the end of two years of study, is devoted to formal course work. The first year is usually given to subjects in the major branches of chemistry in preparation for area (candidacy) examinations. The second year is devoted primarily to advanced subjects in a special field of concentration. The second and final part of the program is devoted principally to research leading to the doctoral thesis. However, the student is encouraged to begin research as early as possible in the program of study.

Research Tools Requirements

These research tools may be a second foreign language, a computer language, a statistics course or another skill acceptable to both the Graduate Coordinator and the research advisor of the student. The language(s) selected may not include the native language of a student's country of origin. Students in all Ph.D. programs may fulfill this requirement by 1) two foreign language courses; 2) one foreign language and a research skill course or 3) two research skill courses. The Language Requirement may be met by completion of a two-semester undergraduate course sequence in French, German, Japanese or Russian with an average grade of B or better. The Research skill requirement may be met by taking courses in programming and/or Statistics.

Credit Requirements

Of the 45 minimum credit requirements, a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least 18 to be taken in chemistry. The remaining course credits (9 or more, with a student's Advisory Committee having the authority to add 6 additional credits to the minimum in special situations) may be taken in chemistry or in a related field such as biology, physics, mathematics or engineering. Credit is not normally allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirements. Planning the program of courses
Course Requirements
Each student in any of the Ph.D. programs in Chemistry shall take both an advanced course in Physical Chemistry and Organic Chemistry and two courses from Advanced Inorganic, Advanced Analytical, Biochemistry, or Polymer Chemistry unless such requirements have been met previously. Since each division (Analytical, Biochemistry, Organic and Physical) has its own specific course requirements, a student intending to specialize in one of these areas is encouraged to meet with the coordinator of that program.

A. Course Requirements (Ph.D.): Analytical Chemistry Specialization
27 Credits in course work are required. They are:

- CHEM.5140 Advanced Analytical Chemistry
- CHEM.5230 Organic Reaction Mechanisms or CHEM.5680 Structural Analysis
- CHEM.5320 Advanced Physical Chemistry
- CHEM.5340 Quantum Chemistry
- CHEM.5430 Modern Inorganic Chemistry
- CHEM.5500 Biochemistry I
- CHEM.5800 Advanced Analytical Biochemistry

Note: With the exception of CHEM.5140, Advanced Analytical Chemistry, one of the following courses may be substituted but only with the permission of the student’s faculty advisor and the analytical coordinator. Of the remaining 15 credits at least 6 must be in chemistry. The approval of the advisor and analytical coordinator are required for non-chemistry courses. Such courses must be justified as being relevant to the student’s course of study.

Course Requirement (Ph.D.): Organic Chemistry Specialization
Required Courses:
The remaining course requirements may be fulfilled by selecting courses from the following list or from graduate courses offered by other departments.

- CHEM.5230 Organic Reaction Mechanisms
- CHEM.5240 Organic Synthesis
- CHEM.5320 Advanced Physical Chemistry
- CHEM.5680 Structural Analysis

Additionally, at least three courses shall be selected from subject areas such as Materials Chemistry, Polymer Sciences, Biochemistry, Physical Chemistry, Analytical Chemistry, unless such requirements have been met previously.

- CHEM.5660 Nanomaterials and Nanostructures
- CHEM.6720 Surface and Colloid Chemistry
- POLY.5030 Advanced Polymer Science I
- POLY.5040 Advanced Polymer Science II
- POLY.5110 Biopolymers
- POLY.5530 Organic Chemistry of Macromolecules
- CHEM.5140 Advanced Analytical Chemistry
- CHEM.5260 Chromatography
- CHEM.5320 Advanced Physical Chemistry
- CHEM.5340 Quantum Chemistry
- CHEM.5430 Modern Inorganic Chemistry
- CHEM.5500 Biochemistry I
- CHEM.5510 Biochemistry II
- CHEM.5620 Pharmaceutical Biochemistry
- CHEM.5630 Principles of Medicinal Chemistry

The remaining course requirements may be fulfilled by selecting courses from the list above or from graduate courses offered by other departments at UML.

C. Course Requirements (Ph.D.): Physical Chemistry Specialization
Required courses:

- CHEM.5320 Advanced Physical Chemistry
- CHEM.5230 Organic Reaction Mechanisms
- CHEM.5430 Modern Inorganic Chemistry
- and a choice from the following:
  - CHEM.5130 Spectroscopy
  - CHEM.5140 Advanced Analytical Chemistry
  - POLY.5030 Advanced Polymer Science I

Written Area Examinations
Upon admission to the Ph.D. program the student must pass exams in his/her major area of specialization. The method of conducting these area exams is designated by the staff in each field of specialization, as follows:

Analytical Chemistry
The area examinations for analytical chemistry will consist of a series of six (6) examinations. The first will be a qualifying examination used to test the students general knowledge of Analytical Chemistry. The student will have two opportunities
to pass the qualifying examination with a score of 5.0 out of 10.0 points. This qualifying exam will be administered at the beginning and end of the area exams. The area examinations will be offered annually, commencing in October and administered at monthly intervals. A minimum of 6.0 out of a possible 10.0 points is required for each individual examination and a total of at least 30.0 out of a possible 50.0 points is required for the successful completion of the Written Area Examination. Failure to perform adequately may resulting the student being required to complete a master’s degree. Continuation towards the Ph.D. degree will be considered on a Case-by-case basis.

Organic Chemistry
Organic students take comprehensive examination consisting of a written and an oral component, taken at the beginning of the second academic year of study (third semester). The exam will focus on the student’s own research. The written document should include the following sections: abstract, comprehensive literature review, experimental design and methods, results to date, future plans, and references, following the style and format of ACS publications. The oral exam will consist of a presentation by the student, followed by examination by the committee members. The questions raised by the committee members can be related to the student’s research, and can also be general chemistry and organic chemistry knowledge that are expected from the student. The oral exam is closed to the public. The student must pass both the written and the oral parts of the cumulative examinations in order to advance to the Ph.D candidacy.

Physical Chemistry
By the third year of graduate study, a Ph.D. student in physical chemistry must take a comprehensive examination. This is an all day written examination with questions designed to test the student’s physical chemistry background, and ability to set up models and solve them mathematically. The student has two chances to pass the comprehensive examination.

Research Proposal
As part of the area examination(s) a Ph.D. candidate must present an oral defense of an original research proposal within 3 months of completing the written area examinations although a specific program may require the proposal to be presented at an earlier date. With the aid and advice of the Advisory Committee the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student’s Advisory Committee with other faculty members in attendance. The proposal is defended by the end of the semester following completion of area exams. The topic of the proposal cannot be closely related to or contained within the thesis project.

Chemistry Seminar
During each year of residence the student is required to attend and participate in CHEM.6010,6020, Chemistry Seminar, and CHEM.6030,6040, Chemistry Colloquium. Each doctoral student is required to present two seminars.

Candidacy for the Doctorate in Chemistry
To be admitted to candidacy for the doctorate, a student must:

1. Satisfy the 27 course credit requirement, with a minimum Grade Point Average of 3.0.
2. Pass the area examinations, which includes completion of a research proposal.
3. Fulfill the research tools requirements.
4. Inform the graduate coordinator in writing that the above requirements have been completed.

Interdisciplinary Ph.D. Option in Biochemistry
This program provides chemistry graduate students with both in-breadth class work in BioChemistry and in-depth thesis research. Emphasis is on the application of modern techniques and concepts of physical and chemical science to the solution of problems of current interest in biology and medicine.

Admission Requirements and Removal of Undergraduate Deficiencies
Admission to the program requires demonstration of an acceptable B.S., B.A., or M.S. degree in chemistry, biology, biochemistry or other related science. Students will be expected to have completed two semesters each of general, organic and physical chemistry as well as introductory biology. Deficiencies must be removed by enrolling in the corresponding undergraduate course during the first year in the program.

Academic Standards for Retention in the Biochemistry Program
The graduate student is expected to maintain an average of 3.0 or better in all his/her graduate-level courses. All other department requirements must also be met.

Research Tools Requirement
These requirements have been described above.

Degree Requirements
There are 45 credits required for the Ph.D. in Chemistry, Biochemistry Option. A total of 27 of these must be in formal courses while the remaining 18 will be accrued in Doctoral Dissertation. Of the 27 required hours of graduate course work, the Biochemistry Program requires that 15 hours are in the specific courses delineated below:

- CHEM.5500 Biochemistry I
- CHEM.5510 Biochemistry II
- CHEM.5600 Advanced Physical Biochemistry
- CHEM.5670 Computational Biochemistry
- CHEM.5700 Protein Biochemistry
12 credits of approved (5000-7000 level courses that support the student’s research focus from approved graduate courses in the Biological Sciences, Chemistry, Biomedical and Nutritional Sciences, or Chemical Engineering Departments. Course selection should be made in consultation with the student’s research advisor. Below is a list of possible course elective courses.

- CHEM.5140 Advanced Analytical Chemistry
- CHEM.5260 Chromatography
- CHEM.5430 Modern Inorganic Chemistry
- CHEM.5630 Chemistry of Natural Products
- CHEM.5690 Advanced Bioinformatics
- CHEM.5700 Advanced Protein Chemistry
- CHEN/BIOL.5350 Principles of Cell and Microbe Cultivation
- CHEN/BIOL.5450 Isolation and Purification of Biotech Products
- BIOL.5670/5690 Recombinant DNA Techniques
- BIOL.5760/5780 Cell Culture
- BIOL.5930 Immunology
- MLSC.5060 Biochemistry of Lipids
- MLSC.5520 Advanced Clinical Biochemistry Seminars

During each semester in residence all full-time students must participate in a seminar course and attend one seminar each week, as required by the Chemistry Department. The student is required to present two one-hour presentations during his/her residence.

Research

A. Initiation of Research and Research Advisor Selection Procedure
The dissertation research of each graduate student may be initiated at any time but not later than the end of the second semester in the program. The student is advised to make serious efforts, prior to the summer following his/her first entrance to the program, to initiate faculty research interviews and attempt to identify the area of his/her research interest and particular research group which may be suitable for pursuing his/her research goals.

B. Examination Committee
The examination committee will be composed of four faculty members chosen after consultation by the student with his/her research advisor at least two of these members must be from the Department of Chemistry faculty.

Examinations
A. Comprehensive Exam

Students are required to successfully complete a Comprehensive Exam based on the 5 core courses by the end of their second year in the program. This exam consists of two parts and students are expected to have satisfactory performance on both sections. Section I consists of a series of questions derived from their course material. Section II is based on current literature and is focused on a particular series of papers that are provided to the students a month before the exam.

B. Oral Research Proposal must be presented during their 5th semester. This proposal based on their dissertation work and is to follow the format outlined in the proposal guidelines. A written copy of the proposal must be submitted to their dissertation committee one week prior to their public examination. Examination committees for the ORP consist of four full-time faculty or professionals. Two members of the committee must be members of the Chemistry department and the other two members of the committee must have a Ph.D. in Biochemistry or the equivalent. Successful completion of the Original Research Proposal defense will advance students to candidacy in the Biochemistry Ph.D. Program. Students will have two opportunities to complete this exam. If the combination of the written and oral presentation is not at the level of a Ph.D. candidate, as judged by the committee, a student will be provided a second opportunity to satisfactorily complete the exam. At the committee’s discretion, a student may be asked to only repeat the written or oral portion of the exam. This must be done by the student’s sixth semester or they will not be advanced to Ph.D. candidacy.

Admission to Candidacy for the Doctorate
To be admitted to candidacy for the doctorate, a student must:

1. Complete all required courses with necessary grade point average. There is an absolute minimum cumulative grade point average (GPA) requirement of 3.0 for all graduate work. At the end of the first semester, if a student is found to be below the minimum GPA, a written warning will be issued. If the cumulative GPA is not raised to 3.0 or higher by the end of the second semester in residence, the student will automatically be dropped from the Ph.D. program but allowed to continue toward a master’s degree in Biochemistry with the approval of the graduate committee. While completing the M.S., a candidate must have a minimum GPA of 3.0 and maintain that GPA throughout the remainder of his or her career. Upon successful completion of the Master of Science degree, the student may reapply for admission to the doctoral program. Each case will be reviewed on an individual basis.
Students reentering the Ph.D. program will then satisfy all the requirements for the degree including passing the comprehensive examination, presentation of their research proposal, and completion of their research and dissertation defense. Seminar presentations and course work accomplished to complete the master’s degree will, of course, be cumulative.

2. Pass the Cumulative Exam.
3. Fulfill the research tools requirement.
4. Successfully present and defend the Oral Research Proposal by the end of the fourth semester of full time study.
5. Present two seminars.
6. Secure written approval of his/her research advisor and the chemistry graduate coordinator. When these requirements have been fulfilled, the Biochemistry Graduate Committee will recommend that the graduate coordinator of the Department of Chemistry notify the Registrar’s Office to place the student on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Ph.D. Option in Environmental Studies

This graduate program is designed as an optional course of study to the traditional Ph.D. in Chemistry for students with backgrounds in engineering (civil, environmental and chemical engineering) and other sciences (physics, biology, etc.) as well as chemistry. Candidates will be exposed to advanced course work in chemistry and environmental engineering and will be able to choose an area of specialization that best suits their interests and previous experience. A combination of faculty from Chemistry, Work Environment and Civil Engineering with a variety of research expertise gives this program unique characteristics and affords the student the opportunity to perform practical interdisciplinary research. It is expected that most students will require at least four years beyond the Bachelor’s degree and two years past the Master’s degree.

Entrance Requirements

In addition to the requirements for admission listed in this catalog, applicant will have an earned bachelor’s degree in one of the following fields: chemistry, chemical or civil engineering, biology, environmental sciences, geology or physics. Students will be expected to have satisfactorily completed undergraduate courses in analytical, organic, and physical chemistry, physics and calculus. However, applicants who have not completed courses in these areas may remedy their deficiencies while in the program and, therefore, are encouraged to apply. Admissions will be determined by a committee consisting of faculty active in the program.

Program Outline

A total of 48 credits are required for the Ph.D. program. Of these, at least 30 credits must be in course work exclusive of seminar and the rest is usually in thesis research. Courses shown below are divided into three categories:

- core course requirements (9 credits),
- areas of specialization (12 credits), and
- elective courses (9 credits).

Additional elective courses from other departments may be substituted with the approval of the student’s Advisory Committee.

In addition, full-time students must register for CHEM.601/CHEM.602 or ENVE.502 Environmental/Analytical seminar every semester.

Each student will be required to give two seminars on current research topics during their graduate career. Students in the Environmental program must select a thesis advisor by the end of the second semester. At this time, an Advisory Committee is appointed and a plan of study is established. The Advisory Committee must consist of at least four members, including the thesis advisor. A minimum of two Chemistry Department faculty are required to be on the committee with two other members from any participating department. An additional member from another department may also be added if agreed upon by the student and thesis advisor. Students must maintain a 3.0 cumulative average in order to continue in the program.

Required Courses (21 credits):

I. Core Courses (9 credits)

- CHEM.5140 Advanced Analytical Chemistry
- CHEM.5320 Advanced Physical Chemistry
- CHEM.5230 Organic Reaction Mechanism or CHEM.5680 Structural Analysis

II. Areas of Specialization (12 credits)

a. Analytical /Environment

- CIVE.5670 Environmental Chemistry I (Aquatic Chemistry)
- CIVE.5680 Environmental Chemistry II (Fate and Transport)
b. Water Environment

- CIVE.5670 Environmental Chemistry I (Aquatic Chemistry)
- CIVE.5680 Environmental Chemistry II (Fate and Transport)
- CHEM.5190 Environmental Chemistry III (Marine Chemistry)
- CIVE.5620 Groundwater Hydrology

III. Elective Courses (9 credits)

- CHEM.5320 Advanced Physical Chemistry
- CHEM.5230 Organic Reaction Mechanisms
- CHEM.5680 Structural Analysis
- CIVE.5670 Environmental Chemistry I (Aquatic Chemistry)
- CIVE.5680 Environmental Chemistry II (Fate and Transport)
- CHEM.5190 Environmental Chemistry III (Marine Chemistry)
- CHEM.6530 Chemical Oceanography
- CHEM.5260 Chromatography
- ENVE.5730 Air Pollution Laboratory (Monitoring and Analysis)
- 93.4150 Advanced Atmospheric Dynamics I
- 93.4160 Advanced Atmospheric Dynamics II
- 93.4300 Atmospheric Diffusion
- ENVE.5720 Energy and the Environment
- MATH.5910 Statistical Modeling and Data Analysis
- CIVE.5650 Industrial Waste Water Treatment Processes
- ENVE.5100 Water Resources Management
- ENVE.5220 Solid Waste Management (Municipal, Industrial and Hazardous)
- ENVE.5250 Epidemiology for Environmental Studies
- ENVE.5270 Environmental Law
- PUBH.5010 Industrial Hygiene
- RADI.5010 Radiation Safety and Control
- RADI.5030 Radiation Biology
- RADI.5080 Environmental Toxicology

Written Area Examinations (Cumulative Examinations)
Beginning in the second year of study, the student must pass examinations in their major area of specialization. The faculty associated with the program administer examinations that are based on course work either completed or in progress as well as seminars, scientific literature and accepted theory in the field of study. Environmental studies students take six cumulative examinations each of which focuses on a different area of environmental science and analytical chemistry. Students must take the examinations consecutively in a given academic year. The topic, date, time and faculty member in charge of a particular exam in the cumulative examination series will be given to the student prior to the first cumulative exam. Students taking cumulative exams are urged to meet with the individual faculty member preparing an exam for more specific information. If a student misses a cumulative exam a grade of zero will be assigned. There are no makeup cumulative exams.

Research Proposal
A Ph.D. candidate must submit an original research proposal and successfully pass an oral defense of that proposal in their second or third year of study. After consulting with their Advisory Committee, the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student's Advisory Committee with other faculty in attendance. The proposal must be defended within three months following completion of the cumulative examinations.

Ph.D. Option in Polymer Science
Students in the Ph.D Program in the Department of Chemistry may elect the Polymer Science Option. The Polymer Science doctoral program is designed to provide students with a background in advanced course work and laboratory techniques that will prepare them to carry out an original investigation leading to an acceptable contribution to the body of contemporary knowledge in the fields of macromolecules.

**Plan of Program**
The doctoral degree normally requires four years of full-time study beyond the bachelor’s degree or a minimum of two to three years of full-time study beyond the master’s degree. The plan of study pursued by each student is dependent on individual requirements and is developed through a conference with his/her Advisory Committee (or temporary advisor).

**Requirements for Admission**
Requirements for admission into the program are the same as those for students entering other Ph.D. programs in Chemistry. It is the student’s responsibility to satisfy any admission requirements stipulated for the Ph.D. in Chemistry.

Undergraduate deficiencies in the student’s background must be remedied promptly, usually by the end of the student’s second semester. During this period, the student must also successfully complete graduate courses appropriate to his/her background. Students will not be formally admitted to the Ph.D. program if their grade point average is below B.

**Advisory Committee**
Upon admission the student will be assigned a temporary adviser selected from the Polymer Science Program by the Coordinator of the Graduate Polymer Program. The student’s major thesis adviser will become the chairperson of the permanent Advisory Committee.

The Advisory Committee will meet at least once each semester to monitor the progress of the student’s research and study. Unsatisfactory performance will lead to the recommendation for termination of the TA or RA sponsorship and the candidacy for the doctorate.

**Program Outline**
The initial part of the program is devoted to formal course work. The first year usually is devoted to subjects in major branches of chemistry and polymers in preparation for the student’s area (cumulative) examinations. The student must choose a Thesis Adviser before the end of the first semester: failure to do so will result in the termination of TA sponsorship. The thesis adviser should be a faculty member of the Polymer Science Program. In special occasions, with the approval from the Coordinator of the Graduate Polymer Science Program, faculty members from other departments can be selected as a thesis adviser, but in that case a faculty member from the Polymer Science Program must agree to serve as a co-adviser to ensure the continuation of the TA sponsorship.

**Written Area Examinations**
Upon formal admission to the Ph.D. program the student is required to pass a series of consecutive cumulative area examinations. Policy and grading underlying each examination will be announced at the beginning of each academic year.

Each student must also work with his/her Thesis Adviser to prepare and present an oral defense of an original research proposal after the completion of the last area exam. This should be completed within the third year of the Ph.D. candidacy.

**Course Requirements**
Of the 45 minimum credit requirements a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least 18 to be taken in chemistry and polymer science (CHEM and POLY prefixes). The remaining course credits (nine or more, with a student’s Advisory Committee having the authority to add six additional credits to the minimum in special situations) may be taken in chemistry or in a related field such as biology, physics, mathematics or engineering. Credit normally is not allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirement. The program of courses is the responsibility of a student’s Advisory Committee and must include advanced subjects in the appropriate areas of chemistry and polymers. When it is necessary to carry less then the normal credit load of 9 per semester, the student must consult the chair of his/her Advisory Committee to initiate the approval process.

**Required Courses**
The student must take the following core courses:

**a. Polymer Science:**
- POLY.5030 Polymer Science I
- POLY.5040 Polymer Science II
- POLY.5050 Polymer Preparation and Characterization
- POLY.5110 Biopolymers
- CHEM.5230 Organic Reaction Mechanisms or an elective course* approved by thesis adviser
- CHEM.5320 Advanced Physical Chemistry or an elective course* approved by thesis adviser
- CHEM.5680 Structural Analysis
- POLY.6010/6020 Polymer Science Seminar
- POLY.6030/6040 Polymer Science Colloquium

*Elective Courses may come from the following:
- Chemistry Department - Organic Chemistry of Macromolecules (POLY), Organic Reaction Mechanisms (CHEM), Advanced Physical Chemistry (CHEM), Surface
and Collodi Chemistry (CHEM), Nanomaterials and Nanostructures (CHEM), Modern Organic Chemistry (CHEM), Principles of Medicinal Chemistry (CHEM), Spectroscopy (CHEM), Pharmaceutical Biochemistry (CHEM), Advanced Protein Chemistry (CHEM), Supramolecular Chemistry (CHEM)

- PLAS Department - Mechanical Behavior of Polymers (OLAS), Plastics Processing I, Polymer Structure (PLAS)
- ChemE Department - Biomaterials Science and Engineering (CHME)

The following course schedule is suggested to prepare the students for the cumulative examinations:

### First Semester

<table>
<thead>
<tr>
<th>Course#</th>
<th>Course Name</th>
<th>Cr.</th>
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</thead>
<tbody>
<tr>
<td>POLY.5030</td>
<td>Polymer Science I</td>
<td>3</td>
</tr>
<tr>
<td>CHEM.5680</td>
<td>Structural Analysis</td>
<td>3</td>
</tr>
<tr>
<td>POLY.6030/6040</td>
<td>Polymer Seminar</td>
<td>3</td>
</tr>
<tr>
<td>POLY.6030/6040</td>
<td>Polymer Colloquium</td>
<td>3</td>
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<td>or</td>
<td>Other Elective</td>
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### Second Semester

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<tr>
<th>Course#</th>
<th>Course Name</th>
<th>Cr.</th>
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<tbody>
<tr>
<td>POLY.5040</td>
<td>Polymer Science II</td>
<td>3</td>
</tr>
<tr>
<td>POLY.5050</td>
<td>Polymer Preparation &amp; Characterization</td>
<td>3</td>
</tr>
<tr>
<td>POLY.6010/6020</td>
<td>Polymer Seminar</td>
<td>3</td>
</tr>
<tr>
<td>POLY.6030/6040</td>
<td>Polymer Colloquium</td>
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<td>or</td>
<td>Other Elective</td>
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### Third Semester

<table>
<thead>
<tr>
<th>Course#</th>
<th>Course Name</th>
<th>Cr.</th>
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<tbody>
<tr>
<td>POLY.5110</td>
<td>Biopolymers</td>
<td>3</td>
</tr>
<tr>
<td>POLY.6010/6020</td>
<td>Polymer Seminar</td>
<td>3</td>
</tr>
<tr>
<td>POLY.6030/6040</td>
<td>Polymer Colloquium</td>
<td>3</td>
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<tr>
<td>or</td>
<td>Other Elective</td>
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</table>

Cumulative Examinations

The remaining required courses may be taken in the following semesters.

### Candidacy for Ph.D. Polymer Science, and Polymer Science/Plastics Engineering Option

To be advanced to candidacy for the doctorate, a student must:

1. Satisfy the course credit requirement with a minimum grade point average of 3.0.
2. Select a Thesis Adviser from the Polymer Science Program by the end of the first semester.
3. Pass the area examinations which includes completion of the research proposal.
4. Secure the approval of his/her Advisory Committee and the Graduate Coordinator of the Department of Chemistry.

Advancement to candidacy in no way guarantees the granting of the degree.

### Master of Science in Chemistry - Professional Science Master’s Options

The Chemistry Department offers two Professional Science Master’s Options within the Master’s of Science in Chemistry. Please read the admissions requirements and programs requirements carefully as they are not identical.

- Professional Science Master’s in Chemistry and Polymer Science Option (PSMCPS) Admissions Requirements for the PSMCPSCourse of Study for the PSMCPSCourse of Study for the PSMCP
- Professional Science Master’s in Pharmaceutical Biochemistry Option Admissions Requirements for the PSMPBCourse of Study for the PSMPB

### Master’s of Science - Professional Science Master’s in Chemistry and Polymer Science Option (PSMCPS)

The goal of this program is to further educate ACS accredited chemists for a professional career in an industrial, government, or non-profit research setting.

This is a 32 credit program which requires the successful completion of 18 credits of chemistry/polymer science courses, 9 credits of management courses, 3 credits of management or chemistry electives, a one-credit ethics seminar; and a one-credit professional internship.

Applicants who have recently graduated, as well as, those who have worked in the chemistry/polymer field for multiple years, and foresee the potential of a managerial role in their future are urged to apply.

### Chemistry Department Admissions Requirements for the PSMCP:

1. SAT or ACT
2. GRE General Test
3. Letters of recommendation
4. Statement of purpose
5. Transcripts
6. CV
7. TOEFL or IELTS (if English is not a native language)
8. Scores from a professional practice examination (if applicable)

Applicants are encouraged to apply early to ensure timely consideration.
Incoming students must possess an ACS undergraduate degree in chemistry (or its full equivalent) and have a minimum cumulative undergraduate GPA of 3.0 from an accredited college or university. Candidates with a closely related major may be admitted with the approval of the Graduate Program Coordinator.

Since advanced study is required in at least three disciplines of chemistry, a number of courses in Analytical/Environmental, Biochemistry, Inorganic, Organic, Physical and Polymer will be available every semester. All students must make up any deficiencies during the first year of their program.

Applications for the Professional Science Masters in Chemistry and Polymer Science are accepted year round, but it is recommended that completed applications be submitted one semester prior to expected matriculation.

Graduate Admissions Requirements:

General requirements for all applicants are a completed application packet supplied by the Graduate Admissions Office which includes:

- Graduate Admissions Application form
- A Statement of Purpose
- Three letters of recommendation pertaining to academic ability and/or professional performance
- Official score report for the Graduate Record Exam, with a satisfactory level score
- Official transcript(s)
- Application fee

Applications may be downloaded or submitted electronically from the Graduate Admissions website.

PSMCPS Course of Study

Chemistry and Polymer Science Course Requirements (18-21 credits total)

Required Core Courses for Chemistry and Polymer Science (Choose 4 courses from the following list. Each course is 3 credits):

- CHEM.5140
  [Advanced Analytical Chemistry](https://www.uml.edu/catalog/courses/CHEM/5140)
- CHEM.5240
  [Modern Organic Synthesis](https://www.uml.edu/catalog/courses/CHEM/5240)
- CHEM.5320
- CHEM.5430
  [Modern Inorganic Chemistry](https://www.uml.edu/catalog/courses/CHEM/5430)
- POLY.5030
  [Adv. Polymer Science I](https://www.uml.edu/catalog/courses/POLY/5030)

Elective Courses for Chemistry and Polymer Science (Choose 2-3 courses from the following list. Students may also use the fifth course from the list above. Each course is 3 credits):

- CHEM.5230
  [Organic Reaction Mechanisms](https://www.uml.edu/catalog/courses/CHEM/5230)
- CHEM.5260
  [Chromatography](https://www.uml.edu/catalog/courses/CHEM/5260)
- CHEM.5500
  [Biochemistry I](https://www.uml.edu/catalog/courses/CHEM/5500)
- CHEM.5680
  [Structural Analysis](https://www.uml.edu/catalog/courses/CHEM/5680)
- CHEM.5800
  [Bioanalytical Chemistry](https://www.uml.edu/catalog/courses/CHEM/5800)
- CHEM.6720
  [Surface and Colloid Chemistry](https://www.uml.edu/catalog/courses/CHEM/6720)
- POLY.5040
  [Adv. Polymer Science II](https://www.uml.edu/catalog/courses/POLY/5040)
- POLY.5530
  [Organic Chemistry of Macromolecules](https://www.uml.edu/catalog/courses/POLY/5530)

Provision is made for a student to elect certain advanced subjects in related fields of chemistry, mathematics, physics,
and engineering with permission of PSM Coordinator & Faculty advisor.

Management Course Requirements (9-12 credits total): Students are required to take a minimum of six credits of advanced (6000 level) courses. Up to two 2-credit basic courses may count towards the degree if they are advanced course prerequisites.

Required Advanced Management Courses (2 courses; 3 credits each):

- MGMT.6350 (https://www.uml.edu/catalog/courses/MGMT/6350) Project Management
- MGMT.6880 (https://www.uml.edu/catalog/courses/MGMT/6880) Professional Communication

Advanced Elective Management Courses (1-2 Courses; 3 credits each)

- FINA.6400 (https://www.uml.edu/catalog/courses/FINA/6400) Financing Innovation & Technology Ventures
- MKTG.6300 (https://www.uml.edu/catalog/courses/MKTG/6300) Market Research for Entrepreneurs
- ENTR.650 (https://www.uml.edu/catalog/courses/ENTR/650) Innovation & Emerging Technology
- MGMT.6300 (https://www.uml.edu/catalog/courses/MGMT/6300) New Product Development

Basic Courses (2 credits each) maybe prerequisites of advanced courses. If necessary, up to two of the following 2 credit courses can be counted towards the program requirements

- MKTG.5010 (https://www.uml.edu/catalog/courses/MKTG/5010) Marketing Fundamentals
- MGMT.5010 (https://www.uml.edu/catalog/courses/MGMT/5010) Organizational Behavior

Other courses may be substituted with permission of the PSM Coordinator and the Faculty Advisor.

Required Science and Ethics Seminar (1 credit total)

Required Professional Internship: (1 credit total)

The duration of the internship component of the PSM degree is expected to be a minimum of 340 hours and be 3 to 6 months in duration. The student will work within a business, government agency or research institute directly related to their area of chemistry. The student is encouraged to participate in real world work situations involving not only technical problems, but also teamwork, communication skills and decision-making.

Before commencing the internship a student must be formally enrolled in the PSM program, have completed a minimum of 18 credit hours (including one management and one ethics course) towards the degree, and have permission of their faculty advisor.

Upon completion the intern will be required to submit a paper in thesis format and defend an oral presentation of their work. Students who possess a full-time position in business, industry or government will be permitted to use work related to their current position as an internship.

Professional Science Masters in Pharmaceutical Biochemistry (PSMPB)

The goal of this program is to further educate scientists with strong backgrounds in chemistry/biochemistry for a professional career in an industrial, government, or non-profit research pharmaceutical setting. This is a 32 credit program which requires the successful completion of 18 credits of chemistry/biochemistry coursework, 9 credits of management coursework, an additional three credits of chemistry or management electives, a one-credit ethics seminar, and a one-credit professional internship.

Applicants who have recently graduated, as well as, those who have worked in the biochemistry/pharmaceutical field for multiple years, and foresee the potential of a managerial role in their future are urged to apply.

Chemistry Department Admissions Requirements for

Academic Catalog 2020 - 2021 / Chemistry - General Information
the PSMPB:

- The PSMPB program will consider applicants with BA/BS undergraduate degrees in chemistry, biochemistry, biology, health professions or related disciplines who possess a significant chemistry background and have a minimum cumulative undergraduate GPA of 3.0 from an accredited college or university.
- Since advanced study is required in at least three disciplines of chemistry, a number of courses in Analytical/Environmental, Biochemistry, Inorganic, Organic, and Physical Chemistry will be available every semester. All students must make up any deficiencies during the first year of their program.
- Applications for the Professional Science Masters in Chemistry and Polymer Science are accepted year round, but it is recommended that completed applications be submitted one semester prior to expected matriculation.

Graduate Admissions Requirements:

General requirements for all applicants are a completed application packet supplied by the Graduate Admissions Office which includes:

- Graduate Admissions Application form
- A Statement of Purpose
- Three letters of recommendation pertaining to academic ability and/or professional performance
- Official score report for the Graduate Record Exam, with a satisfactory level score
- Official transcript(s)
- Application fee
- Applications may be downloaded or submitted electronically from the Graduate Admissions website.

PSMPB Course of Study

Pharmaceutical Biochemistry Course Requirements (18-21 credits total)

Required Core Courses for Pharmaceutical Biochemistry (All students must take CHEM.550 and PLUS two courses from the following list. Each course is 3 credits):

- CHEM.5500
  Biochemistry I
- CHEM.5620
  Pharmaceutical Biochemistry

And two courses from the following list:

- CHEM.5600
  Adv. Physical Biochemistry
- CHEM.5630
  Chemistry of Natural Products
- CHEM.5700
  Protein Chemistry
- CHEM.5800
  Bioanalytical Chemistry

Elective Courses for Pharmaceutical Biochemistry (Choose 2-3 courses from the following list or an additional course from the above list. Each course is 3 credits.):

- CHEM.5140
  Advanced Analytical Chemistry
- CHEM.5260
  Chromatography
- CHEM.5380
  Biochemical Mechanisms
- CHEM.5430
  Modern Inorganic Chemistry
- CHEM.5510
Provision also is made for the student to elect certain advanced subjects in related fields of chemistry, health sciences, biology, and other related disciplines with permission of PSM Coordinator & Faculty advisor.

Management Course Requirements (9-12 credits total):

**Required Courses** (2 courses; 3 credits each):

- MGMT.6350 (Project Management)
- MGMT.6880 (Professional Communication)

**Elective Courses**
(Students choose 1-2 courses from the following list. Each course is 3 credits.)

- PSMA.5350 (Project Management for Science Professionals)
- PSMA.5450 (Professional and Scientific Communication)
- PSMA.5550 (Leadership for Scientists)
- PSMA.5650 (Technical Entrepreneurship)
- FINA.6400 (Financing Innovation & Technology Ventures)
- MKTG.6300 (Market Research for Entrepreneurs)

- ENTR.6500 (Innovation & Emerging Technology)
- MGMT.6300 (New Product Development)

Other courses may be substituted with permission of the PSM Coordinator and the Faculty Advisor.

**Science and Ethics Course** (1 credit total)

**Professional Internship:** (1 credit total)

The duration of the internship component of the PSM degree is expected to be a minimum of 340 hours and be 3 to 6 months in duration. The student will work within a business, government agency or research institute directly related to their area of chemistry. The student is encouraged to participate in real world work situations involving not only technical problems, but also teamwork, communication skills and decision-making. Before commencing the internship a student must be formally enrolled in the PSM program, have completed a minimum of 18 credit hours (including one management and one ethics course) towards the degree, and have permission of the PSM coordinator and their faculty advisor. Upon completion the intern will be required to submit a paper in thesis format and defend an oral presentation of their work. Students who possess a full-time position in business, industry or government will be permitted to use work related to their current position as an internship.

Please address any inquiries to Chemistry PSM Coordinator: Jin Xu (jin_xu@uml.edu).

**Graduate Certificates in Chemistry**

- Chemistry
- Environmental Biotechnology

**Chemistry**

Department of Chemistry

David Ryan, Ph.D. (david_ryan@uml.edu), 978-934-3698

This certificate is aimed at the baccalaureate scientist who would like to expand his/her expertise in a pertinent area of modern chemistry. The certificate consists of two required courses from the concentration core, plus two approved electives. Course credits earned through the Certificate

Graduate Certificates in Chemistry
Program are directly applicable to the course credit requirements of the M.S. and Ph.D. degrees.

**Core Concentrations** (2 courses required for each concentration):

**Analytical Chemistry Sequence:**
- CHEM.5140 (Advanced Analytical Chemistry)
- CHEM.5260 (Chromatography)

**Biochemistry Sequence:**
- CHEM.5500 (Biochemistry I)
- CHEM.5510 (Biochemistry II)

**Physical Chemistry Sequence:**
- CHEM.5130 (Spectroscopy)
- CHEM.5320 (Advanced Physical Chemistry)

**Organic Chemistry Sequence:**
- CHEM.5230 (Organic Reaction Mechanisms)
- CHEM.5680 (Structural Analysis)

or
- CHEM.5630 (Chemistry of Natural Products)

**Polymer Sequence:**
- POLY.5030 (Polymer Science I)
- POLY.5040 (Polymer Science II)

**Advanced Materials Sequence:**
- CHEM.5100 (Microscopy of Advanced Materials)
- CHEM.5680 (Structural Analysis)

After concentration courses are completed, students take any two additional courses listed above or from the list of electives.

**Electives:**
- CHEM.6530 (Chemical Oceanography)
- CHEM.5380 (Biochemical Mechanisms)
- CHEM.5430 (Modern Inorganic Chemistry)
- CHEM.5600 (Advanced Physical Biochemistry)
- CHEM.5700 (Protein Chemistry)
- CHEM.5800 (Bioanalytical Chemistry)
Environmental Biotechnology

**Biological Sciences, Chemistry, Civil & Environmental Engineering departments**

Rich Hochberg, Ph.D. (mailto:rick_hochberg@uml.edu), 978-934-2885

Environmental biotechnology refers to the application of biological technologies to monitor, understand, and remediate environmental problems. This certificate combines courses that explore the ecological impact of anthropogenic environmental change with courses that provide training in current biological technologies that can be brought to bear on environmental problems. Recent advances in biotechnology are providing new avenues for investigating biologically mediated environmental processes, many of which were inaccessible using traditional approaches. New biological technologies are being developed to mitigate environmental problems. These include the biological remediation of pollutants, biological treatment of wastewater and drinking water, source tracking of microbial pathogens, and mitigation of toxic algal blooms. As environmental resources are increasingly strained and new biological technologies with the potential to improve our environment become available, the demand for professionals with training in environmental biotechnology will continue to increase.

**Required Courses** (choose two):

- **BIOL.5230**  
  (https://www.uml.edu/catalog/courses/BIOL/5230)  
  Biology of Global Change
- **CIVE.5780**  
  (https://www.uml.edu/catalog/courses/CIVE/5780)  
  Biological Wastewater Treatment
- **CHEM.5140**  
  (https://www.uml.edu/catalog/courses/CHEM/5140)  
  Advanced Analytical Chemistry
- **CHEM.5260**  
  (https://www.uml.edu/catalog/courses/CHEM/5260)  
  Chromatography
- **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.5950**  
  (https://www.uml.edu/catalog/courses/CIVE/5950)  
  Hazardous Waste Site Remediation
- **BIOL.5670**  
  (https://www.uml.edu/catalog/courses/BIOL/5670)  
  Recombinant DNA Techniques
- **BIOL.5690L**  
  (https://www.uml.edu/catalog/courses/BIOL/5690L)  
  Recombinant DNA Techniques Laboratory (2 credits)

Total: 12-14 credits
CHEM.5130 Spectroscopy (Formerly 84.513) - Credits: 3
This course covers both basic theory and practical applications of modern photon, electron, and X-ray spectroscopies. The techniques covered will include infrared, Raman, visible, circular dichroism, UV, X-ray photoelectron, and X-ray absorption spectroscopies. Qualitative and quantitative applications of these methods to chemistry (organic and inorganic), materials, catalysis, and biochemistry will be discussed.

CHEM.5140 Advanced Analytical Chemistry (Formerly 84.514) - Credits: 3
Designed to provide graduate students and senior undergraduate students with an understanding of the principles and the theory of analytical measurements and instrumentation. The course is divided into three sections consisting of a) analytical measurements including potentiometry and voltammetry, b) spectrophotometric measurements (i.e. molecular spectrometry), and c) ionic equilibria and statistics. This course is required for graduate programs in Analytical Chemistry and Environmental Studies (Ph.D.) and is recommended for students in other graduate programs such as Biology, Biochemistry and Environmental Studies (MS) and other areas of chemistry.

CHEM.5160 Advanced Techniques (Formerly 84.516) - Credits: 3
CHEM.5190 Environmental Chemistry (Formerly 84.519) - Credits: 3
Covers chemical processes and measurements in marine and estuarine systems. Emphasis is placed on water column processes; however, air-water and sediment-water interface phenomena are covered as well. Topics include but are not limited to: ionic equilibria, trace metal complexation, redox processes, mathematical modeling applied to chemical systems, and oceanographic sampling.

CHEM.5220L Organic Synthesis and Characterization Laboratory - Credits: 3
An advanced project-based organic chemistry laboratory course. Students will separate mixtures of compounds by chromatographic methods, elucidate structures using spectroscopic techniques and consult the chemical literature to design and execute a multi-step synthesis. Students will also propose a multi-step synthesis of a compound of interest. Emphasis on laboratory work with a discussion of theoretical background.

CHEM.5190 Environmental Chemistry (Formerly 84.519) - Credits: 3
This course covers both basic theory and practical applications of modern photon, electron, and X-ray spectroscopies. The techniques covered will include infrared, Raman, visible, circular dichroism, UV, X-ray photoelectron, and X-ray absorption spectroscopies. Qualitative and quantitative applications of these methods to chemistry (organic and inorganic), materials, catalysis, and biochemistry will be discussed.

CHEM.5221 Solid-State Materials Chemistry - Credits: 3
This course is an introductory course to materials and solid-state chemistry for graduate students. Topics covered include the electronic and optical properties of solids, the properties of metals and semiconductors, optical properties of materials and their physical origins, and special topics in nanomaterials and materials science. Qualitative and quantitative applications of these materials will be included for energy, electronics, batteries, lighting, catalysis, and coatings.

CHEM.5230 Organic Reaction Mechanisms (Formerly 84.523) - Credits: 3
The course is designed to provide an advanced understanding of the principles controlling structure/reactivity and the experimental techniques used to elucidate the mechanisms of modern organic reactions. The material covered includes: molecular orbital theory applied to bonding and reactivity, stereoelectronic and conformational effects, intermolecular interactions, potential energy surfaces, reaction kinetics, reaction mechanisms, catalytic methods, pericyclic reactions, and photochemistry. Introductory applications of computational chemistry are covered. The course is open to undergraduate students (with permission) interested in a stronger foundation in organic reactions.

CHEM.5240 Organic Synthesis (Formerly 84.524) - Credits: 3
Mechanism, scope and limitations of important selected types of reactions and design of synthetic sequences. Emphasis is placed on methodology of synthesis and current literature.

CHEM.5260 Chromatography (Formerly 84.526) - Credits: 3
Coverage includes the components, theory and performance of chromatographic separations including packed and capillary gas chromatography (GC) and high performance liquid chromatography (HPLC). Modern injectors, detectors, pumping systems, and other hardware used in chromatography are also discussed in detail.

CHEM.5320 Advanced Physical Chemistry (Formerly 84.532) - Credits: 3
Extension of introductory physical chemistry. Open to undergraduates and graduate students in chemistry and related fields. Emphasis is placed on classical and statistical thermodynamics; surface and colloid chemistry; and electronic and vibration-rotation spectra.
CHEM.5340 Quantum Chemistry - Credits: 3
This course will start with the basics of Quantum Mechanics and Quantum Chemistry followed by use of the molecular modeling software GAUSSIAN. Topics to be covered include: Schrödinger equation and wave functions; Particle in a box; Particle in a ring; Heisenberg uncertainty principle; QM operators, Eigenvalue problem; Eigenvectors & eigenvalues; Hermitian operators and commutators; Harmonic oscillator & IR spectroscopy; Rigid Rotator & Rotational Spectroscopy; H-atom, H2+ion; using Mathematics to solve QM problems (e.g. atomic/molecular orbitals visualization), He-atom and variational method; Electron spin and Pauli exclusion principle; EPR/NMR; Semiempirical methods; Many-electron systems; Slater Determinants, Hartree and Hartree-Fock methods; Diatomic molecules; Born-Oppenheimer approx.

CHEM.5360 Advanced Materials Chemistry I - Credits: 3
This course covers the concepts, principles, and applications of physical properties of organic- and polymer-based materials. In a broad sense, organic electronics and photonics, as a modern research and technology field, encompass both molecular organics and polymers in design, synthesis, and fabrication processes in the light of device application. For the practical purpose, this course discusses a collection of technologies that include conducting organics and polymers, organic light emitting diodes (OLED), organic photovoltaics (OP), dye sensitized solar cells (DSSC), nonlinear optical (NLO) two-photon absorption (2PA) chromophores, electro-optical (EO) polymers, and photodynamic therapeutic (PDT) and antibacterial inactivation (aPDI) drugs.

CHEM.5380 Biochemical Mechanisms (Formerly 84.538) - Credits: 3
Discussion of various biochemical reactions from the point of view of organic reaction mechanisms. Kinetics, coenzymes and methods of the study of enzyme and catalysis and mechanisms are emphasized.

CHEM.5430 Modern Inorganic Chemistry (Formerly 84.543) - Credits: 3
A theoretical treatment of atomic structure and chemical bonds, included are such topics as Russell Saunders’ coupling, molecular orbital theory, ligand field theory, and descriptive coordination chemistry.

CHEM.5500 Biochemistry I (Formerly 84.550) - Credits: 3
An advanced study of the structure and properties of proteins, nucleic acids, carbohydrates and lipids, including kinetics and mechanisms of enzyme action and detailed description of metabolic pathways of carbohydrates and lipids.

CHEM.5510 Biochemistry II (Formerly 84.551) - Credits: 3
A continuation of 84.550 with emphasis on metabolic pathways of amino acids and nucleic acid, biosynthesis of proteins and selected topics in molecular biology and various areas of biochemistry.

CHEM.5550L Laboratory in Modern Biochemistry and Biophysics - Credits: 2
This is a laboratory course designed to teach basic biochemistry techniques using a series of well-characterized proteins in a research-like setting. The course will meet twice a week throughout the semester. The first half of the semester will be focused on teaching specific biochemical techniques. In the second half of the semester, students will develop an independent research question using protein(s) from a list using the techniques that were learned in the first half of the semester. Students will produce a report using an ACS Journal style based on their results and they will also present their results to the class at the end of the semester. Students will also prepare a review on the protein that they are using for their independent project.

CHEM.5600 Advanced Physical Biochemistry (Formerly 84.560) - Credits: 3
Physical chemistry encompasses a group of principles and methods helpful in solving many different types of problems. This course will present selected principles of thermodynamics, kinetics, statistical thermodynamics and quantum mechanics as they are applied to biochemical systems. Various experimental techniques will be strongly emphasized in view of their importance in biochemical research.

CHEM.5620 Biopharmaceutical Development (Formerly 84.562) - Credits: 3
Pharmaceutical Biochemistry examines the biochemical and molecular mechanisms of drug interaction. Topics include basic aspects of molecular complementarity (molecular recognition), specificity and stability of ligand binding (energetic), as well as crystallographic and computational approaches.

CHEM.5630 Chemistry Of Natural Products (Formerly 84.563) - Credits: 3
Covers the proof of structure of various types of natural products, approaches to the total synthesis of these products
and the biosynthetic pathways.

**CHEM.5660 Nanomaterials and Nanostructures (Formerly 84.566) - Credits: 3**

Nanoscience and nanotechnology focus on the understanding and control of matter at the dimension of 1-100 nanometers, i.e., the nanoscale. Nanoscale structures, materials and devices have unique properties and functions solely because of their sizes. Research and technology development in nanoscience and nanotechnology aim at understanding the fundamental nanoscale phenomena, synthesizing, fabricating and imaging nanomaterials and nanostructures, and constructing nanoscale systems that offer unprecedented properties and functions. In this course, we will discuss the fundamental nanoscale phenomena. We will learn variety of nanomaterial characterization techniques including scanning probe, electron probe, absorption and particle spectroscopies. Fabrication processes of top-down and bottom-up approaches will be discussed, including molecular and material self-assembly. We will study surface phenomena and surface energy that are of critical importance for nanomaterials and nanostructures. We will also learn various ways to control the structures and properties of nanomaterials and surfaces. A variety of nanomaterials and nanostructures will be discussed, including metal, semiconductor, organic and inorganic nanoparticles, carbon nanomaterials, and various natural and synthetic nanostructured surfaces. Applications of these nanomaterials in nanomedicine and theranostics will also be discussed.

**CHEM.5670 Computational Biochemistry (Formerly 84.567) - Credits: 3**

This course will provide and introductory survey of the basis of theory/simulations of biomolecules. It is accessible to anyone who has completed two semesters of undergraduate chemistry and who has some background in physical chemistry. Topics/examples will be borrowed from modern biological chemistry, molecular recognition, and self-assembly, as well as principles and concepts of the field, including host-guest interactions, supramolecular systems in chemistry, biology, nanotechnology, and materials science. This course will provide detailed understanding of the general principles and concepts of the field, including host-guest chemistry, molecular recognition, and self-assembly, as well as highlight a wide variety of examples and applications of supramolecular systems in chemistry, biology, nanotechnology, and materials science.

**CHEM.5680 Structural Analysis (Formerly 84.568) - Credits: 3**

Practical applications of instrumental data in the determination of the structure of organic compounds and polymers. Includes mass spectrometry, ultra-violet spectroscopy, infrared spectroscopy and nuclear magnetic resonance spectroscopy. Open to undergraduate students with permission.

**CHEM.5700 Protein Chemistry (Formerly 84.570)**

**Credits: 3**

This course outlines the assembly process, structural and functional attributes of protein. Special attention will be given to three-dimensional structures, folding, post translational modifications, misfolding and degradations, as well as biochemical and biophysical techniques used to elucidate protein structure and function.

**CHEM.5800 Bioanalytical Chemistry (Formerly 84.580) - Credits: 3**

Analytical biochemistry involves the separation, detection, and analysis of biological molecules. This course addresses advanced theory and applications of contemporary biochemical techniques and instrumentation. Topics covered include chromatographic and electrophoretic separation techniques, detection of biomolecules by spectroscopy and radiochemical methods, biological preparations, and structural analysis of proteins, nucleic acids, polysaccharides and lipids.

**CHEM.5850 Modern Organic Chemistry - Credits: 3**

This course aims to provide deepened and widened knowledge of concepts, reactivity, and synthesis in modern organic chemistry. It encompasses: main group chemistry, carbonyl/enol/enolate chemistry, heterocyclic compounds, fragmentations, rearrangements, frontier molecular orbital theory, pericyclic reactions, reactive intermediates, organometallic chemistry, selective synthesis, stereochemistry, catalysis, asymmetric synthesis, and multi-step synthesis.

**CHEM.5950 Supramolecular Chemistry - Credits: 3**

Supramolecular chemistry can be described as 'chemistry beyond the molecule' and involves the study of complex structures held together by weaker interactions. In general, non-covalent bond types, such as electrostatic interactions, van der Waals’ forces, hydrogen bonds, and metal coordination, are used, but reversible covalent bonds can also be included. This course will provide detailed understanding of the general principles and concepts of the field, including host-guest chemistry, molecular recognition, and self-assembly, as well as highlight a wide variety of examples and applications of supramolecular systems in chemistry, biology, nanotechnology, and materials science.

**CHEM.6010 Chemistry Seminar (Formerly 84.601) - Credits: 0-2**

Required of all graduate students. Presentation of current topics by graduate students. "Variable credit course, student chooses appropriate amount of credits when registering."

**CHEM.6020 Chemistry Seminar (Formerly 84.602)**
Credits: 0-2
Required of all graduate students. Presentation of current topics by graduate students. "Variable credit course, student chooses appropriate amount of credits when registering."

CHEM.6030 Chemistry Colloquium (Formerly 84.603) - Credits: 0-1
Required of all graduate students. Presentation of current topics by visiting scientists and staff. "Variable credit course, student chooses appropriate amount of credits when registering."

CHEM.6040 Chemistry Colloquium (Formerly 84.604) - Credits: 1
Required of all graduate students. Presentation of current topics by visiting scientists and staff.

CHEM.6310 Principles of Medicinal Chemistry I (Formerly 84.631) - Credits: 3
This course teaches fundamental principles of drug development, including small organic compounds and biologics. Key aspects of their synthesis, physical characteristics, and pharmaceutical properties are discussed. Topics covered include discovery strategies, statistic-based modeling (e.g., QSAR), structure-based and mechanism-based design methods, and combinatorial techniques.

CHEM.6320 Principles of Medicinal Chemistry II (Formerly 84.632) - Credits: 3
The mechanisms of prototypical drug classes are discussed, including structure-property relationships. Computational methods and means of visualizing drug-substrate interactions at the molecular level are emphasized. Drug design and function are integrated with relevant topics in related disciplines, including biochemistry, biology and physiology.

CHEM.6410 Co-Op Internship (Formerly 84.641) - Credits: 0-1
Practical training for International Students in a Co-operative agreement with Industry or a Government Laboratory for 1 semester. "Variable credit course, student chooses appropriate amount of credits when registering."

CHEM.6510 Selected Topics: Chemistry (Formerly 84.651) - Credits: 3
Advanced topics in various fields of chemistry. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary chemistry.

CHEM.6520 Selected Topics: Chemistry (Formerly 84.652) - Credits: 3
CHEM.6530 Chemical Oceanography (Formerly 84.653) - Credits: 3
CHEM.6720 Surface and Colloid Chemistry (Formerly 84.672) - Credits: 3
Surface and colloid chemistry describes the nanoscopic and mesoscopic regimes that connect molecular and macroscopic length scales. The course focuses on how phenomena at macroscopic surfaces and interfaces arise from molecular interactions. Intermolecular and surface forces discussed in detail include van der Waals and electrostatic forces, and how these together with steric interactions give rise to different molecular aggregates (self-assembled structures of surface active molecules and polymers) in bulk solution and in the vicinity of solid surfaces. Examples of modern experimental techniques for measurements of surface forces and for characterization of surfaces and aggregates are discussed and demonstrated.

CHEM.7050 Supervised Teaching Ch & Ps (Formerly 84.705) - Credits: 0
CHEM.7310 Graduate Project in Chemistry (Formerly 84.731) - Credits: 1
Continued research project supplementing the research credits for a doctoral student. This course will require special permission from the Graduate Coordinator.

CHEM.7330L Graduate Project - Chemistry (Formerly 84.733) - Credits: 3
CHEM.7410 Master's Thesis - Chemistry (Formerly 84.741) - Credits: 1
Master's Thesis - Chemistry

CHEM.7430 Master's Thesis - Chemistry (Formerly 84.743) - Credits: 3
CHEM.7460 Master's Thesis - Chemistry (Formerly 84.746) - Credits: 6
CHEM.7490 Master's Thesis - Chemistry (Formerly 84.749) - Credits: 0-9
CHEM.7510 Graduate Doctoral Research Credit  
(Formerly 84.751) - Credits: 1  
CHEM.7530 Doctoral Dissertation/Chemistry  
(Formerly 84.753) - Credits: 3  
CHEM.7560 Doctoral Dissertation/Chemistry  
(Formerly 84.756) - Credits: 6  
CHEM.7590 Doctoral Dissertation /Chemistry  
(Formerly 84.759) - Credits: 0-9  
CHEM.7630 Continued Graduate Research (Formerly  
84.763) - Credits: 3  
CHEM.7690 Continued Graduate Research (Formerly  
84.769) - Credits: 9  
POLY.5030 Polymer Science I (Formerly 97.503) -  
Credits: 3  
A study of the principles of condensation, free radical, ionic,  
coordination and ring opening polymerization. The topics  
include the effect of polymerization techniques on reaction  
kinetics and molecular weight, and the evaluation of reactivity  
ratios in copolymerization reactions.  
POLY.5040 Polymer Science II (Formerly 97.504) -  
Credits: 3  
Introduction to chain statistics and thermodynamics of  
macromolecular solutions, methods of study of molecular  
weight and chain conformation, and the properties of polymers  
in bulk including viscoelasticity and crystallinity.  
POLY.5050 Polymer Preparation Characterization I -  
Credits: 3  
In this graduate-level laboratory class, the students will learn a  
variety of valuable techniques for the syntheses and  
characterization of high molecular weight polymers. This  
course offers a combination of traditional/historical polymer  
synthesis (i.e. Urea/Formaldehyde thermoset formation,  
interfacial polymerization of Nylon, determination of reactivity  
ratios for copolymerizations) and modern polymerization  
techniques (i.e. RAFT, ATRP, Living ROP) along with relevant  
polymer characterization techniques used in today's synthetic  
polymer landscape (i.e. GPC, MALDI, light scattering, NMR,  
TGA, DSC, etc.).  
POLY.5110 Biopolymers (Formerly 97.511) - Credits: 3  
Topics include conformation and configuration of vinyl  
polymers and polypeptides, energetics of chain folding and  
examination of the forces dictating ordered structures, helix to  
coil transitions in biopolymers with emphasis on polypeptide  
structures, instrumental analysis of biopolymer conformation,  
synthesis of biopolymers including polypeptides, polysaccharides  
and polynucleotides, and examination of relationships between  
synthetic polymers and naturally occurring polymers.  
POLY.5530 Macromolecules Organic Chemistry  
(Formerly 97.553) - Credits: 3  
An advanced study in polymer science concerned with the  
synthesis of macromolecules and their mechanisms of  
formation.  
POLY.6010 Polymer Science Seminar (Formerly  
97.601) - Credits: 0-2  
Required of all Polymer Science graduate students. Presentation  
of current topics in polymer science by graduate students.  
"Variable credit course, student chooses appropriate amount of  
credits when registering."  
POLY.6020 Seminar in Polymer Science (Formerly  
97.602) - Credits: 0-2  
Required of all Polymer Science graduate students. Presentation  
of current topics in polymer science by graduate students.  
"Variable credit course, student chooses appropriate amount of  
credits when registering."  
POLY.6030 Polymer Science Colloquium (Formerly  
97.603) - Credits: 0-1  
Required of all Polymer Science graduate students. Presentation  
of current topics in polymer science by visiting scientists and  
staff.  
POLY.6040 Polymer Science Colloquium (Formerly  
97.604) - Credits: 0-1  
Required of all Polymer Science graduate students. Presentation  
of current topics in polymer science by visiting scientists and  
staff.  
POLY.6490 Introduction to Conjugated Polymers  
(Formerly 97.649) - Credits: 3  
This course is an introduction to the fundamental science and  
potential applications of conjugated polymers in optical and  
electronic technologies. The topics covered include history,  
synthesis and molecular structure, including solid state  
polymerization; crystallinity and morphology, including  
assembly methods; electronic structure including energy bands,  
conjugation defects and photoelectron spectroscopy; properties
of the insulating forms including light absorption and emission, thermochromism, carrier transport, electroluminescence and nonlinear optical properties; properties of the conducting forms, including "doping"; some specific devices.

POLY.7050 Supervised Teaching in Polymer Science  
(Formerly 97.705) - Credits: 0

POLY.7430 Master's Thesis in Polymer Science  
(Formerly 97.743) - Credits: 3

POLY.7460 Master's Thesis in Polymer Science  
(Formerly 97.746) - Credits: 6

POLY.7490 Master's Thesis in Polymer Science  
(Formerly 97.749) - Credits: 9

POLY.7510 Thesis Review (Formerly 97.751) -  
Credits: 1
This is a one credit thesis review course.

POLY.7530 Doctoral Dissertation in Polymer Science  
(Formerly 97.753) - Credits: 3

POLY.7560 Doctoral Dissertation in Polymer Science  
(Formerly 97.756) - Credits: 6

POLY.7590 Doctoral Dissertation in Polymer Science  
(Formerly 97.759) - Credits: 0-9

POLY.7690 Continued Graduate Research (Formerly 97.769) - Credits: 9
Department of Computer Science

The UMass Lowell Computer Science graduate program provides computer scientists with an education of sufficient breadth and depth to prepare them for leadership positions in both industrial and academic environments. It is distinguished by a balanced mixing of the practical, engineering aspects of computer science, with substantial exposure to the theoretical foundations of the field. This mission is supported by departmental and university research labs and Centers. Our graduate program is intended primarily for students with undergraduate degrees in computer science, or for those who have completed a degree in a related area (Engineering, Mathematics, Physics, etc.) and who possess a substantial background in computer science.

- Resources
- Master of Science
- Master of Science, Professional Science Master’s Entrepreneurship Option
- Master of Science, Bioinformatics Option
- Master of Science, Information Technology MSIT (Online Program)
- Doctor of Philosophy and Admission Requirements

Resources

The Computer Science Department has strong industrial ties through its faculty members, its participation in the research activity in various University Centers, its internal laboratories and institutes, its continuing relationships with many local computer and software manufacturers, and its industrial advisory committee. These relationships provide sources of short and long range research projects, hardware donations and student funding, while also providing insight to and understanding of the short and long term directions of local industry. To support instructional and research activities, the Department of Computer Science maintains a large heterogeneous network, including PCs, workstations, and a collection of more specialized equipment. All systems and servers are connected to / accessible via the University’s network.

Department Research Groups / Laboratories:

- Compilers and Parallel Systems
- Computational Mathematics Research Group
- Computing Theory and Algorithms Group
- Database and Software System Research Group
- Discovery and Knowledge Representation Research Group
- Engaging Computing Group
- Institute for Visualization and Perception Research
- Laboratory for Artificial Intelligence and Robotics
- Network and Systems Security Laboratory
- Robotics Lab
- Text Machine Lab for Natural Language Processing

The Master of Science Degree Program

The Master of Science degree program in Computer Science serves several audiences, from the professional with extensive industrial experience to the recent graduate aiming ultimately for an advanced research degree. In all cases, a major objective is to prepare the student for a professional work environment in which continued growth is the norm.

The Computer Science Department offers to outstanding undergraduates a Bachelor’s-Master’s (BS/MS) program. The major advantage of this program is that it allows students to integrate their undergraduate and graduate education, possibly reducing the amount of time required for completion and reducing the administrative overhead for the student.

To be accepted into the BS/MS program, students are expected to have at least a B (3.0) grade point average, both overall and in Computer Science, and to apply during their junior year. The rules governing eligibility for the program appear in the current UMass Lowell online Graduate Catalog.

Master Degree Course Requirements:
Each degree candidate will be required to pass, with an average of B or better, and not more than two grades below B, the following minimum number of credits, distributed to include core courses and electives.

Core Courses (12 credits, 4 courses):

- COMP.5030 (https://www.uml.edu/catalog/courses/COMP/5030) Algorithms
- One course from Group II
- One course from Group III
- One course from Group IV

Group I (Foundations):

- COMP.5020 (https://www.uml.edu/catalog/courses/COMP/5020)
Foundations of Computer Science

COMP.5030
(https://www.uml.edu/catalog/courses/COMP/5030)
Algorithms

COMP.5310
(https://www.uml.edu/catalog/courses/COMP/5310)
Design of Programming Languages

COMP.5340
(https://www.uml.edu/catalog/courses/COMP/5340)
Compiler Construction

COMP.7100
(https://www.uml.edu/catalog/courses/COMP/7100)
Approximation Algorithms

Group II
(Systems and Networks):

COMP.5150
(https://www.uml.edu/catalog/courses/COMP/5150)
Operating Systems I

COMP.5160
(https://www.uml.edu/catalog/courses/COMP/5160)
Operating Systems II

COMP.5300
(https://www.uml.edu/catalog/courses/COMP/5300)
Special Topics

COMP.5610
(https://www.uml.edu/catalog/courses/COMP/5610)
Computer & Network Security I

COMP.5620
(https://www.uml.edu/catalog/courses/COMP/5620)
Computer & Network Security II

COMP.5630
(https://www.uml.edu/catalog/courses/COMP/5630)
Data Communications I

COMP.5640
(https://www.uml.edu/catalog/courses/COMP/5640)
640) Data Communications II

230) Computer Vision I

COMP.5660 (https://www.uml.edu/catalog/courses/COMP/5660) Malware Analysis

COMP.5670 (https://www.uml.edu/catalog/courses/COMP/5670) IoT Security and Privacy

COMP.5690 (https://www.uml.edu/catalog/courses/COMP/5690) Computer and Network Forensics

COMP.6610 (https://www.uml.edu/catalog/courses/COMP/6610) Advanced Topics in Network Security

COMP.5270 (https://www.uml.edu/catalog/courses/COMP/5270) Human Computer Interaction

COMP.5280 (https://www.uml.edu/catalog/courses/COMP/5280) Evaluation of Human - Computer Interaction

COMP.5410 (https://www.uml.edu/catalog/courses/COMP/5410) Data Visualization

COMP.5420 (https://www.uml.edu/catalog/courses/COMP/5420) Natural Language Processing

COMP.5430 (https://www.uml.edu/catalog/courses/COMP/5430) Artificial Intelligence

Group III (Human-Computer Interaction, Visualization, Robotics and AI):
COMP.5440
(https://www.uml.edu/catalog/courses/COMP/5440)
Data Mining

COMP.5450
(https://www.uml.edu/catalog/courses/COMP/5450)
Machine Learning

COMP.5460
(https://www.uml.edu/catalog/courses/COMP/5460)
Computer Graphics I

COMP.5470
(https://www.uml.edu/catalog/courses/COMP/5470)
Computer Graphics II

COMP.5480
(https://www.uml.edu/catalog/courses/COMP/5480)
Robot Design

COMP.5490
(https://www.uml.edu/catalog/courses/COMP/5490)
Mobile Robots

COMP.5495
(https://www.uml.edu/catalog/courses/COMP/5495)
Robot Learning

COMP.5520
(https://www.uml.edu/catalog/courses/COMP/5520)
Foundations in Digital Health

COMP.5500
(https://www.uml.edu/catalog/courses/COMP/5500)
Topics

COMP.6440
(https://www.uml.edu/catalog/courses/COMP/6440)
Advanced Topics in Data Mining

**Group IV**
(Information Management and Analysis):

COMP.5130
(https://www.uml.edu/catalog/courses/COMP/5130)
Internet and Web Systems I
COMP.5140
(https://www.uml.edu/catalog/courses/COMP/5140)
Internet and Web Systems II

COMP.5510
(https://www.uml.edu/catalog/courses/COMP/5510)
Bioinformatics for CS

COMP.5730
(https://www.uml.edu/catalog/courses/COMP/5730)
Database I

COMP.5740
(https://www.uml.edu/catalog/courses/COMP/5740)
Database II

COMP.5800
(https://www.uml.edu/catalog/courses/COMP/5800)
Topics in Computer Science

COMP.6730
(https://www.uml.edu/catalog/courses/COMP/6730)
Advanced Database Systems

Electives
(18 credits, 6 courses in the COMP.5*** & COMP.6*** series or up to six credits from the list below)

List of other approved courses:

COMP.7010
(https://www.uml.edu/catalog/courses/COMP/7010)
Computer Science Research

EECE.5560
(https://www.uml.edu/catalog/courses/EECE/5560)
Fundamentals of Robotics

EECE.5821
(https://www.uml.edu/catalog/courses/EECE/5821)
Computer Architecture and Design

Total:
: 30 Credits

Master’s Thesis:

An optional master’s thesis can be substituted for at most six credits, and can be used to substitute for two elective courses. Students who wish to do a thesis must file a Proposed Thesis Committee form with the Graduate Coordinator prior to begin working on
the thesis.

The Master of Science, Professional Science Master’s Entrepreneurship Option

This program is no longer accepting new applicants.

Course Requirements:

- 34 Course Credits (11 courses)
- Eight Graduate level courses in Computer Science and three graduate level courses in Management, plus 1-credit Professional Internship and two zero-credit Seminars, under the direction of the Graduate Coordinator, from approved list of courses.

The Master of Science, Bioinformatics Option

Course Requirements:

- 30 Courses Credits (10 courses)
- Eight Graduate level courses in Computer Science and two graduate level courses in Biology, under the direction of the Graduate Coordinator, from an approved list of courses.

The Master of Science, Information Technology (Online Program)

The program is offered fully online, providing a pathway for students who have completed a Bachelor’s in Information Technology degree and for working professionals who want to pursue advanced graduate studies in information technology. The online delivery framework provides an accessible format for students juggling work and family responsibilities.

Students may also count course from two graduate IT certificate programs in Systems Models and Management and Network Security towards the Master’s Degree in Information Technology.

The 10-course master’s degree program is designed to provide both a principled and applied exposure toward designing, managing and deploying networked systems of computers. The program places emphasis on practical skills based on Linus/Unix, Windows and Apple platforms, but also teaches general principles along with their technical and ethical foundations.

Admissions Requirements:

1. Completion of an undergraduate BS or BA degree from an accredited institution.

2. Mathematical Maturity: Students should have completed a minimum of one semester of precalculus mathematics, one semester of discrete mathematics and one semester of statics as part of their undergraduate studies, or possess the equivalent experience.

3. C Programming proficiency, to include a minimum of one semester of C Programming an one semester of Data Structures, or the equivalent experience.

Note: Students who do not meet the above requirements, may need to take additional undergraduate courses in order to meet the requirements.

Program Outline:

30 Course Credits (10 Courses)

**System Infrastructures Courses:** (Choose 2 of the following)

- MSIT.5110
  (https://www.uml.edu/catalog/courses/MSIT/5110)
  Network and Systems Administration (3 credits)

- MSIT.5170
  (https://www.uml.edu/catalog/courses/MSIT/5170)
  Operating Systems Foundations (3 credits)

- MSIT.5190
  (https://www.uml.edu/catalog/courses/MSIT/5190)
  Virtual Systems (3 credits)

- MSIT.5140
  (https://www.uml.edu/catalog/courses/MSIT/5140)
  Systems Security and Auditing (3 credits)

**Network Infrastructure Courses:** (Choose 2 of the following)

- MSIT.5600
  (https://www.uml.edu/catalog/courses/MSIT/5600)
  Network Infrastructures (3 credits)

- MSIT.5610
  (https://www.uml.edu/catalog/courses/MSIT/5610)
  Computer Network Security (3 credits)

- MSIT.5620
  (https://www.uml.edu/catalog/courses/MSIT/5620)
  Digital Forensics (3 credits)

- MSIT.5630
Secure Mobile Networks (3 credits)

- **MSIT.5630**

Cloud Computing (3 credits)

- **MSIT.5650**

Software Management Courses: (Choose 2 of the following)

- **MSIT.5180**

  Large Scale Application Deployment (3 credits)

- **MSIT.5310**

  Project Management (3 credits)

- **MSIT.5320**

  Managing Large Data (3 credits)

Program Electives: (Choose 4 additional MSIT.xxxx courses from this Program Electives or from any of the first three categories above, as long as you have not already taken the course to fulfill the above category requirements).

- **MSIT.5350**

  Agile and Iterative Project Management (3 credits)

- **MSIT.5360**

  Data Mining (3 credits)

- **MSIT.5410**

  Information Security, Privacy and Regulatory Compliance (3 credits)

- **MSIT.5430**

  Intrusion Detection Systems (3 credits)

- **MSIT.5450**

  Designing and Building a Cybersecurity Program (3 credits)

- **MSIT.5460**

  Introduction to Malware Analysis

The Doctor of Philosophy Degree Program

The Doctor of Philosophy degree program aims to provide a student, whether planning on an industrial or academic career, with a challenging research environment and the opportunity to tackle theoretical or applied projects of major scope, depth, and originality.

Admission Standards and Criteria

General Requirements

In addition to the general requirements for admission, applicants for admission to the graduate program at both the Master of Science and Doctor of Philosophy level are expected to have an undergraduate degree in Computer Science or a related discipline such as Mathematics, Physics, or Engineering. They should submit an official application (obtainable from the Graduate Admissions Office). In addition to undergraduate transcripts and letters of recommendation, applicants are expected to submit an official score from the Graduate Record Examination (GRE). Any student may be required, at the discretion of the department, to complete transitional or remedial courses without graduate credit.

MS Admission Requirements

In order to be fully matriculated into the MS program, students must demonstrate competency in the following six knowledge areas:

- Data Structures and Programming in C, C++, or Java
- Operating Systems
- Analysis of Algorithms
- Calculus
- Discrete Mathematics
- Probability and Statistics

Competency is typically demonstrated by producing a transcript of previous academic experience which contains passing grades in courses related to these six areas, or by earning a B or better in the courses below. Knowledge in areas that have not been satisfied at the time of entrance into the M.S. program become conditions on full matriculation. It is the student's responsibility to fulfill his/her conditions at the earliest possible time. The following is the list of courses which
satisfy each of the six knowledge areas.

Data Structures and Programming in C, C++ or Java:
- COMP.1020
  (https://www.uml.edu/catalog/courses/COMP/1020)
  Computing II

Operating Systems:
- COMP.3080
  (https://www.uml.edu/catalog/courses/COMP/3080)
  Introduction to Operating Systems

Algorithms:
- COMP.4040
  (https://www.uml.edu/catalog/courses/COMP/4040)
  Analysis of Algorithms

Calculus:
- MATH.1310
  (https://www.uml.edu/catalog/courses/MATH/1310)
  Calculus I and MATH.1320
  (https://www.uml.edu/catalog/courses/MATH/1320)
  Calculus II

Discrete Math:
- MATH.3210
  (https://www.uml.edu/catalog/courses/MATH/3210)
  Discrete Math I and MATH.3220
  (https://www.uml.edu/catalog/courses/MATH/3220)
  Discrete Math II

Probability and Statistics:
- MATH.3860
  (https://www.uml.edu/catalog/courses/MATH/3860)
  Probability and Statistics I

**Ph.D. Admission Requirements**

In addition to the requirements for admission into the Master of Science in Computer Science program, admission into the Doctor of Philosophy degree program requires a Masters degree in Computer Science. If the student does not already have an MS in CS, they may be admitted into the MS/Ph.D. program; in this program, students must complete the required coursework for the MS in CS as well as degree requirements for the Ph.D. in CS.

**Financial Support**

The Department has a limited number of teaching assistantships available to qualified graduate students. These assistantships can be renewed for up to four semesters. Other support is available through funded research programs in the departmental laboratories and, possibly, through support from other university departments.

**Master of Science Degree in Computer Science**

- Bioinformatics Option
- Entrepreneurship Option

**Admissions requirements**

Admissions requirements for the MS in CS are designed to ensure that MS candidates enter the program on roughly the same level as our own BS in CS graduates. See CS Graduate Admissions Requirements for details.

**Master’s Thesis**

An optional master’s thesis can be substituted for at most six credits, and can be used to substitute for one pair of Project- or General-area courses. Students who wish to do a thesis must file a Proposed Thesis Committee form with the Graduate Coordinator prior to beginning work on the thesis.

**Doctor of Philosophy Degree Coursework Requirements**

- Admission Requirements
- Candidacy Requirements
- Course Requirements
- Additional Requirements
- Computational Mathematics Option

**Admission Requirements**

In addition to the requirements for admission into the Master of Science in Computer Science program, admission into the Doctor of Philosophy degree program requires a Masters degree in Computer Science. If the student does not already have an MS in CS, they may be admitted into the MS/Ph.D.
program; in this program, students must complete the required coursework for the MS in CS as well as degree requirements for the Ph.D. in CS.

**Candidacy Requirements**

Despite acceptance into the program, in order to be admitted to candidacy, student must:

- Complete the degree requirements for the MS in CS (unless he or she possesses an MS in CS or a closely related engineering, scientific, or mathematical discipline)
- Pass the departmental qualifying examinations.

**Course Requirements:**

- 6 courses (18 credits) from the Masters course group list (http://www.cs.uml.edu/%7Egcoord/MS_Degree_Course_Requirements.pdf) (pdf), with at most 4 courses from a single Masters course group (https://www.uml.edu/docs/ms-degree-req_tcm18-53252.pdf) (pdf). No course applied towards an MS degree can be used to satisfy course distribution requirements for the Doctoral degree.
- Thesis Credits: 24 Credits
- Total: 42 credits

**Course Requirements for Students Matriculated Prior to January 2009**

**Major Area**

- 6 credits (course pairs list)

**Minor Area I**

- 6 credits (two courses from the course pairs list)

**Minor Area II**

- 6 credits (two courses from the course pairs list)

**Ph.D. Thesis**

- 24 credits
- Total: 42 credits

The major and minor area course requirements for the Ph.D. degree are above and beyond the corresponding requirements for the MS degree, but may continue and deepen specializations begun at that level. The primary purpose of the major and minor courses is to provide breadth of knowledge. Therefore, students are encouraged to select courses from a variety of areas. Among all course pairs for the MS and Ph.D. combined, at most one pair may contain a course "piggybacked" onto a core course.

**Additional Requirements**

- passing qualifying exams (rules (https://www.uml.edu/docs/QualRules_tcm18-148146.pdf) pdf)
- submission and defense at an oral examination of a thesis proposal
- completion of the thesis
- final defense of the thesis during another oral examination
- acceptance of two papers for publication in a peer-reviewed (refereed) journal or conference approved by the thesis advisor. At least one of these publications must be in the thesis area. This rule applies to students whose thesis proposals were defended on or after July, 2007.
- Students are required to report completion of each of these milestones according to the [Procedures for Student Progress Through the Ph.D. Program](https://www.uml.edu/Sciences/computer-science/Programs/Masters/Doctorate/Checklist.aspx).

**Computational Mathematics Option**

Requirements: (beyond a master’s degree)

- 18 Course Credits (6 courses)
- Four Graduate level courses in Computer Science and two graduate level courses in Mathematics, under the direction of an advisor, from an approved list of courses
- 24 Dissertation Credits
- Supervised by faculty from the Mathematics and Computer Science Departments
- Any student interested in this program should contact the Chair of the CS Department and/or the Chair of the Mathematics Department.
Graduate Certificate Programs

The department of Computer Science offers the following graduate level certificate Programs:

- Human-Computer Interactions
- Cyber Security
- System Models and Management
- Telecommunications

To fulfill requirements and earn a certificate, the required courses for the certificate must be completed within a five year period with a minimum 3.0 grade point average, and with no more than 3 credits below B. Courses completed for one certificate may not be used for another certificate.

Human-Computer Interaction Certificate

Coordinator: Jill Drury, Jill_Drury@uml.edu

Admission Requirements: Prerequisites as specified in the Catalog for admission to the MS program in Computer Science. Candidates with a Bachelors degree in some other suitable area and extensive programming experience should contact the CS Graduate Program Coordinator.

All courses for the Human-Computer Interaction certificate may be used toward a graduate degree in Computer Science, subject to the approval of the Graduate Coordinator and meeting the requirements for admission to the MS program.

Core Courses:

- COMP.5270
  (https://www.uml.edu/catalog/courses/COMP/5270)
  Introduction to HCI (3 credits)
- COMP.5280
  (https://www.uml.edu/catalog/courses/COMP/5280)
  Evaluation of HCI (3 credits)
- COMP.5680
  (https://www.uml.edu/catalog/courses/COMP/5680)
  Seminar in HCI (3 credits)

Elective:

One three-credit course taken from the following list:

- COMP.5130
  (https://www.uml.edu/catalog/courses/COMP/5130)
  Internet and Web Systems I

Cyber Security

Coordinator: William Moloney, 978-934-3640, bill@cs.uml.edu

This certificate program is available to students who have an undergraduate degree in Information Technology, Computer Science, Information Systems and related majors. Students should be familiar with the C programming language and have a math background that includes at least pre-calculus math, statistics and a first course in discrete structures. The certificate courses do not have pre-requisite requirements among themselves, and may be taken in any order.

NOTE: Courses taken for this certificate may not be used towards the MS in Computer Science degree.

Admission Requirements:
• Transcript showing proof of completion of an undergraduate BS or BA degree from an accredited institution
• Mathematical experience to include a minimum of one semester of pre-calculus, one semester of discrete mathematics and one semester of statistics, or the equivalent experience
• C programming proficiency, to include a minimum of one class of C programming and one class of data structures, or the equivalent experience
• Approval of the Graduate Coordinator

Choose four courses (12 credits total):

- MSIT.5620 (https://www.uml.edu/catalog/courses/MSIT/5620) Digital Forensics
- MSIT.5600 (https://www.uml.edu/catalog/courses/MSIT/5600) Network Infrastructures
- MSIT.5640 (https://www.uml.edu/catalog/courses/MSIT/5640) Secure Mobile Networks

NOTE: Courses taken for this certificate may not be used towards the MS in Computer Science degree.

**Admission Requirements:**

- Transcript showing proof of completion of an undergraduate BS or BA degree from an accredited institution
- Mathematical experience to include a minimum of one semester of pre-calculus, one semester of discrete mathematics and one semester of statistics, or the equivalent experience
- C programming proficiency, to include a minimum of one class of C programming and one class of data structures, or the equivalent experience
- Approval of the Graduate Coordinator

Required Courses: The certificate is comprised of the following courses:

Choose four courses, 12 credits

- MSIT.5180 (https://www.uml.edu/catalog/courses/MSIT/5180) Large Scale Application Deployment
- MSIT.5110 (https://www.uml.edu/catalog/courses/MSIT/5110) Network and Systems Administration
- MSIT.5190 (https://www.uml.edu/catalog/courses/MSIT/5190) Managing Virtual Systems
- MSIT.5430 (https://www.uml.edu/catalog/courses/MSIT/5430) Intrusion Detection Systems

**Telecommunications**

**Coordinator:** Benyuan Liu, Ph.D. (mailto:bliu@cs.uml.edu)
This graduate certificate consists of courses from both the Computer Science and Electrical Engineering Departments. It is intended for students who hold a baccalaureate degree in science or engineering and who wish to concentrate on hardware/software issues pertaining to telecommunications.

Admissions requirement:
- BS in Computer Science/Engineering/Mathematics

Course requirements:
- COMP.5630 (https://www.uml.edu/catalog/courses/COMP/5630) Data Communications I
- COMP.5640 (https://www.uml.edu/catalog/courses/COMP/5640) Data Communications II
- EECE.5430 (https://www.uml.edu/catalog/courses/EECE/5430) Introduction to Communication Theory
- or another three credit course with the permission of the Certificate Coordinator

All courses for the Telecommunications certificate may be used toward a graduate degree in either the Electrical Engineering or the Computer Science Department subject to the approval of the appropriate graduate coordinator and meeting the requirements for admission to the MS program.

MS and Ph.D. Course Pairs

The following is the list of approved course pairs for both the MS and the Ph.D.

NOTE: Among all course pairs for the MS and Ph.D. combined, at most one pair may contain a course “piggybacked” onto a core course.

- COMP.5630 Data Communications I
- COMP.5640 Data Communications II
- COMP.5630 Data Communications I
- COMP.5550 Computer Networks
- COMP.5150 Operating Systems I
- COMP.5160 Operating Systems II
- COMP.5460 Graphics I
- COMP.5470 Graphics II
- COMP.5460 Graphics I
- COMP.5411 Scientific Data Visualization
- COMP.527 Human-Computer Interaction
- COMP.568 Human-Computer Interaction Seminar
- COMP.5270 Human-Computer Interaction
- COMP.5650 Evaluation of Human-Computer Interaction
- COMP.5220 Object-Oriented Analysis and Design
- COMP.5230 Software Engineering I
- COMP.5230 Software Engineering I
- COMP.5240 Software Engineering II
- COMP.5230 Software Engineering I
- COMP.5210 A Discipline for Software Engineering
- COMP.5230 Software Engineering I
- COMP.5260 Project Management
- COMP.5730 Database I
- COMP.5740 Database II
- COMP.5510 Computer Architecture
- COMP.5530 Parallel Processing
- COMP.5510 Computer Architecture
- COMP.5150 Operating Systems I
- COMP.5150 Operating Systems I
• COMP.5200 Storage Architecture
• COMP.5150 Operating Systems I
• COMP.5530 Parallel Processing
• COMP.5040 Algorithms II
• COMP.5530 Parallel Processing
• COMP.5030 Algorithms I
• COMP.5530 Parallel Processing
• COMP.5310 Programming Language Design
• COMP.5380 Semantics of Programming Languages
• COMP.5310 Programming Language Design
• COMP.5390 Computational Logic
• COMP.5380 Semantics of Programming Languages
• COMP.5390 Computational Logic
• COMP.5430 Artificial Intelligence
• COMP.5380 Semantics of Programming Languages
• COMP.5430 Artificial Intelligence
• COMP.5390 Computational Logic
• COMP.5130 Internet and Web Systems I
• COMP.5140 Internet and Web Systems II
• COMP.5340 Compiler Writing I
• COMP.5350 Compiler Writing II
• COMP.5310 Design of Programming Languages
• COMP.5340 Compiler Construction I
• COMP.5480 Robot Design
• COMP.5490 Mobile Robots
• COMP.5610 Computer Security I
• COMP.5620 Computer Security II
• COMP.5430 Artificial Intelligence
• COMP.5440 Machine Learning and Data Mining


M.S. in Computer Science Bio/Cheminformatics Option

Admissions Criteria and Requirements

Applicants for admission to the Master of Science Program with a Bio/Cheminformatics option typically have an undergraduate degree in computer science or a related discipline such as mathematics, physics, biochemistry or engineering. Students wishing to enroll in the Master’s program in Computer Science with Bio/Cheminformatics option must demonstrate competency in the knowledge areas listed below. Competency in these areas is usually demonstrated by producing a transcript of previous academic experience which contains related courses passed with a B or better, or by earning a B or better in the courses listed below. Competency in the biology and chemistry area may be demonstrated by successfully passing a CLEP exam. Additional information regarding these exams may be obtained at the CollegeBoard website. The following are the knowledge areas in which competency must be demonstrated:

• Biology BIOL.1110 Principles of Biology I
• Chemistry CHEM.1210 Chemistry I and CHEM.1220 Chemistry II
• Discrete Mathematics MATH.3210 Discrete Structures I and MATH.3220 Discrete Structures II
• C or C++ through Data Structures
• COMP.2500 Accelerated C with Data Structures or COMP.1010 Computing I and COMP.1020 Computing II
• Programming Languages
• COMP.3010 Organization of Programming Languages
Core courses: Total 9 credits

- COMP.5020 Foundations of CS
- COMP.5030 Algorithms
- COMP.5310 Design of Programming Languages

Course Pairs:

The following course pairs are selected from the approved list of Computer Science pairs, these courses have been chosen because they complement the goals of the bio/cheminformatics option.

Total 12 Credits (Two pairs of courses from the approved list of CS pairs.)

- COMP.5030 Algorithms I
- COMP.5460 Graphics I
- COMP.5040 Algorithms II
- COMP.5470 Graphics II
- COMP.5730 Database I
- COMP.5730 or COMP.5740 Database I or II
- COMP.5740 Database II
- COMP.5500 Data Mining
- COMP.5730 or COMP.5740 Database I or II
- COMP.5460 or COMP.5470 Graphics I or II
- COMP.5220 Analysis and Design
- COMP.5411 Scientific Data Visualization
- COMP.5230 or COMP.5250 Software Engineering I or II
- COMP.5500 Data Mining
- COMP.5230 or COMP.5250 Software Engineering I or II
- COMP.5210 SWD in Context
- COMP.5260 Project Management
- COMP.5030 or COMP.5040 Algorithms I or II
- COMP.5430 Artificial Intelligence
- COMP.5530 Parallel Processing
- COMP.5500 Advanced Data Mining
- COMP.5030 or COMP.5040 Algorithms I or II
- COMP.5130 Internet and Web Systems I
- Topics Course Data Mining
- COMP.5140 Internet and Web Systems II
- COMP.5030 or COMP.5040 Algorithms I or II
- COMP.5030 or COMP.5040 Algorithms I or II
- COMP.5100 Computational Methods in Molecular Biology
- COMP.5430 Artificial Intelligence

Electives - Total 9 credits

Three additional courses will be taken from the list of approved bio/cheminformatics approved courses. The list below is for example only and it includes the current approved courses. This list will be updated as new courses are added to the program.

- BIOL.5050* (3 credits) Bioinformatics
- BIOL.5070* (1 credit) Bioinformatics Laboratory (coreq. BIOL.4050)
- BIOL.5190 (3 credits) Biochemistry I
- BIOL.5200 (3 credits) Biochemistry II
- BIOL.5010 (3 credits) Selected Topics I
- BIOL.5020 (3 credits) Selected Topics II
- BIOL.5670 Recombinant DNA Techniques
• CHEM.6510 Selected Topics in Chemistry: Protein and Chemical Informatics
• CHEM.5500 (3 credits) Biochemistry I
• CHEM.5510 (3 credits) Biochemistry II
• CHEM.5670 (3 credits) Biocheminformatics
• CHEM.5680 (3 credits) Computational Chemistry
• CHEM.5700 (3 credits) Advanced Protein Chemistry
• CHEM.5800 Advanced Analytical Biochemistry

MATH.5930 (3 credits) Experimental Design (Mathematics Department)

Although Organic Chemistry is not required as a prerequisite, some of the courses offered as part of this degree rely on knowledge of this subject.

Students should be aware that the above courses may only be used toward the Bio/Cheminformatics option. If the entire requirements of the option are not completed then these courses cannot be applied in isolation toward the M.S. in Computer Science.

Program Total: 30 credits (assuming prerequisites have been filled)

An optional master’s thesis can be substituted for at most 6 credits, and may be used to substitute for one pair of related courses.

MS in Computer Science - Entrepreneurship Option

Entrepreneurship Option

This program is no longer accepting applicants.
This is a Masters Degree Option within the Computer Science Graduate Program. It is directed to people with a strong undergraduate background in Computer Science who are interested in both deepening their technical knowledge and in understanding the tools required for developing a company directed towards software services and products.

Admission Requirements: as specified in the Catalog for admission to the MS program in Computer Science.

MS Requirements

Non-thesis option:

• 7 courses from Computer Science, satisfying the MS core and distribution requirements. (total of 21 credits)
• 3 College of Management courses (total of 9 credits) chosen from: ENTR.6500 (https://www.uml.edu/catalog/courses/ENTR/6500); Innovation and Emerging Technologies (3 credit) MKTG.6300 (https://www.uml.edu/catalog/courses/MKTG/6300); Market Research (3 credit) ENTR.6350 (https://www.uml.edu/catalog/courses/ENTR/6350); Financing Innovation & Technology Ventures (3 credit) ENTR.6450 (https://www.uml.edu/catalog/courses/ENTR/6450); New Product Development (3 credit)

and taken within the first two semesters of full-time study (first six graduate courses).

1 course from either Computer Science or Management, as deemed appropriate in consultation with the faculty adviser(s). (3 credits)

Total Credits: 33

Thesis option:

• 6 courses (18 credits) from Computer Science, satisfying the MS core and distribution requirements.
• 3 College of Management courses (9 credits) chosen from: ENTR.6500 (https://www.uml.edu/catalog/courses/ENTR/6500); Innovation and Emerging Technologies (3 credit) MKTG.6300 (https://www.uml.edu/catalog/courses/MKTG/6300); Market Research (3 credit) ENTR.6350 (https://www.uml.edu/catalog/courses/ENTR/6350); Financing Innovation & Technology Ventures (3 credit) ENTR.6450 (https://www.uml.edu/catalog/courses/ENTR/6450); New Product Development (3 credit)

and taken within the first two semesters of full-time study (first six graduate courses).

• 6 credits of Masters Thesis. The primary adviser shall be
from CS, with a member of the thesis committee from the College of Management. The thesis will articulate the results of appropriate market research, a detailed business plan, and will deliver a prototype of a product. A course taken from either CS or Management could substitute for 3 thesis credits, if approved by both advisers as being critical for the thesis.

**Total Credits: 33**

Visit Graduate Admissions (https://www.uml.edu/Grad/default.aspx) for more information.
COMP.5000 Fundamental of Computer Science  
(Formerly 91.500) - Credits: 3
Mathematical topics necessary for graduate study in computer science in the areas of discrete mathematics, probability, linear algebra and proof techniques. Material may include topics such as: summations, sets, relations, functions, recurrences, graphs, trees, elementary combinatorics, basic axioms and laws of probability, discrete random variables, probability distributions, matrices, Boolean algebra, logarithms.

COMP.5020 Foundations of Computer Science  
(Formerly 91.502) - Credits: 3
An advanced introduction to theoretical computer science. This course will cover the fundamentals of automata, formal languages, and computability theory.

COMP.5030 Algorithms (Formerly 91.503) - Credits: 3
Advanced algorithms and complexity analysis. Dynamic programming; greedy algorithms; amortized analysis; shortest path and network flow graph algorithms; NP-completeness; approximation algorithms; number-theoretic algorithms; string matching; computational geometry. Additional topics may include linear programming, parallel algorithms, fast Fourier transforms, polynomial, integer, and matrix algorithms. Readings may include conference and journal papers from the algorithms literature. Abstract types, lists, trees, graphs, sets; relevant algorithms and their worst and average case analyses; fast transforms; polynomial, integer, and matrix algorithms; NP-completeness.

COMP.5040 Advanced Algorithms: Computational Geometry (Formerly 91.504) - Credits: 3
Advanced algorithms topics, such as design and analysis of geometric and combinatorial algorithms, computability and complexity.

COMP.5100 Computational Complexity Theory  
(Formerly 91.510) - Credits: 3
This course covers polynomial-time hierarchy and polynomial space, circuit complexity, structure of NP, probabilistic machines and complexity classes, complexity of counting, interactive proof systems, probabilistically checkable proofs, complexity of approximation problems, and average-case NP-completeness.

COMP.5130 Internet And Web Systems I (Formerly 91.513) - Credits: 3
This course is a survey of Web programming technologies. It begins with a discussion of what Web servers and clients are, how they interact, and how one sets them up. We then explore a wide variety of Web technologies including HTML, JavaScript, JavaServer Pages, Java Servlets, and XML and its many related technologies. Our goal in this course is to provide the basic understanding and knowledge of how the Internet and World Wide Web operate and the technical knowledge required to establish and maintain an Internet/Web site and to develop and introduce new capabilities and features on such sites.

COMP.5140 Internet & Web Systems II (Formerly 91.514) - Credits: 3
A continuation of 91.513 with a focus on current topics and topics of special interest. Examples of recent topics include: The semantic Web and ontologies, Web services, Peer-to-peer networks, Information Search and Retrieval, Autonomous intelligent agents and Multi-modal presentations.

COMP.5150 Operating Systems I (Formerly 91.515) - Credits: 3
This course provides insight into multiprocessing operating systems including processor memory, peripheral, and file systems management in batch, timesharing, real time, and distributed systems targeted for various hardware. Particular emphasis will be placed on techniques of virtual memory as well as the problems of concurrency in both centralized and distributed systems. An OS simulation is a required programming project. Some topics to be covered are process synchronization; high-Level mechanisms for concurrency; processor scheduling and system analysis; deadlock; virtual memory; distributed systems; computer security.

COMP.5160 Operating Systems II (Formerly 91.516) - Credits: 3
The design and implementation of an interactive multiprocessing operating system to run on a bare hardware system. Separate teams manage the major subsystems with in-class design reviews to coordinate system integration. A functioning system is a class requirement.

COMP.5180 Operating Systems III (Formerly 91.518) - Credits: 3
The design and implementation of an interactive multiprocessing operating system to run on a bare hardware system. Separate teams manage the major subsystems with in-class design reviews to coordinate system integration. A functioning system is a class requirement.

COMP.5230 Computer Vision I (Formerly 91.423 & 91.523) - Credits: 3
Computer vision has seen remarkable progress in the last decade, fueled by the ready availability of large online image collections, rapid growth of computational power, and advances in representations and algorithms. Applications range from 3-D scene reconstruction, to visual Simultaneous Localization and Mapping (SLAM) for robotics, to real-time
human body pose estimation. This introductory computer vision course explores various fundamental topics in the area, including the principles of image formation, local feature analysis, segmentation, multi-view geometry, image warping and stitching, structure from motion, and object recognition.

COMP.5270 Human Computer Interaction (Formerly 91.527) - Credits: 3

The purpose of this class is to ground students in the basics of how humans interact with technology, and make students aware of the breadth of topic areas related to human-computer interaction (HCI). This course emphasizes theoretical constructs such as the Model-Human Processor, and includes seminal readings by the original researchers. Further, the course emphasizes techniques for understanding users’ tasks, formulating users’ requirements, and assessing proposed designs using heuristic evaluation. As part of understanding users’ needs, students will consider social, organizational, and ethical perspectives on information technology. Students are also exposed to specialty topics in human-computer interaction such as multi-user computing, universal access to computer applications, and internationalizing interfaces. This course includes a project to design, develop, document, and orally present a prototype interface. At the end of the course students will be able to cite basic principles of human interaction and devise and carry out a usability engineering plan to aid in developing new human interfaces.

COMP.5280 Evaluation of Human-Computer Interaction (Formerly 91.528) - Credits: 3

This course is an introduction to methods used to evaluate the design of human-computer interaction (HCI). Students will apply examples of all three of the major types of HCI evaluation techniques: inspection, analytical, and empirical techniques. The course also covers HCI experiment design and data analysis, including threats to experimental validity. The course project consists of a formal usability test. This project requires students to learn principles of ethical treatment of human subjects, complete the University’s Institutional Review Board applications and training for human-subject testing, conduct testing sessions, analyze data, recommend design changes, and document results in a professional manner. At course completion, students will have demonstrated skills for assessing the effectiveness of interface designs and will understand how evaluation fits into computer products’ lifecycles.

COMP.5300 Special Topics (Formerly 91.530) - Credits: 0-3

Topics of mutual interest to the instructor and student(s). “Variable credit course, student chooses appropriate amount of credits when registering.”

COMP.5310 Design of Program Languages (Formerly 91.531) - Credits: 3

A one-semester course designed to provide students with hands-on understanding of the underlying concepts of programming languages, the principles of their design, and the fundamental methods for their implementation. An executable metalanguage such as Scheme or SML is used throughout the course, facilitating the design of high-level, concise interpreters that are easy to comprehend. The approach is analytical because the salient features of the imperative, functional, object-oriented, and logic programming paradigms are described in the executable meta-language.

COMP.5340 Compiler Construction I (Formerly 91.534) - Credits: 3

This course implements a compiler for a complete language. Topics include grammars, syntax, elements of parsing and recursive descent, semantics, basic code generation, fast compilation runtime support. Programming project required.

COMP.5400 Visual Analytics (Formerly 91.540) - Credits: 3

This course covers the basic topics for the interdisciplinary field of visual analytics. This course is not just for computer science students but also for analysts and scientists in different disciplines. The topics include visual analytics science and technology, perception, cognitive processes and human tasks and reasoning, data and knowledge representation, visualization and interaction, statistical and analytic methods, data mining and knowledge discovery, and evaluation and usability. Numerous examples of systems, tools and applications will be presented.

COMP.5411 Data Visualization (Formerly 91.541) - Credits: 3

This course looks at classical and novel methodologies for the visualization of large and complex data sets. The course covers both scientific and information visualization starting with data modeling, human perception and cognition, basic and advanced techniques, interaction, formal models, real time systems, and frameworks for integrated analysis and visualization. Examples used come from numerous areas including the biomedical literature and security.

COMP.5420 Natural Language Processing (Formerly 91.442 & 91.542) - Credits: 3

This course introduces principles and techniques behind natural language processing (NLP), and covers a large selection of important automatic text processing tasks. Selected topics
include n-gram language models, part-of-speech tagging, statistical parsing, word sense disambiguation, discourse segmentation, information extraction, sentiment analysis, machine translation. Quantitative techniques are emphasized, with a focus on applying statistical models to large collections of text. The course provides students with a hands-on experience in building a substantial NLP application of their choice.

COMP.5430 Artificial Intelligence (Formerly 91.543) - Credits: 3
Search and games, knowledge representation paradigms, natural language understanding, planning, perception. Use of the LISP language for one or more programming projects.

COMP.5440 Data Mining (Formerly 91.544) - Credits: 3
This introductory data mining course will give an overview of the models and algorithms used in data mining, including association rules, classification, clustering, etc. The course will teach the theory of these algorithms and students will learn how and why the algorithms work through computer labs.

COMP.5450 Machine Learning (91.545) - Credits: 3
This introductory course gives an overview of machine learning techniques used in data mining and pattern recognition applications. Topics include: foundations of machine learning, including statistical and structural methods; feature discovery and selection; parametric and non-parametric classification; supervised and unsupervised learning; use of contextual evidence; clustering, recognition with strings; small sample-size problems and applications to large datasets.

COMP.5460 Computer Graphics I (Formerly 91.546) - Credits: 3
Introduction to the hardware, software and mathematics of 2- and 3-dimensional interactive computer graphics systems, including standards, modeling, transformations, hidden-surface removal, shading, and realism.

COMP.5470 Computer Graphics II (Formerly 91.547) - Credits: 3
Lighting models, photo-realism, animation, constructive solid geometry, and distributed graphics.

COMP.5480 Robot Design (Formerly 91.548) - Credits: 3
A broad interpretation of robotics to mean systems that interact with people, each other, and the world around them, using sensors, actuators, communications, and a control program. Project- and lab-based course that involves electronics, embedded coding, mechanical design, and research.

COMP.5490 Mobile Robots (Formerly 91.549) - Credits: 3
This course will focus on the artificial intelligence side of robotics in a project- and lab-based course. Topics to be covered include robot architectures, mapping and localization, learning, vision, multi-agent systems and current research areas.

COMP.5495 Robot Learning - Credits: 3
This course will cover a variety of machine learning approaches that allow robots to learn manipulation tasks from their own actions and experiences, as well as through interaction with humans. Topics will include methods from a) imitation learning, b) learning from demonstration, and c) Reinforcement Learning. We will discuss methods including, but not limited to, data gathering and pre-processing, skill encoding, reproduction, and generalization, skill refinement, obstacle avoidance, symbol grounding, symbolic planning, feature selection and segmentation, and active learning. The course includes student presentations and a final project where students develop an existing approach and extend it further by applying and implementing their own ideas. There are no formal pre-requisites however, this course covers material that utilize a good deal of machine learning and there will be no time to cover all the background material. Therefore, I strongly recommend having a graduate-level machine learning course (COMP.5450), equivalent research experience, or the willingness to do significant studying outside of class. Students are also expected to have fair knowledge of (a) Linear algebra, (b) calculus, and (c) statistics.

COMP.5500 Topics (Formerly 91.550) - Credits: 3
Topics of mutual interest to the instructor and student(s).

COMP.5510 Bioinformatics for CS - Credits: 3
Complete genomic sequences of human, other mammals, and numerous other organisms are known for some time. From early on, comparisons or analyses of genomic sequences require aids on computer programming. After brief introductions to molecular biology for Computer Science students, the course will examine computer algorithms used in bioinformatics problems including sequence alignment, phylogeny, DNA sequencing, and data analyses.

COMP.5520 Foundations in Digital Health - Credits: 3
Digital health is concerned about utilizing computational
technologies to develop health systems, in order to improve healthcare quality. These technologies include various software and hardware solutions such as web apps and wearable devices. This will introduce the foundations and methods in digital health and hand on lab sections to both undergraduate and graduate students, which include the scientific problems, challenges, and application tools of the domain, the tasks we need to handle with, and the applications of various methods such as statistics, machine learning and deep learning. After taking this course, students will obtain a clear concept about what is digital health and knowledge of a wide range of resources and tools to solve the problems and tasks in this domain.

COMP.5610 Computer & Network Security I (Formerly 91.561) - Credits: 3
Basic concepts and techniques of computer network security; data encryption algorithms; public-key cryptography and key management; data authentication; network security protocols in practice; wireless network security; network perimeter security; the art of anti malicious software; the art of intrusion detection. Students will implement encryption and authentication algorithms as network applications.

COMP.5620 Computer Security II (Formerly 91.562) - Credits: 3
Applied computer security topics such as a computer and network forensics, virtual private networks, denial of service, viruses and worms, intrusion detection systems, smart cards, biometrics, programming language security, web security and privacy, e-commerce; case studies of deployed systems; policy and legal considerations.

COMP.5630 Data Communications I (Formerly 91.563) - Credits: 3
Resource sharing; computer traffic characterizations; multiplexing; network structure; packet switching and other switching techniques; design and optimization; protocols; routing and flow control; simulation and measurement; communications processors.

COMP.5640 Data Communications II (Formerly 91.564) - Credits: 3
Continuation of 91.563

COMP.5660 Malware Analysis - Credits: 3-33
This class covers both introductory and advanced topics on binary reverse engineering techniques including virtual machines as sandboxes, basic and advanced dynamic analysis, a crash course on assembly language, reverse engineering tools, shellcode analysis and anti-reverse engineering techniques.

COMP.5670 IoT Security and Privacy - Credits: 3
The key objectives of this class include: understand IoT frameworks, applications and security and privacy concerns; be familiar with IoT hardware security; master IoT systems security; master IoT software security; master IoT network security; understand the IoT data security and privacy.

COMP.5680 Seminar in Human-Computer Interaction (Formerly 91.568) - Credits: 3
The two main purposes of this seminar course are to involve students in current human-computer interaction (HCI) research and to learn to critique others' HCI research. Each offering of the seminar will center on a theme of applying HCI techniques to a particular type of interaction such as human interfaces for robots, pervasive computing, or social media. Students will be expected to read and critique a number of papers from the current literature in the designated topic area. Further, class members will form a research team (led by the course instructor) to perform original research in the topic area. Class members will co-author a paper based on their research results with the goal of submitting it to a conference. By the end of the course, students will be able to describe the state-of-the-art in the course topic, recognize examples of good and poor research techniques, document research to high academic standards, and become productive members of HCI research teams.

COMP.5690 Computer and Network Forensics - Credits: 3
This class introduces students to computer forensics and network forensics. Computer forensics tackles forensic investigation of stand-alone computers while network forensics deals with forensic investigation of networked computers and networks. The class will cover topics such as laws and legal compliance, forensic imaging and analysis, log-file analysis, network traffic analysis and case study.

COMP.5700 Topics (Formerly 91.570) - Credits: 3
Topics of mutual interest to the instructor and student(s).

COMP.5730 Data Base I (Formerly 91.573) - Credits: 3
Study of various database models including hierarchical, network, relational, entity-relationship, and object-oriented models. This course also covers data design, integrity, security, concurrency, recovery, query processing, and distribution.
COMP.5740 Data Base II (Formerly 91.574) - Credits: 3
Continuation of Data Base I. Various issues in the implementation of database systems will be covered.

COMP.5800 Topics in Computer Science (Formerly 91.580) - Credits: 3
Topics of mutual interest to the instructor and student(s).

COMP.5870 Computer Science Education in Secondary School (Formerly 91.587) - Credits: 3

Directed Study in Computer Science

COMP.5901 Directed Study in Computer Science - Credits: 3

COMP.5920 Special Topics: Computer Science (Formerly 91.592) - Credits: 3
"Variable credit course, student chooses appropriate amount of credits when registering."

COMP.5930 Cooperative Education (Formerly 91.593) - Credits: 0-1

COMP.6040 Network Optimization (Formerly 91.604) - Credits: 3
This course covers advanced topics in network optimization on continuous and discrete models, including the max-flow problem, the min-cost flow problem, simplex methods for min-cost flow, dual ascent methods for min-cost flow, auction algorithms for min-cost flow, nonlinear network optimization, convex separable network problems, and network problems with integer constraints.

COMP.6130 Advanced Topics in Information Retrieval and Mining (Formerly 91.613) - Credits: 3
This is a proposed new 600-level course. The topics are advanced topics in Information Retrieval and Mining, including (but not limited to) Search and Information Retrieval, Visual Text Mining, Document Retrieval and Analysis, Non-textual Retrieval (including Image-, Sound, Video-Retrieval). The course’s format is a seminar: (advanced, doctoral) students will be reading and presenting the current state-of-the-art literature. Course requirements include weekly bibliography reports (at least 2 new entries each week) class presentations, two term papers, and a term project.

COMP.6410 Advanced Topics in Visualization (Formerly 91.641) - Credits: 3
This course covers advanced topics in data visualization. Coverage will be topical and may include advanced graph &text visualization, modern coordinated visualizations, collaborative visualization knowledge visualizations, security visualization, web-based visualization, and high-performance visualization. Theory will also be covered.

COMP.6440 Topics in Data Mining (Formerly 91.644) - Credits: 3
This course continues with 91.421/91.544 Data Mining and explores the state of the art research advances in mining large amount of data especially algorithms in association classification, clustering, and applications such as web mining and spatio-temporal data mining.

COMP.6610 Advanced Topics in Network Security (Formerly 91.661) - Credits: 3
This is a topic course, with a subtitle to be determined by the instructor. it covers advanced topics in network security of mutual interests to the faculty and students.

COMP.6730 Advanced Database Systems (Formerly 91.673) - Credits: 3
This course covers advanced topics in database management systems, including query processing and optimization, indexing, transaction management, data warehousing, data mining, etc. It also covers spatio-temporal databases, search engines, stream and sensor databases, and open problems for research.

COMP.7010 Computer Science Research (Formerly 91.701) - Credits: 1

COMP.7020 Computer Science Research (Formerly 91.702) - Credits: 6

COMP.7030 Computer Science Research (Formerly 91.703) - Credits: 3

COMP.7060 Directed Research (Formerly 91.706) - Credits: 6

COMP.7100 Approximation Algorithms (Formerly 91.710) - Credits: 3
This course covers advanced topics in approximation algorithms for NP-hard problems, including combinatorial
algorithms and LP-based algorithms for set cover, k-cut, k-center, feedback vertex set, shortest superstring, knapsack, bin packing, maximum satisfiability, scheduling, Steiner tree, Steiner Forest, Steiner network, facility location, k-median, semidefinite programming. It also covers counting problems, shortest vector, hardness of approximation, and open problems for research.

COMP.7410 Thesis Review (Formerly 91.741) - Credits: 1
COMP.7430 Master's Thesis - Computer Science (Formerly 91.743) - Credits: 3
COMP.7460 Master's Thesis - Computer Science (Formerly 91.746) - Credits: 6
COMP.7490 Master's Thesis - Computer Science (Formerly 91.749) - Credits: 9
COMP.7510 Doctoral Thesis Research (Formerly 91.751) - Credits: 1-3
COMP.7530 Doctoral Dissertation/Computer Science (Formerly 91.753) - Credits: 3
COMP.7560 Doctoral Dissertation/Computer Science (Formerly 91.756) - Credits: 6
COMP.7590 Doctoral Dissertation/Computer Science (Formerly 91.759) - Credits: 9
COMP.7690L Continued Graduate Research (Formerly 91.769) - Credits: 9
MSIT.5110 Network and Systems Administration (Formerly 94.511) - Credits: 3

This course introduces the concepts and techniques of systems and network administration. The course covers topics in a wide range from host management, network management, host and network security to automating system administration. In this course learners will be installing and configuring various popular network based services in a Linux environment.

MSIT.5140 Systems Security and Auditing (Formerly 94.514) - Credits: 3

This course examines the strategies for deploying and auditing secure systems. IT auditors primarily study computer systems and networks form the point of view of examining the effectiveness of their technical and procedural controls to minimize risks. Risk analysis and the implementation of corresponding best practice control objectives will be studied. The material will include methodologies that help auditors to:

Discover what’s really going on at a point in time; Find out about potential problems, before it’s too late to fix them; Evaluate business problems objectively; Make informed, if difficult decisions; Implement corrective actions, changes and improvements where needed.

MSIT.5170 Operating Systems Foundations (Formerly 94.517) - Credits: 3

This course investigates the organization and deployment of contemporary operating systems. The process model is examined both generically and in the context of the current Linux/Unix and Windows implementations. Process attributes such as address spaces, threads, channels and handles, access rights, scheduling behavior and states and state transitions will be studied. Memory management, deadlock management and the file system development are also evaluated. A subsystem of system configuration options will be considered during the course in order to highlight the functional deployment of the core OS issues discussed. Pre-req: BS in IT or equivalent. Cannot be used toward MS or PhD in Computer Science.

MSIT.5180 Large Scale Application Deployment (Formerly 94.518) - Credits: 3

This course will develop a systematic framework for the life cycle management of large scale applications. Beginning with requirements assessments, and impact analysis, and continuing through regulatory compliance, lifetime maintenance, scalability concerns, and end-of-life evolution, the material in this course will characterize the stages and transitions of large scale applications. Deployment and management tools will be examined in the context of live applications, with an emphasis on convergent analysis and configuration. Several case studies will be considered, including operating systems, database applications, mailing systems and collaboration systems.

MSIT.5190 Virtual Systems (Formerly 94.519) - Credits: 3

This course will investigate the current state of virtualization in computing systems. Virtualization at both the hardware and software levels will be examined, with emphasis on the hypervisor configurations of systems such as Vmware, Zen and Hyper-V. The features and limitations of virtual environments will be considered, along with several case studies used to demonstrate the configuration and management of such systems. Para-virtualized software components will be analyzed and their pros and cons discussed. Processor and peripheral support for virtualization will also be examined, with a focus on emerging hardware features and the future of virtualization.

MSIT.5200 Digital Storage Architectures (Formerly 91.520 and COMP.5200) - Credits: 3
This course will focus on existing and proposed technologies for storing digital information. Both hardware and software issues will be examined, beginning with device and controller organization and proceeding through aggregation techniques, interconnect architectures and host consideration. At each level, specific components will be evaluated with respect to critical storage criteria, such as bandwidth and latency, fault tolerance, infrastructure requirements and cost. Students must already have completed a bachelor’s degree in a related discipline and must meet all undergraduate prerequisite requirements specified for graduate IT programs to enroll in this course and in a graduate career.

**MSIT.5310 Project Management (Formerly 94.531) - Credits: 3**

This course explores the application of knowledge, skills, tools, and techniques that project managers use when managing information technology projects as well as the current IT factors that affect IT project management decision making. Special emphasis will be placed on learning the best practices currently used by organizations and practitioners to ensure the best chance for project success by learning and applying the concepts of managing scope, risk, budget, time, expectations, quality, people, communications, procurement, and externally provided services. Students will be expected to perform research in the above areas as well as using tools such as Microsoft Project to solve project management related problems. Special attention will also be placed on the issues affecting project managers today such as PMOs, virtualization, green IT, and out sourcing. Practical examples will be used to demonstrate the concepts and techniques, plus you will receive hands on experience by working on a case study.

**MSIT.5320 Managing Large Data Sets (Formerly 94.532) - Credits: 3**

The amount of data generated by businesses, science, Web, and social networks is growing at a very fast rate. This course will cover the algorithms and database techniques required to extract useful information from this flood of data. Data mining, which is the automatic discovery of interesting patterns and relationships in data, is a central focus of the course. Topics covered in data mining include association discovery, clustering, classification, and anomaly detection. Special emphasis will be given to techniques for data warehousing where extremely large datasets (e.g., many terabytes) are processed. The course also covers Web mining. Topics covered include analysis of Web pages and links (like Google) and analysis of large social networks (like Facebook).

**MSIT.5330 Developer Operations (DevOps) - Credits: 3**

"DevOps" is a set of practices to support software development and business operations in live production environments. By using agile practices and automation, these practices enable software to be developed and deployed to users quickly and with high quality. In this course you will learn DevOps tools and techniques. Tools include micro services, continuous integration and deployments, monitoring, and infrastructure-as-code. Techniques include oh DevOps engineers blur traditional roles of IT, development, release engineering, and quality assurance. Case studies in DevOps from companies such Amazon and Facebook will be studied. For experimentation purposed, Linux will be used on AWS together with open source tools such as Jenkins, Ansible, and Kubernetes. Students must already have completed a bachelor’s degree in a related discipline and must meet all undergraduate prerequisite requirements specified for graduate IT programs to enroll in this course and in a graduate career.

**MSIT.5350 Agile and Iterative Project Management (Formerly 94.535) - Credits: 3**

This course explores the differences between the Traditional Project management and the Agile management approaches, introduces the principles of Agile Development through applications within each major Project Management process: Project Initiation, Project Planning, Project Execution, and Project Closing. The project will be developed in a timely manner, using Agile techniques that encourage frequent adaptation, self-organization, accountability and with a focus towards rapid delivery. Upon completion, students will understand how to apply Agile principles and practices, recognize ways to increase team performance through better communication and close involvement of stake holders, and recognize the key success criteria for implementing Agile Projects.

**MSIT.5360 Data Mining (Formerly 94.536) - Credits: 3**

Today, we are surrounded by big data applications. Smartphone and sensor data, medical and scientific data, financial data, web and text data, and social network data are just a few examples. As a result, mining useful information and discovering knowledge from the big data are increasingly important. It is fair to say that, without data mining, we would not be able to make good use of this large amount of data. In this course, we learn the state-of-the-art techniques in data mining and analysis. Topics include types and properties of data, exploring data, classification, association analysis, cluster analysis, and anomaly detection.

**MSIT.5410 Information Security, Privacy and Regulatory Compliance (Formerly 94.541) - Credits: 3**

This course focuses on enterprise-level information security, privacy and regulatory compliance through study of the rapidly
emerging Information Governance (IG) discipline which is applied to electronic documents, records management and output of information organization-wide. The key principles of IG will be examined including the security, privacy and compliance of corporate e-documents/records as well as email, social media, instant messaging, cloud computing, and mobile computing. The student will learn how IG leverages existing information technologies to enforce policies, procedures and controls to manage information risk in compliance with legal and litigation demands, external regulatory requirements, and internal governance objectives.

MSIT.5430 Intrusion Detection Systems (Formerly 94.543) - Credits: 3

Intrusion Detection Systems is a survey of the hardware and software techniques that are applied to the detection, identification, classification and remediation of compromised information systems. From this introduction to intrusion detection systems, students will develop a solid foundation for understanding IDS and how they function. This course will give students a background in the technology of detection network attacks. It will introduce all the concepts and procedures used for IDS (intrusion Detection Systems) and IPS (Intrusion Prevention Systems). Students will have hands-on experience with implementing and configuring software and hardware based IDS in a network infrastructure. This course is designed with a network administrator in mind.

MSIT.5450 Designing and Building a Cybersecurity Program (Formerly 94.545) - Credits: 3

This course focuses on best practices for designing and building a comprehensive Cybersecurity Program based on the NIST Framework for Improving Critical Infrastructure Cybersecurity ("The Framework"). The Framework was issued on February 12, 2014, as directed by President Obama in Executive Order 13636. This framework provides guidance for reducing cybersecurity risk for organizations, and this course will examine its basic tenets of: "Cybersecurity Fundamentals", techniques applied to "Building a Controls Factory", "Cybersecurity Programs" "Establishing Cybersecurity Centers of Expertise" and "The Cybersecurity Program Implementation Roadmap".

MSIT.5600 Network Infrastructures (Formerly 94.560) - Credits: 3

This course provides an introduction to the fundamental concepts in the design and implementation of computer communication networks, their protocols, and applications. Topics to be covered include: an overview of network architectures, applications, network programming interfaces (e.g. sockets), transport, congestion, routing, and data link protocols, addressing, local area networks, network management, and emerging network technologies. Cannot be used toward MS or D.Sc. in Computer Science.

MSIT.5610 Computer Network Security (Formerly 94.561) - Credits: 3

This course is aimed to provide students with a solid understanding of key concepts of computer network security and practical solutions to network security threats. Topics to be covered include common network security attacks, basic security models, data encryption algorithms, public-key cryptography and key management, data authentication, network security protocols in practice, wireless network security, network perimeter security and firewall technology, the art of anti-malicious software, and the art of intrusion detection. Pre-Req: BS in IT or Equivalent. Cannot be used toward MS or D.Sc. in Computer Science.

MSIT.5620 Digital Forensics (Formerly 94.562) - Credits: 3

Identifying, preserving and extracting electronic evidence. Students learn how to examine and recover data from operating systems, core forensic procedures for any operating or file system, understanding technical issues in acquiring computer evidence and how to conduct forensically sound examinations to preserve evidence for admission and use in legal proceedings.

MSIT.5630 Secure Mobile Networks (Formerly 94.563) - Credits: 3

This course covers principles and practices of wireless networks, including cellular networks, wireless LANs, ad hoc mesh networks, and sensor networks. The potential attacks against these wireless networks and the security mechanisms to defend these networks will be discussed. Topics to be covered include cellular network architecture, wide-area mobile services, wireless LANs and MACs, introduction to emerging wireless networks, survey of malicious behaviors in wireless networks, survey of wireless WANs and LANs, securing wireless routing, securing mobile applications, wireless intrusion detection and prevention, challenges in securing next-generation wireless networks, and privacy issues in wireless networks.

MSIT.5650 Cloud Computing (Formerly 94.565) - Credits: 3

This course starts with an overview of modern distributed models, exposing the design principles, systems architecture, and innovative applications of parallel, distributed, and cloud computing systems. The course will focus on the creation and maintenance of high-performance, scalable, reliable systems,
providing comprehensive coverage of distributed and cloud computing, including: Facilitating management, debugging, migration, and disaster recovery through virtualization. Clustered systems for research or e-commerce applications. Designing systems as web services. Principles of cloud computing using examples from open-source and commercial applications.

**MSIT.5660 Advanced Cloud Computing (Formerly 94.566) - Credits: 3**

This course is a continuation of the 94.565 Cloud Computing course and will cover in further detail such topics as Cloud Based Storage, Virtualization, Service Oriented Architecture (SOA), High Availability, Scaling, and Mobile Devices. The course will also study the role of Open Source cloud software such as Hadoop, OpenStack and others. Similar to the first course where hands-on projects included the use of Cloud Services such as Amazon Web Services (AWS), Google Apps and App Engine, and Windows Azure, this course will continue with those services and add others such as Rackspace and VMware. Current articles and publications in this fast moving field of Cloud Computing will also be followed.
Program Options

Master's of Science in Environmental Studies

- Atmospheric Science Option (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
- Environmental Geoscience Option (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
- Professional Science Masters Environmental Geoscience Option (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
- Professional Science Master's Atmospheric Science Option (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Graduate Certificate Programs

- Certificate in Environmental Geoscience
- Certificate in Environmental Atmospheric Science

Professional Internship and Seminar

This professional internship is required for students in this program and is expected to represent a minimum of 350 hours and will have a 3-6 month duration. The internship is designed to provide students with an opportunity to obtain real-world experience in business, government agencies, non-profit organizations or research institutes. To be eligible for the internship students will be expected to have completed half of their STEM courses, two business/communication courses, attained a minimum GPA of 3.0 and received departmental permission. Through this experience the student engages in real-world work situations involving technical problems, teamwork, communication skills and decision-making. Students who are employed full-time in a pertinent field may fulfill the internship requirement by completing an approved project, which adds to the students current set of skills. All Professional Internships require supervision by program faculty.

Master of Science in Environmental Studies

- Atmospheric Science Option

For information on the Master’s Program in Environmental Studies/Environmental Engineering, visit the Civil and Environmental Engineering Department.

Graduate Certificate In Environmental Geoscience

- Admission Requirements
- Certificate Pathway
- Curriculum

This certificate is designed for students who have an interest in the environmental aspects of the geosciences. Students who would benefit from this certificate are:

1. individuals who hold an undergraduate degree in geo/environmental science who want to increase their technical skills with additional geoscience courses,
2. individuals with an undergraduate degree in Civil/Environmental Engineering who want to broaden their expertise and
3. individuals who hold other science and engineering degrees and work in the environmental field.

Students who successfully complete the Graduate Certificate in Environmental Geoscience at UMass Lowell with a GPA of 3.5 or higher may waive the GRE requirement if applying to the MS Environmental Studies - Environmental Geoscience (option) program. Upon acceptance into the Environmental Geoscience program, the 12 credits from the Graduate certificate in Environmental Geoscience with a course grade of 3.0 or higher may be transferred into the MS Environmental Studies - Environmental Geoscience (option) program.

Admission Requirements:
• Baccalaureate degree in science, engineering, or similar area from an accredited institution with a Minimum GPA of 3.0. This requirement may be waived if the applicant has a significant professional experience or submits other evidence supporting the likelihood of academic success.

• Graduate Certificate Application Form
• Application Fee
• Official transcript from the baccalaureate institution.
• Citizens of non-English speaking countries who have never earned an academic degree in the United States must submit TOEFL scores.

Certificate Pathway

Four courses (minimum of 12 credits) are required for an Environmental Geoscience Certificate. Select one course from Area I and one course from Area II. Select two additional courses from any of the three areas.

Curriculum

Area I. Surface Processes (Elect 1) (3 cr)
- GEOL.5020 Quantitative Geomorphology (3 cr)
- GEOL.5100 Glacial and Pleistocene Geology (3 cr)
- GEOL.5240 Regional Hydrogeology (3 cr)

Area II. Geochemistry and Geophysics (Elect 1)
- GEOL.5150 Topics in Environmental Geochemistry (3 cr)
- GEOL.5310 Isotopes in Environmental & Geosciences (3 cr)
- GEOL.5560 Applied Geophysics (3 cr)

Area III. Electives
- GEOL.5200 Structural Geology (3 cr)
- GEOL.5220 Structural Geology Laboratory (1 cr)
- GEOL.5410 Environmental and Engineering Geology (3 cr)

Two Additional courses from any of the above three areas (6 cr)

Total Credits (12 cr)

Graduate Certificate in Environmental Geoscience

Geoscience

• Admission Requirement
• Certificate Pathway
• Curriculum

This certificate is designed for students who have an interest in the environmental aspects of the geosciences. Students who would benefit from this certificate are:

1. individuals who hold an undergraduate degree in geo/environmental science who want to increase their technical skills with additional geoscience courses,
2. individuals with an undergraduate degree in Civil/Environmental Engineering who want to broaden their expertise and
3. individuals who hold other science and engineering degrees and work in the environmental field.

Students who successfully complete the Graduate Certificate Geoscience at UMass Lowell with a GPA of 3.5 or higher may waive the GRE requirement if applying to the MS Environmental Studies - Environmental Geoscience (option) program. Upon acceptance into the Environmental Geoscience program, the 12 credits from the Graduate certificate in Environmental Geoscience with a course grade of 3.0 or higher may be transferred into the MS Environmental Studies-Environmental Geoscience (option) program.

Admission Requirements:

• Baccalaureate degree in science, engineering, or similar area from an accredited institution with a minimum GPA of 3.0. This requirement may be waived if the applicant has significant professional experience or submits other evidence supporting the likelihood of academic success.
• Graduate Certificate Application Form.
• Application Fee.
• Official transcripts from the baccalaureate institution.
• Citizens of non-English speaking countries who have never earned an academic degree in the United States must submit TOEFL scores.
Four courses (minimum of 12 credits) are required for an Environmental Geoscience Certificate. Select one course from Area I and one course from Area II. Select two additional courses from any of the three areas.

Curriculum

- **Area I. Surface Processes (Elective 1)** (3 credits) 89.502
  Quantitative Geomorphology (3 credits) 89.510
  Glacial and Pleistocene Geology (3 credits) 89.524
  Regional Hydrogeology (3 credits)

- **Area II. Geochemistry and Geophysics (Elective 1)** (3 credits) 89.515 Topics in Environmental Geochemistry (3 credits) 89.531 Isotopes in Environmental & Geosciences (3 credits) 89.556 Applied Geophysics (3 credits)

- **Area III. Electives** (3 credits) 89.520 Structural Geology (3 credits) 89.522 Structural Geology Laboratory (1 credit) 89.541 Environmental and Engineering Geology (3 credits)

  **Two Additional courses from of of the above three areas (6 credits)**

  **Total credits (12 credits)**

Graduate Certificate in Environmental Atmospheric Science

- Admission Requirements
- Certificate Pathway
- Curriculum

This certificate is designed for students who have an interest in the environmental aspects of the Atmospheric Sciences. The intended audience is practitioners in the environmental field who want to broaden their expertise. The target audience would encompass individuals with engineering or science degrees. There are two suggested concentrations (see below) one addressing the needs of individuals interested in air quality the other energy.

Students who successfully complete the Graduate Certificate in Environmental Atmospheric Science at UMass Lowell with a GPA of 3.5 or higher may waive the GRE requirement if applying to the MS Environmental Studies-Atmospheric Science (option) program.

Admission Requirements:

- Baccalaureate degree in science, engineering or similar area from an accredited institution with a minimum GPA of 3.0. This requirement may be waived if the applicant has significant professional experience or submits other evidence supporting the likelihood of academic success.
- Graduate Certificate Application Form.
- Application Fee.
- Official transcript from the baccalaureate institution.
- Citizens of non-English speaking countries who have never earned an academic degree in the United States must submit TOEFL scores.

Certificate Pathway:

Four courses (minimum of 12 credits) are required for an Environmental Atmospheric Science Certificate. Required course from Area I and three courses from Area II.

Curriculum

**Area I. Foundation Course (3 cr)**

- ATMO.5010 (https://www.uml.edu/catalog/courses/ATMO/5010)
  Boundary Layer Meteorology (3 cr)

**Area II. Environmental and Energy Courses (Elect 3) (9 cr)**

- ATMO.5080 (https://www.uml.edu/catalog/courses/ATMO/5080)
  The Climate System (3 cr)
- ATMO.5100 (https://www.uml.edu/catalog/courses/ATMO/5100)
  Regional Climate and Weather Modeling (3 cr)
- ATMO.5230 (https://www.uml.edu/catalog/courses/ATMO/5230)
  Air Pollution Control (3 cr)
- ATMO.5710 (https://www.uml.edu/catalog/courses/ATMO/5710)
  Air Pollution
- ATMO.6740 (https://www.uml.edu/catalog/courses/ATMO/6740)
  Air Quality Modeling (3 cr)
- ENVI.5720
  (https://www.uml.edu/catalog/courses/ENVI/5720)
  Energy and Environment (3 cr)
- PUBH.6190
  (https://www.uml.edu/catalog/courses/PUBH/6190)
  Measurement of Chemical Exposures (3 cr)
- MECH.5210
  (https://www.uml.edu/catalog/courses/MECH/5210)
  Solar Fundamentals (3 cr)
- MECH.5810
  (https://www.uml.edu/catalog/courses/MECH/5810)
  Advanced Fluid Mechanics (3 cr)

Total Credits (12 credits)

Air Quality suggested courses:

- ATMO.5010
  (https://www.uml.edu/catalog/courses/ATMO/5010)
  (required) and three of the following:
- ATMO.5100
  (https://www.uml.edu/catalog/courses/ATMO/5100)
- ATMO.5230
  (https://www.uml.edu/catalog/courses/ATMO/5230)
- ATMO.5710
  (https://www.uml.edu/catalog/courses/ATMO/5710)
- ATMO.6740
  (https://www.uml.edu/catalog/courses/ATMO/6740)
- PUBH.6190
  (https://www.uml.edu/catalog/courses/PUBH/6190)

Energy suggested courses:

- ATMO.5010
  (https://www.uml.edu/catalog/courses/ATMO/5010)
  (required) and three of the following:
- ATMO.5080
  (https://www.uml.edu/catalog/courses/ATMO/5080)
- ATMO.5100
  (https://www.uml.edu/catalog/courses/ATMO/5100)
- ENVI.5720
  (https://www.uml.edu/catalog/courses/ENVI/5720)
- MECH.5210
  (https://www.uml.edu/catalog/courses/MECH/5210)
- MECH.5810
  (https://www.uml.edu/catalog/courses/MECH/5810)
ATMO.5010 Boundary Layer Meteorology (Formerly 85.501) - Credits: 3

This course draws upon the equations of motion in the atmosphere to develop a theoretical understanding of the atmospheric boundary layer. This understanding is compared with real observations taken with the Department's rawinsonde equipment, as well as published data. The emphasis is on blending theory and practice to enhance the student's understanding of the behavior of the atmosphere.

ATMO.5020 Advanced Synoptic Meteorology (Formerly 85.502) - Credits: 3

This course is designed for graduate students who have a strong background in mathematics and physics, but whose meteorology preparation is weak. The basic concepts of weather forecasting and analysis on synoptic scales are covered theoretically as well as in application to case studies and current weather. The coursework encourages the development of three - dimensional visualization techniques and an appreciation of the physics which controls weather systems.

ATMO.5030 Remote Sensing (Formerly 85.503) - Credits: 3

This course is a survey of ground based, balloon, rocket probe, radar and satellite remote sensing techniques. Optical and radio frequency remote sensing techniques are surveyed. The focus is on the determination of physical, chemical and dynamical quantities by remote sensing measurements. The theory is presented used to interpret data obtained by remote sensing techniques. Various inversion methods are discussed used to obtain spatial discrete quantities from line - of - sight observations. Modeling and simulation techniques are described and practiced.

ATMO.5050 Atmospheric Measurements and Data Analysis - Credits: 3

Against the backdrop of unprecedented global environmental change, meteorological and climatological observations have been thrust into the scientific and public spotlight. ATMO.5050 explores the range of instrumentation, measurement principles, and data analysis techniques used to monitor Earth’s ever-changing weather and climate. From hands-on work with state-of-the-art field instruments, to computational data processing and visualization, students will gain a broad set of skills that will position them to succeed in both the observational and computational atmospheric science sub-fields.

ATMO.5080 The Climate System (Formerly 85.508) - Credits: 3

The main elements of the Climate System are the atmosphere, ocean, biosphere, land surface, and the cryosphere; the primary input of energy is from the Sun. This course examines these elements, the ways in which they interact and how they can be modeled. The Global Energy Budget is examined and both natural and human-caused climate change are considered.

ATMO.5100 Regional Weather and Climate Modeling (Formerly 85.510) - Credits: 3

Mesoscale atmospheric dynamics and regional climate dynamics. Application of regional weather and climate model to regional weather, climate modeling and forecast problems. Multi-scale physical processes, such as mesoscale and convective-scale phenomena, low-level jets, mountain waves and orographic precipitation, land/sea breezes, cyclones etc., will be discussed in order to understand the linkage between regional weather and climate.

ATMO.5130 Physical Meteorology (Formerly 85.513) - Credits: 3

This course explores the essentials of cloud physics, beginning with the basic laws of thermodynamics of both dry and moist atmospheres. Condensation, nucleation, and drop growth are studied in detail at an advanced level.

ATMO.5150 Atmospheric Structure and Dynamics (Formerly 85.515) - Credits: 3

The temperature, pressure and density structure of the atmosphere are reviewed, as well as the chemical composition. Topics include atmospheric and solar radiation, atmospheric heat budget and the hypsometric equation. Dynamics of the atmosphere explores the behavior of fluids on a rotating earth, global circulation, synoptic scale motions, perturbation theory of wave motions. Elements of climatic change and the effects of anthropogenic emissions on climate and weather will also be discussed.

ATMO.5160 Mesoscale Atmospheric Dynamics (Formerly 85.516) - Credits: 3

This course is designed for students to apply atmospheric dynamics and physical analysis techniques to mesoscale and convective-scale phenomena, including mesoscale convective systems, severe thunderstorms, tornadoes, dry lines, low-level jets, mountain waves and orographic precipitation, land/sea breezes, boundary layer rolls, and hurricanes. Emphasis will be given to the physical understanding of these processes instead of forecasting.
ATMO.5180 Forecasting and Synoptic Techniques I  
(Formerly 85.518) - Credits: 3

This is the first of a two-course sequence that provides graduate students a combined theoretical and applied understanding of synoptic-scale meteorology, with an emphasis on forecasting applications. The first course introduces the concepts of vorticity advection and the quasi-geostrophic approximation, and applies them synoptic-scale cyclones, including nor’easters. The graduate students will learn to use Gempak graphics and will be introduced to the National Weather Service Weather Event Simulator, a combined hardware and software package that simulates the NWS forecast environment.

ATMO.5190 Forecasting and Synoptic Techniques II  
(Formerly 85.519) - Credits: 3

This is the second of a two-course sequence that provides graduate students a combined theoretical and applied understanding of synoptic-scale meteorology, with an emphasis on forecasting applications. This second course builds on the content of the first, extending quasi-geostrophic approximation to Q-vectors and isentropic potential vorticity. The National Weather Service Weather Event Simulator, a combined hardware and software package that simulates the NWS forecast environment will be used to study case studies that have been programmed for the Simulator. Together with 85.518, this two-course sequence satisfies the NWS certification requirements for analysis and prediction of weather systems.

ATMO.5230 Air Pollution Control (Formerly 85.523) - Credits: 3

This course describes air pollutants, their characterization, ambient concentrations, effects on human health and the ecology, and the environmental laws and regulations that set standards on emission rates and ambient concentrations. The basics of air pollutant dispersion and transport are also covered. The main focus of the course is on emission control technologies for particulate matter, carbon monoxide, sulfur oxides, nitrogen oxides, organic and inorganic toxic pollutants. The following technologies are discussed: cyclones, scrubbers, electrostatic precipitators, baghouses, adsorption, absorption and incineration. The automobile and its emission control are reviewed. Alternative methods are also discussed, such as fuel substitution, conservation and efficiency improvement.

ATMO.5240 Simple Atmospheric Models (Formerly 85.524) - Credits: 3

The basic wave types and fundamental dynamics of atmospheric motion are considered through analytical and numerical modeling of the main simplifications (models) of the full equations of motion for the atmosphere. These models are derived by making assumptions that greatly simplify the full equations and which isolate individual wave types and specific physical mechanisms. Together, these models describe the basic aspects of atmospheric motion: the maintenance and structure of the jet stream, the genesis and propagation of synoptic storms, and the forced and internal contributions to seasonal patterns of midlatitude climate variability.

ATMO.5290 Advanced Forecasting (Formerly 85.529) - Credits: 3

This course builds on the student’s basic understanding of storm systems and extends their theoretical knowledge to particular weather patterns. Topics include nowcasting, long-range forecasting, snow squalls, sea breeze, and especially deep convection. Particular attention is paid to the structure and development of supercells. Students will also be required to write a special report on a topic assigned by the professor, and present this in class as a special lecture.

ATMO.5400 Tropical Meteorology (Formerly 85.540) - Credits: 3

An introduction to the tropical atmosphere, including tropical climatology, structure and dynamics of easterly waves, tropical cyclones and monsoon circulation’s.

ATMO.5500 Satellite and Rad Meteorology (Formerly 85.550) - Credits: 3

ATMO.5710 Air Pollution Phenomenology (Formerly 85.571) - Credits: 3

The course centers on transport, dispersion and transformation of air pollutants in the atmosphere. Atmospheric structure and dynamics are reviewed. The atmospheric dispersion equation is developed for instantaneous and steady-state releases of pollutants, including the Gaussian Plume Equation for point, line and area sources. The sources and transport of particulate matter are discussed, including haze and visibility impairment. Other topics are photooxidants (ozone), acid deposition, stratospheric ozone depletion and the greenhouse effect.

ATMO.5810 Meteorology for Teachers (Formerly 85.581) - Credits: 3

The purpose of this course is to provide the middle school teacher with: a thorough understanding of several key concepts and processes of meteorology; the ability to effectively present meteorology topics that are appropriate for the middle school science classroom; the tools necessary to develop inquiry based lessons for the classroom.
ATMO.5910 Directed Study (Formerly 85.591) - Credits: 1-3
ATMO.5950 Professional Experience Atmospheric Science (Formerly 85.595) - Credits: 1-3
Professional experience with a private or public employer. Written report and supervisor evaluation required.

ATMO.6410 Special Topics in Meteorology (Formerly 85.641) - Credits: 3
ATMO.6420 Special Topics in Meteorology (Formerly 85.642) - Credits: 3
ATMO.7010 Graduate Research Seminar (Formerly 85.701) - Credits: 1
ATMO.7310 Master's Research (Formerly 85.731) - Credits: 1-6
ATMO.7320 Graduate Research (Formerly 85.732) - Credits: 2
ATMO.7330 Master's Research in Atmospheric Sciences (Formerly 85.733) - Credits: 1-6
ATMO.7430 Master's Thesis in Atmospheric Sciences (Formerly 85.743) - Credits: 1-6
ATMO.7530 Doctoral Dissertation in Atmospheric Sciences (Formerly 85.753) - Credits: 3-8
ATMO.7600 Continuing Graduate Research (PhD) (Formerly 85.760) - Credits: 1-9
Continuing Graduate Research at the PhD level. May be taken for variable credit.

ATMO.7630 PhD Research in Atmospheric Sciences (Formerly 85.763) - Credits: 2
ATMO.7650 Doctoral Dissertation (Formerly 85.765) - Credits: 1-9
ATMO.7680 Doctoral Dissertation (Formerly 85.768) - Credits: 9
ENVI.5000 Graduate Seminar in Environmental Sciences - Credits: 1
The Graduate Seminar in Environmental Sciences includes speaker presentations by invited external and internal faculty, as well as student presentations. Graduate seminar students will also be expected to evaluate professional papers and complete several writing assignments specific to presentations and/or research papers. The class includes interdisciplinary topics in Atmospheric Sciences, Geosciences, and Environmental Sciences. The goals are to improve oral and written communication skills and expand knowledge of state-of-the-art research approaches and research themes.

ENVI.5010 Wetlands Ecology (Formerly 18.501) - Credits: 3
Types, characteristics and definitions, functions and values, regulation and management of wetlands; with due regard given to geology, soils and hydrology, and biological/ecosystem interactions.

ENVI.5020 Freshwater Ecology - Credits: 3
Freshwater Ecology is a 3-credit lecture course that covers the basic concepts regarding the physical structure, water quality, and ecological communities of freshwater lake and pond as influenced by the environment. Physical and chemical concepts (e.g., lake circulation patterns, thermal stratification, nutrient budgets, etc.) are incorporated with the lake biota (e.g., phytoplankton, zooplankton, and fish) and synthesized to provide perspective on ecosystem function. Within this scientific framework, we will also study the application of practical lake management using current lake and watershed-based management tools and options.

ENVI.5040 Geographic Information Systems (Formerly 87.504) - Credits: 3
This course will cover most of the elements of a geographic information system commonly found in basic and mid-level GIS applications. Topics will include file organization, data entry including digitizing and image registration, geocoding, thematic mapping, Structured Query Language (SQL) applications, map algebra, raster operations, interpolative methods, distance mapping, density mapping, cost surfaces, and an introduction to modeling. This course will use the Arcview GIS platform.

ENVI.5100 Environmental Pollution - Credits: 3
This class is designed for graduate students in Environmental, Earth and Atmospheric Sciences, Environmental Engineering, Environmental Chemistry and Biology. The class describes the origin, transport, and transformation of pollutants in the environmental behavior and biological impacts of contaminants. Students also will learn about national and international regulations regards pollutant emissions and technology for control and remediation.

ENVI.5160 Climate Change: Science, Communication,
and Solutions (Formerly 81.516/Biol.5160) - Credits: 3

Like many of the ‘grand challenges’ currently facing society, climate change is a complex problem that cuts across academic disciplines, including the physical sciences, biology, engineering, economics, political sciences, and behavioral psychology. In this course, we integrate recent research from many of these disciplines to explore the scientific basis of climate change, its impacts on the natural world and human society, and societal responses to it. Through interactive simulations, class discussions, lectures, current scientific literature, and student-led projects, the goal of this course is to empower students to come to their own decisions about how society can address the climate change challenge. Students taking this course at the graduate level will lead group projects.

ENVI.5170L Climate Change: Science, Communication, Solutions Recitation Lab - Credits: 1

This course is designed to integrate closely with the lecture course, Climate Change: Science, Communication, and Solutions. Students will use interactive simulations, build models, and create media projects that explore climate change and sustainability. Topics include the physical climate system and carbon cycle, human energy systems, and climate policy and economics. Students take this course at the graduate level will lead group projects.

ENVI.5200 Methods in Environmental Impact Assessment and Analysis (Formerly 87.520) - Credits: 3

This course describes, and illustrates with case studies, environmental evaluation required to implement projects and policies potentially affecting the environment. Methods available to integrate technical impact predictions, prepare Environmental Statements, and make informed decisions regarding environmental effects will be covered. Incorporation of sustainability and permitting with environmental analyses will also be examined.

ENVI.5720 Energy and Environment (Formerly 87.572) - Credits: 3

This course discusses the world and U.S. primary energy resources and consumption, including fossil, nuclear and renewable energy sources. Principles of thermodynamics are reviewed, especially in regard to energy usage efficiency improvement. A significant part of the course is devoted to electricity production, including site visits to fossil and nuclear power plants. The environmental effects are discussed of energy extraction and consumption, such as SOx, NOx and particulate matter emissions, acid deposition, the greenhouse effect, radioactive waste disposal. Also the risks of accidents are discussed in fossil and nuclear fuel usage.

ENVI.5810 Understanding Massachusetts Contingency Plan (Formerly 18.581) - Credits: 3

The Massachusetts Contingency Plan (MCP) is a body of regulations designed to streamline and accelerate the assessment and cleanup of releases of oil and hazardous materials to the environment. This course serves as an introduction to the MCP and will explore the intent and use of key aspects of this working document. Though primarily a regulatory course, some topics to be covered are technical by nature. Prerequisites: None. Though not required, some familiarity with relevant environmental science and/or engineering principles is desirable.

ENVI.5850 Climate Change in the Classroom (Formerly 87.585) - Credits: 3

The course is designed to help teachers from all levels improve their ability to foster student learning about the earth’s changing climate. The course addresses the scientific, sociological, and pedagogical dimensions associated with climate change science. How to incorporate climate change into existing curriculum across disciplines is considered.

GEOL.5010 Paleoclimatology (Formerly 89.501) - Credits: 3

This course provides students with an overview of paleoclimatology by examining the use of proxy records, such as marine and lake sediment sequences, ice cores, tree rings, corals and historical data to reconstruct past climatic conditions. Dating methods will be introduced. Throughout, we will critically analyze our understanding of past climates and environments and identify directions for future research. Topics include: abrupt climate change, human evolution and climate, biosphere-climate interactions and paleoclimate modeling.

GEOL.5020 Quantitative Gemorphology (Formerly 89.502) - Credits: 3

This course follows the path of material as it is weathered from bedrock, moved down hillslopes and transported via glaciers and rivers. Emphasis is on 1) quantifying erosion and sediment transport, 2) applying computer-based models and conservation of mass equations to earth surface processes and 3) understanding long-term landform evolution.

GEOL.5100 Geology of New England (Formerly 89.510) - Credits: 3
New England has an ancient and diverse geologic history. This course covers the tectonic and sedimentary processes that formed the bedrock of New England and New York, the Pleistocene history of ice sheet erosion and deposition, and the most recent period of human interactions with the landscape.

**GEOL.5130 Exploring the Solar System - Credits: 3**

We live in a remarkable era of robotic space exploration. In this course, we will walk through the formation of the Solar System and the comparative evolutions of the planets, moons, and other objects from a geological perspective, with special attention paid to the latest research and missions. We will also consider the prospects for life on other planetary bodies in our Solar System and in extrasolar planetary systems.

**GEOL.5150 Topics in Environmental Geochemistry (Formerly 89.515) - Credits: 3**

Case-based course dealing with the application of thermodynamics and kinetics, acid-base equilibria, oxidation-reduction reactions, radioactive and stable isotopes, and mineral chemistry to the understanding and solution of environmental problems. Other topics will be considered based on student interest.

**GEOL.5200 Structural Geology (Formerly 89.520) - Credits: 3**

An analysis of crustal deformation through detailed study of geologic structures with emphasis upon the response of geologic materials to stress and strain. Field techniques, tectonic principles, and geometrical analysis are employed.

**GEOL.5240 Regional Hydrogeology (Formerly 89.524) - Credits: 3**

Concentrating on the storage and steady state flow of groundwater at a basin-wide scale, the course studies flow nets, fluid potential, and numerical modeling of flow controlled by basingeometry and geology; water movement in the zone of aeration, the interaction of groundwater with surface water, the transport and dispersion of contaminants, and the use of modeling for groundwater management.

**GEOL.5250 Groundwater Modeling - Credits: 3**

This course covers the concepts and practice of mathematical and numerical modeling of saturated groundwater flow and solute transport. Students will use industry-standard groundwater modeling software, including MODFLOW, MODPATH, MT3DMS, SEAWAT, and PHT3D for single- and variable-density flow, particle tracking, and solute and reactive transport. Emphasis will be on formulating mathematical representations of flow, use of groundwater models with graphical user interfaces, and post-processing and analysis of model results.

**GEOL.5310 Isotopes in Environmental and Geosciences (Formerly 89.531) - Credits: 3**

The course will show how radioactive and stable isotopes can be used to understand environmental and geological systems. Topics to be covered include radiometric dating using short and long half-life isotopes, radiogenic isotopic tracers, and stable isotopes.

**GEOL.5560 Applied Geophysics (Formerly 89.556) - Credits: 3**

Application of geophysics to problems in geology and environmental science. Principles and techniques of gravity, magnetic, electrical, and seismic methods. Field projects and surveys.

**GEOL.5850 Oceanography for Teachers (Formerly 89.585) - Credits: 3**

This course will introduce students to basic oceanographic principles and processes. Content will be linked to National and State Science Standards. Students will create a number of oceanography-based lessons linked to the standards. Pedagogy will be modeled in relation to teacher instruction and student learning.

**GEOL.5930 Special Topics: Environmental Geoscience (Formerly 89.593) - Credits: 3**

Student/Instructor selected in-depth study of a specific topic(s) within the Environmental Geosciences of a closely related field.

**GEOL.7310 Master's Research in Environmental Geoscience (Formerly 89.731) - Credits: 1-6**

**GEOL.7410 Master's Thesis in Environmental Geoscience (Formerly 89.741) - Credits: 1-9**
Marine Science

The University of Massachusetts School of Marine Sciences (SMS) offers both Master’s (M.S.) and Doctoral (Ph.D.) programs in marine science. Students graduating with a MS or Ph.D. degree from SMS receive a joint degree from the University of Massachusetts Amherst, Boston, Dartmouth and Lowell. The degree programs are fundamentally grounded in a broad, integrated, interdisciplinary approach to the study of marine science. Students located at the four participating campuses are required to complete core courses in the areas of biological, physical, and chemical oceanography, as well as a course in policy/management to equip them for interdisciplinary studies and research before focusing upon an area of concentration.

The programs prepare students for employment opportunities in the private and governmental sectors and academia. Emphasis is placed on the education of researchers and scholars who will contribute not only to basic research but also to the application of that research in a coherent approach to resource management and economic development issues.

Combining facilities and resources on four campuses into a single, coherent graduate program greatly expands the opportunities for SMS students. Students have access to a much greater range of education and research opportunities, expertise, and facilities than exists on one campus alone. Each campus has a number of departments and interdepartmental programs with areas of strength in marine-sciences related teaching, research, and outreach that either complement or constitute critical units of SMS.

SMS is also closely affiliated with a number of on-campus research centers and institutes and off-campus marine research facilities, expanding its realm of research opportunities and resources.

Core Courses

To achieve interdisciplinary breadth and depth, each SMS student will be required to take courses in four areas:

- Biological Oceanography (BO)
- Chemical Oceanography (CO)
- Physical Oceanography (PO)
- Socio-Economics of Coastal/Marine Systems (S/E)
- Marine-related Technologies (MT)

Courses in BO, CO, and PO are generally taken in the first 4 to 6 semesters (preferably in the first 2). For each area, course content is fairly uniform, though there may multiple offerings between campuses.

Courses in S/E and MT are taken after selection of an area of concentration. Course content is not uniform and selection of course should be consistent with a students concentration area. Depending on the students concentration, the socio-economic requirement might be met best by courses in policy, economics, law or international/intergovernmental relations. Courses satisfying the technology requirement could be drawn from such areas as marine measurement technology, wastewater and environmental mitigation technology, Geographic Information Systems (GIS), Data/Information Management Systems, graphic display technologies or marine modeling approaches.

To build on the core courses, each SMS student selects an area of concentration and chooses electives appropriate to this concentration, as approved by their faculty advisor and/or thesis committee. Reflecting the interdisciplinary character of SMS, both natural and social science courses support certain concentrations, and many courses support more than one concentration.

Students typically take most of their courses on the campus where they and their major faculty advisor are in residence. Some courses, however, including at least two core courses each semester, will also be taught using the University’s substantial distance learning facilities. Students may also choose to be in residence at different campuses for a period of time during their course of study, in order to take certain courses or to take advantage of research opportunities.

Admissions Standards

Successful applicants will generally have completed an undergraduate or graduate degree with a GPA of 3.00 or better and have an undergraduate major in one of the basic scientific disciplines or engineering, or will have strong multidisciplinary training with completion of at least six semesters of coursework in the natural sciences, generally to include biology, chemistry, and/or physics. Preparation in mathematics at least through integral calculus is strongly encouraged. Students who do not meet these criteria need to identify a faculty advocate who must bring a request for exception before the Admissions Committee. At the discretion of the Admissions Committee applicants may make up deficiencies in prior coursework either before or after admission is granted to the SMS. Consideration will be on a case-by-case basis, and the recommendation of the committee will be forwarded to the Dean for approval.

Candidates may apply for admission at either the Masters or Doctoral level. Students admitted directly into the Doctoral Program are expected to have exceptional academic credentials and/or work experience. Students entering with a Bachelors degree may be required to complete the requirements of a Masters degree before admission to the Doctoral Program. Students entering with a Masters can be admitted at the Doctoral level provided the degree, coursework and research experience warrant such a decision by the Admissions Committee.
Application Criteria

The Admissions Committee will evaluate a number of additional criteria in its consideration of applications. The following five items must be submitted for consideration by the UMass School of Marine Sciences (SMS):

A single application form has been prepared for the use of applicants for admission to the UMass School of Marine Sciences. It is available in the graduate admissions offices of each participating campus.

Three letters of recommendation from those familiar with the applicants academic and/or work experience are required.

Official transcripts of all undergraduate and graduate coursework.

Graduate Record Examination (GREs) scores and The Test of English as a Foreign Language (TOEFL, if the applicant is not a native English speaker). Typically, for the GREs students should have a combined score 1200 or greater. For TOEFL, a minimum of 550 (or 213 on the computer based exam) is highly recommended.

Statements of interest and intent are also requested. The statement of interest should provide reviewers an indication of the motivation of the student for pursuing graduate work. The statement of intent should describe how graduate training would address the students career goals.

*It is imperative that prospective students take an active role in contacting faculty member(s) who could potentially advise them, as well as making an effort to seek funding before applying to SMS. Students must also understand that we have a limited number of TA positions, so to be considered they must get their applications in before the deadline.

Admissions Procedures

Applications for admission to the graduate programs of the UMass School of Marine Sciences are currently being processed by the Office of Graduate Studies at the University of Massachusetts Dartmouth. You will send your application and its associated materials and should address any inquiries about your application to that campus.

Students considering entry into the fall semester must be aware of the following dates:

December 15th: Students who are interested in obtaining a TA must have a completed application and all other appropriate forms sent to the Graduate Office. Prospective students who are not interested in receiving a teaching assistantship are highly encouraged to apply at this time as well.

January 15th: Admissions Committee will have evaluated all applicants and will send a revised list of all prospective students to the SMS faculty. Any revisions and reconsiderations to the list will be made within a week.

February 1st: The Dean will send final acceptance letters to students who are being awarded a TA, as well as those students who have sufficient funding and an SMS advisor.

The Dean will send conditional letters of acceptance to students who have found an advisor, but have a lack of funding.

The Dean will send letters of deferral to qualified students who have been waitlisted, due to having no apparent advisor and inadequate funding.

The Dean will send letters of rejection to students who do not meet the standards of the school.

March 1st: Students should be receiving their acceptance, deferral, and rejection letters between February 1st and March 1st. Students who have been accepted with funding and an advisor are expected to reply within one month of receiving the letter.

April 15th: All students accepted with funding and an advisor must reply by this date, in order to be able to enter into the SMS program.

May 1st: The admissions committee will evaluate all acceptances and deferments from students who had to send in their applications by April 15th. Depending on the number of students admitted, the Admissions Committee will consider the following, in order:

1. Students who have an advisor, but no funding.
2. Students who have no advisor or funding.

May 15th: The Dean will send final letters of acceptance and rejection to the two groups of students listed above.

June 15th: Students who are accepted by or after May 15th have until this date to reply, in order to enter into the SMS program. All admission decisions are closed by this date.

Students considering entering in the spring semester must be aware of the following dates:

September 1st: Students must have a completed application and all other appropriate forms sent to the Graduate Office.

September 30th: Admissions Committee will have evaluated all applicants and will send a revised list of all prospective students to the SMS faculty. Any revisions and reconsiderations to the list will be made within a week.
GRADUATE – ALL COLLEGES

The Marine Sciences and Technology Master’s Program

The Marine Sciences and Technology Master’s Program, offered by the School of Marine Sciences (SMS), requires a minimum of 30 credit hours with the thesis option and 33 credit hours with the non-thesis option. Students are required to take three core courses (9 credits) and choose additional courses (15 credit minimum for thesis option, 22 credit minimum for non-thesis option) appropriate to a selected area of concentration. Attendance at a weekly seminar series is required (1 credit each for two semesters), and each student must present at least one seminar in their third or fourth semester. Fulltime MS students normally complete their degree requirements in four semesters. Part-time MS students are encouraged to take two courses per semester.

Core Course Requirements

Each SMS student must complete three core courses (9 credits), which includes 2 out of 3 of the core courses in the biological, chemical, and physical oceanography and a third core course in marine policy and/or management areas (including law and economics). The Core column in the SMS course list identifies the core courses and their respective areas. The core courses are intended to provide a common grounding in the biological, chemical, and physical oceanographic areas of marine sciences and technology, and in related marine policy and management disciplines. Courses covering technology and quantitative skills are generally subject to student choice and guidance committee approval, though there may be requirements specific to each option area. At least two core courses are offered each semester using the University’s substantial distance learning facilities and technology. Students normally complete the core courses in the first two semesters.

November 15th:
All students who are accepted must reply no later than this date, in order to enter into the SMS program. All admission decisions are closed by this date.

Admission decisions will be made as expeditiously as possible once the application file is complete. The SMS application deadlines will go into effect once the semester begins. Prospective candidates must observe these deadlines throughout the entire application process. Those who apply out of sequence will automatically be placed in the next cycle of admissions.

The Dean will send out acceptance and rejections letters by October 15th. Accepted students are encouraged to reply promptly.

Concentrations and Electives

To build on the core courses, each SMS student selects an area of concentration and chooses a marine policy or management core course and electives appropriate to this concentration, as approved by their faculty advisor and/or thesis committee. Concentrations and Courses describes the concentrations and lists the electives associated with each concentration.

Students typically take most of their elective courses on the campus where they and their major faculty advisor are in residence. Some elective courses, however, will also be taught via distance learning. In addition, students may choose to be in residence at different campuses for a period of time during their course of study, in order to take certain courses or to take advantage of research opportunities.

Weekly Seminars

Weekly seminars presented by students and by visiting speakers are intended to broaden the scope of each student's experience and to provide experience in verbal communication. Each MS student must present at least one seminar in the third or fourth semester. Attendance at the weekly seminars is required during all four semesters, for which students receive 1 credit for each of the first two semesters but no credit for the second two semesters.

Thesis and Non-Thesis Options

MS students may choose either a thesis or non-thesis option. Each student electing the thesis option will be assigned a Thesis Committee, chaired by the students major advisor, which will be responsible for insuring that the student fulfills all requirements of the SMS as well as other campus requirements, including presentation of a thesis defense consisting of a public lecture on the thesis, and a subsequent oral examination by the Thesis Committee. Each student electing the non-thesis option, in addition to an additional 3 credits, must complete a substantial research paper that must be read and approved by the major advisor and at least one other faculty member.

Sequence of Courses by Semester

In the first two semesters, fulltime MS students normally complete the core courses (9 credits), register for the seminar series (one credit each semester), and take electives (9 credits). Additional coursework and the thesis or the non-thesis research paper are typically completed in the third and fourth semesters. A minimum total of 30 credits (thesis) or 33 credits (non-thesis)
is required for the degree. The following tables summarize the sequence of courses for each of the four semesters.

**Semester 1**

<table>
<thead>
<tr>
<th>Courses</th>
<th>Credits</th>
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<tbody>
<tr>
<td>Core courses</td>
<td>6</td>
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<tr>
<td>One elective</td>
<td>3</td>
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<tr>
<td>Seminar series</td>
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Total: 10 Credits

**Semester 2**

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<th>Courses</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>Core courses</td>
<td>3</td>
</tr>
<tr>
<td>One elective</td>
<td>6</td>
</tr>
<tr>
<td>Seminar series</td>
<td>1</td>
</tr>
</tbody>
</table>

Total: 10 Credits

**Semester 3**

<table>
<thead>
<tr>
<th>Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
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<td>One elective(minimum)</td>
<td>3</td>
</tr>
<tr>
<td>Thesis/non-thesis</td>
<td>1 - 6</td>
</tr>
<tr>
<td>Seminar series(required)</td>
<td>no credit</td>
</tr>
</tbody>
</table>

Total: 10+ Credits

**Semester 4**

<table>
<thead>
<tr>
<th>Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>One elective(minimum)</td>
<td>3</td>
</tr>
<tr>
<td>Thesis/non-thesis</td>
<td>1 - 6</td>
</tr>
<tr>
<td>Seminar series(required)</td>
<td>no credit</td>
</tr>
</tbody>
</table>

Total: 10+ Credits

**Marine Sciences & Technology Doctoral Program**

The Marine Sciences and Technology Ph.D. program, offered by School of Marine Sciences (SMS), includes four core courses taken by all students (12 credits), courses in a concentration area beyond the core, seminars, and dissertation research.

Work in the concentration area usually includes a minimum of 24 credit hours of courses and helps the student prepare for the written and oral candidacy examinations. Ph.D. students are not normally accepted as part-time students. Courses may be taken at any SMS-affiliated program on the four campuses, in other departments, or at other area institutions, and may be included in a students program of studies as determined by the students major advisor and/or dissertation committee.

**Core Course Requirements**

Each SMS student must complete four core courses (12 credits), one in each of four core areas: biological oceanography, chemical oceanography, physical oceanography, and Marine Policy and/or Management areas (including law and economics). The Core column in the SMS course list identifies the core courses and their respective areas. The core courses are intended to provide a common grounding in the biological, chemical, and physical oceanographic areas of marine sciences and technology, and in related marine policy and management disciplines. At least two core courses are offered each semester using the Universitys substantial distance learning facilities and technology. Students normally complete the core courses in the first two semesters.

SMS has developed core courses that are taught via distance learning, one in each of the core areas (biological, chemical and physical oceanography), which will satisfy the requirements of SMS students. These courses will ensure that all SMS students master key concepts and skills central to an interdisciplinary marine sciences and technology graduate program. The core courses may be team taught in some cases.

**Concentrations and Electives**

To build on the core courses, each SMS student selects an area of concentration and chooses a marine policy or management core course and electives appropriate to this concentration, as approved by their faculty advisor and/or thesis committee. Concentrations and Courses describes the concentrations and lists the electives associated with each concentration.

Students typically take most of their elective courses on the campus where they and their major faculty advisor are in residence. Some elective courses, however, will also be taught via distance learning. In addition, students may choose to be in residence at different campuses for a period of time during their course of study, in order to take certain courses or to take advantage of research opportunities.

**Weekly Seminars**

Weekly seminars presented by students and by visiting speakers are intended to broaden the scope of each students experience and to provide experience in verbal communication. Each M.S. student must present at least one seminar in the third or fourth semester. Attendance at the weekly seminars is required during...
all four semesters, for which students receive 1 credit for each of the first two semesters but no credit for the second two semesters.

Candidacy Examinations and Dissertation

Generally, at the end of the fourth semester but no later than the end of the sixth semester, after passing the comprehensive written and oral examinations, the student and major faculty advisor select additional faculty who constitute the students graduate committee, and the student presents a written dissertation proposal to the committee. The students major advisor and committee may determine a later date for the presentation of the dissertation proposal. A students committee is chaired by the students major advisor and guides the students research. Committee members may be selected from SMS faculty, other departments, and other institutions. All committees must include at least one SMS faculty member from a campus other than the campus where the student resides.

Successful performance in the core courses is required for advancement to degree status. A grade of B or better in each core course and an overall average of 3.0 in the core courses are required. There is a retake option on a course for which the student receives a grade of B- or less.

No later than the sixth semester, the students committee administers the written and oral candidacy examinations. The candidacy examinations are comprehensive and cover the core areas and the students area of concentration. They are designed to test the intellectual competence and maturity of the student in the broad area of marine sciences and technology and in the selected area of concentration. Upon successful completion of the Ph.D. candidacy examinations, the student is awarded an M.S. degree.

A scholarly dissertation based on original research is required of all Ph.D. candidates. Dissertation research may be done in the laboratory or the field, or may be carried out in part during residence with an appropriate private business or government agency. Presentation and defense of a satisfactory dissertation, normally to be completed within five years from the date of advancement to candidacy, fulfill the degree requirements. The dissertation defense consists of a public lecture on the dissertation and a subsequent oral examination by the candidates dissertation committee.

Sequence of Courses by Semester

In the first two semesters, Ph.D. students normally complete the core courses (12 credits), register for the seminar series (one credit each semester), and take two electives (6 credits). Additional coursework (24 credits minimum) is normally completed by the end of the fifth semester, in order to complete the written and oral candidacy examinations no later than the sixth semester. Upon advancement to candidacy, Ph.D. students register each semester for dissertation research and other courses as appropriate until graduation.
IM.769 Continuing Graduate Research (Formerly IM.769) - Credits: 9
Graduate Research.

MARI.6300 Biological Oceanography (Formerly IM.630) - Credits: 3
MARI.6500 Physical Oceanography (Formerly IM.650) - Credits: 3
MARI.7430 Master's Thesis (Formerly IM.743) - Credits: 3
MARI.7460 Master's Thesis (Formerly IM.746) - Credits: 6
MARI.7490 Master's Thesis (Formerly IM.749) - Credits: 9
MARI.7510 Doctoral Dissertation (Formerly IM.751) - Credits: 1-9
Doctoral Dissertation Research

MARI.7530 Doctoral Dissertation (Formerly IM.753) - Credits: 3
Doctoral Dissertation Research

MARI.7550 Doctoral Dissertation (Formerly IM.755) - Credits: 5
Doctoral Dissertation Research

MARI.7560 Doctoral Dissertation (Formerly as IM.756) - Credits: 6
Doctoral Dissertation Research

MARI.7590 Doctoral Dissertation (Formerly IM.759) - Credits: 9
Doctoral Dissertation Research

MARI.7690 Continuing Graduate Research (Formerly IM.769) - Credits: 9
Graduate Research.
Department of Mathematical Sciences

Graduate Programs offered:

- Master’s of Science in Mathematics
  - Applied and Computational Option
  - Mathematics for Teachers Option
  - Probability and Statistics Option
- Doctor of Science Program in Computational Mathematics
- Graduate Certificates
  - Applied Statistics

Applicants to the master’s and doctoral programs must have an undergraduate degree from an accredited four-year college or university with a major in mathematics or a related discipline and a satisfactory grade point average. Minimal course prerequisites for each of the options are listed in the descriptions below, and additional information can be obtained from the coordinator for that option, whose name is listed at the end of this brochure. Each option coordinator provides individualized advising during the course of graduate study. Applicants must submit the Graduate School application form, three letters of reference, and an official undergraduate transcript indicating receipt of the bachelor’s degree.

Students holding the bachelor’s degree may take courses as a non-degree student while applying for matriculation and may transfer up to four courses (12 credits) taken before matriculation with grades of B or better. Up to 12 credits taken at another accredited U.S. or Canadian university may be transferred into a program, but no more than a total of 12 credits taken either at another institution or at the University of Massachusetts Lowell before matriculation, or any combination of the two, may be transferred.

Most courses are offered in the late afternoon or evening, and part-time study is possible. A limited number of teaching assistants are available each year. Students should be fully accepted into the graduate program by March to be eligible for a TA position for the following September.

Formal admissions procedures must be initiated through Graduate Admissions (https://www.uml.edu/Grad/default.aspx). Students may take a limited number of graduate courses before formal acceptance into a program. Check with the graduate coordinator for details.

- Combined Bachelor’s-Master’s Program

Master of Science in Mathematics

Admission to the Master of Science in Mathematics program requires a four-year undergraduate degree from an accredited college or university with a satisfactory grade point average. Students will choose to earn the degree with one of the following options:

- General
- Applied and Computational Mathematics
- Probability and Statistics
- Mathematics for Teachers
- Industrial Mathematics Professional Science Master’s (this option is not accepting new students)

Each option consist of thirty credit hours (equivalent to 10 three-credit hour courses) with the exception that the Industrial Mathematics PSE Option is a 37 credit program, including a required internship and sequence of PMSA seminars.

Program requirements include both required courses and electives (which may be offered in other departments). Up to six credits at the 400 level may be considered for inclusion in the program of study. In addition, with the permission of the student advisor and the graduate committee, three or six credits may be obtained by completing a thesis. Most courses are offered on a regular basis in the late afternoon and early evening so that all programs can be completed on a part-time basis.

General Option

This is the default option if students do not choose any of the three options above. The requirements include:

**Core courses:**

- MATH.5010

  (https://www.uml.edu/catalog/courses/MATH/5010) Real Analysis
- MATH.5090
  (https://www.uml.edu/catalog/courses/MATH/5090) Probability and Mathematical Statistics
- MATH.5300
  (https://www.uml.edu/catalog/courses/MATH/5300) Applied Math 1

The remaining 7 courses are to be chosen from the offerings of the math department in consultation with the student’s graduate advisor.

- Mathematical Sciences course listing
  (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Applied and Computational Mathematics Option

The Applied and Computational Mathematics Option focuses on techniques of mathematical modeling and the basic tools needed to investigate problems from both a theoretical and computational viewpoint. This option requires that the undergraduate degree must be in mathematics or a related discipline. Courses range from classical applied to modern applications of mathematical software.

- Degree pathway (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Probability and Statistics

The Probability and Statistics Option provides the necessary mathematical skills to solve many of the data analysis problems in, industry, science, engineering, and management. Courses range from theory in probability to applied hands-on courses in statistical programming, including R and SAS statistical software.

- Degree pathway (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Mathematics for Teachers

The Master of Science in Mathematics for Teachers Program aims to give students a balanced combination of theory and practice, to enhance their appreciation and understanding of Mathematics as a science, and to provide them with the tools necessary to instill in their own students an interest in the subject. Three semester of calculus (12 credits) are the prerequisites for this option. Note that this is not a teaching certification program - contact the Graduate School of Education for information about certification.

- Degree pathway (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Industrial Mathematics Professional Science Master’s

This program is no longer accepting applications.

Admission Requirements

This option requires that the undergraduate degree must be in mathematics or a related discipline. This requirements include.

Degree Requirements - Total Number of Credits: 34

Required Core Mathematics Courses - four courses (12 credits)

- MATH.5010
  (https://www.uml.edu/catalog/courses/MATH/5010) Real Analysis I
- MATH.5090
  (https://www.uml.edu/catalog/courses/MATH/5090) Introduction to Probability & Statistics
- MATH.5300
  (https://www.uml.edu/catalog/courses/MATH/5300) Applied Mathematics I
- MATH.5630
  (https://www.uml.edu/catalog/courses/MATH/5630) Computational Mathematics

Science Cluster - (four courses - 12 credits) - One cluster of 12 credits from the following.

Algorithms Cluster

- MATH.5800
  (https://www.uml.edu/catalog/courses/MATH/5800) Discrete Math for Science and Engineering
- COMP.5030
  (https://www.uml.edu/catalog/courses/COMP/5030) Algorithms
- COMP.5040
- COMP.5440
  (https://www.uml.edu/catalog/courses/COMP/5440)
440) Machine Learning and Data Mining

Random Processes Cluster

- MATH.5840 (https://www.uml.edu/catalog/courses/MATH/5840) Stochastic Processes
- EECE.5090 (https://www.uml.edu/catalog/courses/EECE/5090) Linear Systems Analysis
- EECE.5480 (https://www.uml.edu/catalog/courses/EECE/5480) Coding and Information Theory

Physics Cluster

- MATH.5330 (https://www.uml.edu/catalog/courses/MATH/5330) Mathematical Methods of Quantum Mechanics
- PHYS.5350 (https://www.uml.edu/catalog/courses/PHYs/5350) Introductory Quantum Mechanics I
- PHYS.5530 (https://www.uml.edu/catalog/courses/PHYs/5530) Electromagnetism I
- PHYS.5540 (https://www.uml.edu/catalog/courses/PHYs/5540) Electromagnetism II

Statistics Cluster

- MATH.5760 (https://www.uml.edu/catalog/courses/MATH/5760) Statistical Programming using SAS
- MATH.5880 (https://www.uml.edu/catalog/courses/MATH/5880) Mathematical Statistics
- MATH.5910 (https://www.uml.edu/catalog/courses/MATH/5910) Linear Statistics Modeling and Regression
- MATH.5930 (https://www.uml.edu/catalog/courses/MATH/5930) Experimental Design

Epidemiology/Biostatistics Cluster

- MATH.5760 (https://www.uml.edu/catalog/courses/MATH/5760) Statistical Programming in SAS
- MATH.5910 (https://www.uml.edu/catalog/courses/MATH/5910) Linear Statistics Modeling and Regression
- PUBH.5750 (https://www.uml.edu/catalog/courses/PUBH/5750) Introduction to Biostatistics and Epidemiology
- PUBH.6890 (https://www.uml.edu/catalog/courses/PUBH/6890) Advanced Regression Modeling

* (Variations of these clusters of different ones can be proposed with the guidance of the student’s advisor.)

PSM sequence of the Developmental Seminar (0 credit), Internship(zero credit) and Reflective Seminar (1 credit)

- PSMA.5000 (https://www.uml.edu/catalog/courses/PSMA/5000) Professional Development Seminar (0 credit)
- PSMA.5100 (https://www.uml.edu/catalog/courses/PSMA/5100) Internship (0 credit)
- PSMA.5010 (https://www.uml.edu/catalog/courses/PSMA/5010) Reflective Seminar (1 credit)

Each student must complete an internship lasting a minimum of 350 hours. Before starting the internship, the student must have completed at least 18 credit hours in the program, including 6 credit hours of PLUS coursework, must have completed the course PSMA.5000 (https://www.uml.edu/catalog/courses/PSMA/5000) Professional Development, and must have a GPA of at least 3.3. In cases where a PSM student is employed in their career field the PSM student will be required to do a PSM project at
their place of employment. The student should register for the
course PSMA.5100 (https://www.uml.edu/catalog/courses/PSMA/5100) PSM
Internship during the internship period.

In the semester immediately following completion of the PSM
Internship (or PSM Project for students employed in their
career field) the student is required to take PSMA.5010
(https://www.uml.edu/catalog/courses/PSMA/5010) Reflective
Seminar (1 credit).

Professional Plus Courses (9 credits)

- MKTG.5450
  (https://www.uml.edu/catalog/courses/MKTG/5450) Professional and Scientific Communication

Plus two additional courses (six credits) from the following list:

- MKTG.5010
  (https://www.uml.edu/catalog/courses/MKTG/5010), MKTG.6300
  (https://www.uml.edu/catalog/courses/MKTG/6300)
- MGMT.5010
  (https://www.uml.edu/catalog/courses/MGMT/5010), MGMT.5750
  (https://www.uml.edu/catalog/courses/MGMT/5750)
- MECH.5760
  (https://www.uml.edu/catalog/courses/MECH/5760)
- ENTR.6450
  (https://www.uml.edu/catalog/courses/ENTR/6450), ENTR.6500
  (https://www.uml.edu/catalog/courses/ENTR/6500)
- FINA.6400
  (https://www.uml.edu/catalog/courses/FINA/6400)
- PSMA.5350
  (https://www.uml.edu/catalog/courses/PSMA/5350), PSMA.5650
  (https://www.uml.edu/catalog/courses/PSMA/5650)
- MLSC.7700
  (https://www.uml.edu/catalog/courses/MLSC/7700)

Other graduate courses may also be taken in place of an
elective course with permission of the student’s advisor.

Doctoral Program

The Computational Mathematical Program is an
interdisciplinary doctoral program, offered by the Department
of Mathematics and the Department of Computer Science. The
goal of the program is to train students and conduct cutting
deck research on a wide range of topics in computational
mathematics. The program prepares students for both the
academic and industry careers.

Admission and degree requirements can be found in the
academic catalog.

For further details, contact the Graduate Coordinator of the
Mathematics or the Computer Science department.

Graduate Certificate in Mathematics - Applied
Statistics

The Mathematical Sciences Department offers a Graduate
Coordinator: Hung Phan, Ph.D (Mathematics), 978-934-
6817, Hung_Phan@uml.edu (mailto:Hung_Phan@uml.edu)

This certificate provides professionals in biology, business,
computer science, engineering, insurance, medicine, 
pharmaceutical and other sciences with statistical tools for
survival in a highly competitive world marketplace.

Experimental design provides methodology for gaining
information in an efficient manner. Use of designed
experiments in product development is known as off-line
quality control. Clinical trials are examples of designed
experiments in the medical field. Statistical modeling (linear
regression analysis) includes systematic procedures for
collecting and analyzing data in order to predict a response
variable based on one or more predictor variables. The
techniques covered in design of experiments are special cases of
the general approach to statistical modeling. Certificate holders
will be equipped with quantitative tools that form the heart of
a quality approach to development and improvement of
products and services. Most courses are offered in the evening.

This is a 12-credit certificate.
Required of Students without Probability/Statistics  
Background: (3 credits)

- MATH.5090  
  (https://www.uml.edu/catalog/courses/MATH/5090)  
  Introduction to Probability and Mathematical Statistics

Required of All Students: (6 credits)

- MATH.5910  
  (https://www.uml.edu/catalog/courses/MATH/5910)  
  Statistical Modeling and Linear Regression Analysis
- MATH.5930  
  (https://www.uml.edu/catalog/courses/MATH/5930)  
  Experimental Design

Electives: (6 credits)

- Electives may be selected from among the courses listed in the graduate school catalog subject to approval by the graduate coordinator.
MATH.5000 Discrete Structures (Formerly 92.500) - Credits: 3
An introduction to discrete mathematics, including combinatorics and graph theory. The necessary background tools in set theory, logic, recursion, relations, and functions are also included. Masters degree credit for Teacher Option Only.

MATH.5010 Real Analysis (Formerly 92.501) - Credits: 3
The class is aimed to give rigorous foundations to the basic concepts of Calculus such as limits of sequences and functions, continuity, Riemann integration. The main focus is given to rigorous proofs rather than computations. Tentative topics are: Real numbers (algebraic, order and distance structures); Archimedean property; Sequences and their limits. Bolzano-Weierstrass theorem; Cauchy sequences and completeness; Limit of a function; Continuity of a function at a point and on a set; Uniform continuity; Open and closed sets, idea of compactness, compactness of a closed interval; Sequences of functions, uniform convergence; Riemann integration. Prerequisites: Calculus I-III or equivalent, Discrete Structures or equivalent.

MATH.5070 Applied Functional Analysis I (Formerly 92.507) - Credits: 3

MATH.5090 Probability and Mathematical Statistics (Formerly 92.509) - Credits: 3
This course provides a solid basis for further study in statistics and data analysis or in pattern recognition and operations research. It is especially appropriate for students with an undergraduate science or engineering major who have not had a rigorous calculus-based probability and statistics course. The course covers the topics in probability models, random variables, expected values, important discrete and continuous distributions, limit theorems, and basic problems of statistical inference: estimation and testing.

MATH.5100 Computers and Calculators in Classroom (Formerly 92.510) - Credits: 3
Explores the roles of computers and calculators in instruction, examines some of the available software, and considers their use in a variety of areas of school mathematics, such as algebra, geometry (Euclidean and analytic) probability and statistics, and introductory calculus. Mathematics Masters degree credit for Teacher Option Only.

MATH.5130 Number Theory (Formerly 92.513) - Credits: 3
Study of primes, congruences, number-theoretic functions, Diophantine approximation, quadratic forms and quadratic number fields. Additional topics as time permits.

MATH.5260 Topology (Formerly 92.426/526) - Credits: 3
Metric spaces, topological spaces, connectedness, compactness, the fundamental group, classifications of surfaces, Brouwer’s fixed point theorem.

MATH.5300 Applied Mathematics I (Formerly 92.530) - Credits: 3
Infinite Series, Complex Algebra, Ordinary Differential Equations, Special Functions, Fourier Series, Vector Spaces, Operators and Matrices.

MATH.5310 Applied Mathematics II (Formerly 92.531) - Credits: 3

MATH.5430 Ordinary Differential Equations (Formerly 92.543) - Credits: 3

MATH.5450 Partial Diff Equations (Formerly 92.545) - Credits: 3

MATH.5500 Mathematical Modeling (Formerly...
92.550) - Credits: 3
Applications of mathematics to real life problems. Topics include dimensional analysis, population dynamics, wave and heat propagation, traffic flow. Pre-requisite: 92.132 Calculus II.

MATH.5510 Calculus of Variations (Formerly 92.551) - Credits: 3
The first variational problem, necessary conditions. Euler’s equation. Generalization to dependent and independent variables. Constraints and Lagrange multipliers. Application to dynamics and elasticity. Direct methods.

MATH.5550 Applied Math for Life Scientists (Formerly 92.555) - Credits: 3
The objective of this course is to give students an opportunity to learn how to use a computer algebra system in the context of reviewing some of the key mathematical topics that are used in the life sciences. The first half of the course includes a review of mathematical topics ranging from trigonometry through differential equations. A parallel introduction to a computer algebra system is also included in the first half. In the second half, students will study a mathematical topic such as pattern recognition or models for growth and complete a project using the computer algebra system. (UMassOnline).

MATH.5630 Computational Mathematics (Formerly 92.563) - Credits: 3

MATH.5640 Applied Linear Algebra (Formerly 92.564) - Credits: 3
Use of iterative algorithms to find exact or approximate constrained solutions to large, and often sparse, systems of linear equations, and on applications, such as medical imaging, in which such problems arise. Maximization of likelihood and entropy. Emphasis on exploiting sparseness, accelerating convergence, and stabilizing calculations in the presence of noise. Block-iterative methods and bounds for singular values will be included. Basic results in matrix theory presented as needed.

MATH.5650 Special Functions (Formerly 92.565) - Credits: 3
Introduction to functions beyond those studied in calculus and which arise in applied mathematics, including gamma, beta, elliptic, Bessel, orthogonal polynomials... Asymptotic approximation will be introduced.

MATH.5680 Approximation Theory (Formerly 92.568) - Credits: 3
MATH.5720 Optimization (Formerly 92.572) - Credits: 3
Optimization without calculus; geometric programming; convex sets and convex functions; review of linear algebra; linear programming and the simplex method; convex programming; iterative barrier-function methods; iterative penalty-function methods; iterative least-squares algorithms; iterative methods with positivity constraints; calculus of variations; applications to signal processing, medical imaging, game theory.

MATH.5750 Applied Statistics with R (Formerly 92.575) - Credits: 3
This is a methods course focusing on the applications of statistics using R programming language. Topics include: Study designs, review of inference and regression, categorical data, logistic regression, rates and proportions, and nonparametric methods. Additional topics may be considered if time permits. Only one of 92.575(R) and 92.576(SAS) may be applied toward a Masters degree in Mathematics.

MATH.5760 Statistical Programming using SAS (Formerly 92.576) - Credits: 3
An introduction to creation and manipulation of databases and statistical analysis using SAS software. SAS is widely used in the pharmaceutical industry, medical research and other areas. Cannot be used as a Math Elective.

MATH.5780 Statistical Inference and Data Mining (Formerly 92.578) - Credits: 3
Topics in nonasymptotic direct computational methods for statistical inference in data mining. Background in probability and statistics required.

MATH.5840 Stochastic Process (Formerly 92.584) - Credits: 3
Markov chains and processes, random walks, stationary, independent increments, and Poisson processes. Ergodicity. Examples (e.g., diffusion, queuing theory, etc.).
MATH.5870 Measure and Probability Theory
(Formerly 92.587) - Credits: 3
This course presents the mathematical foundations of Probability Theory, including the concepts of Probability Space and random variable. Various types of convergence of sequences and measurable functions will be introduced, and precise statements and proofs of the probability limit theorems (Law of Large Numbers, Central Limit Theorems, etc.) will be given. Theory of measure and Lebesgue integration will be introduced. If time permits, conditional probabilities will be discussed.

MATH.5880 Mathematical Statistics (Formerly 92.588) - Credits: 3
Random variables, densities, joint and conditional distributions, expectations, variance, estimation, sufficiency and completeness, hypothesis testing, limiting distributions.

MATH.5900 Statistical Quality Control (Formerly 92.590) - Credits: 3
Overview of quality and managing quality, Define Measure Analyze Improve Control (DMAIC), the six sigma approach to quality, visual representation of data, Pareto charts, histograms, process capability vs specification (process) limits, t-tests, ANOVA, and other statistical hypothesis testing in quality, normal probability plots, control charts, measurement system analysis, application of regression analysis to manufacturing and/or design, Minitab.

MATH.5910 Linear Statistics Modeling and Regression (Formerly 92.591) - Credits: 3

MATH.5920 Multivariate Statistics (Formerly 92.592) - Credits: 3
Nonlinear model building via the method of least squares. Discriminant and factor analysis, principal components, profile analysis, canonical correlation, cluster analysis. Experience on real data sets.

MATH.5930 Experimental Design (Formerly 92.593) - Credits: 3
How to design, carry out, and analyze experiments.

Randomized block designs, randomization, blocking, matching, analysis of variance and covariance, control of extraneous variables.

MATH.6510 Selected Topics in Mathematics
(Formerly 92.651) - Credits: 3
Intended to satisfy individual student needs. Topics include various fields of mathematics.

MATH.6530 Selected Topics (Formerly 92.653) - Credits: 3
Advanced topics in various fields of mathematics and related fields. Since topical coverage varies from term to term, a student may be allowed to receive credit more than once for this course.

MATH.7060 Directed Research - Credits: 1-6
Direct supervision with a dissertation advisor.

MATH.7420 Thesis Review (Formerly 92.472) - Credits: 1
MATH.7430 Graduate Research/Math (Formerly 92.743) - Credits: 3
Department of Physics and Applied Physics

The Department of Physics and Applied Physics offers programs leading to the degrees of Master of Science and Doctor of Philosophy.

The M.S. degree may be taken in physics or radiological science and protection (health physics) or in the applied physics option in optical sciences. Course requirements for the M.S. program consist of a total of 30 credits, including work on a thesis or project. The M.S. may serve as a basis for further study toward a Ph.D. degree. Students are expected to complete the M.S. program in two years.

The Ph.D. program requires 60 credits, including thesis research. Candidates for the degree must pass a written and oral comprehensive examination and a doctoral research admission examination (taken after successfully completing two semesters of an advanced research project) and demonstrate a proficiency in computer programming. Areas of research include experimental and theoretical nuclear physics, experimental and theoretical solid-state physics and material science, optics, laser physics and far infrared spectroscopy, scattering theory, quantum optics, relativity, particle physics, atmospheric and environmental physics, energy applications, applied mechanics, and radiological sciences.

Research Programs

Members of the Department are engaged in research programs in the following areas in which opportunities for advanced degree research are offered:

- Nuclear Physics,
- Solid State Physics,
- Laser Physics,
- Optics,
- Submillimeter-Wave Science and Technology,
- Theory of Elementary Particles,
- Quantum Field Theory,
- Atomic Physics,
- Relativity,
- Atmospheric Physics,
- Nuclear and Solar Energy,
- Applied Mechanics,
- Computational Physics,
- Radiological Sciences and Medical Physics.

Areas of study in nuclear physics include high-resolution neutron scattering, fission-product properties, and high-spin nuclear states (work conducted at national heavy-ion accelerators via in-beam gamma-ray spectroscopy).

Research equipment includes

- a 5.5-MeV Van de Graaff accelerator,
- neutron time-of-flight spectrometer,
- helium-jet fission-product transfer system,
- fast neutron irradiation facility,
- MW nuclear research reactor,
- 400-kilocurie Co-60 source for gamma-ray irradiation.

Principal areas of optics research include Raman, fluorescence, UV-visible-near-IR spectroscopy, and characterization of nonlinear optical properties of polymeric and semiconductor materials.

Solid state physics and materials science studies include photonic and opto-electronic devices, polymers and biological materials.

Research equipment includes

- an advanced materials characterization laboratory,
- transmission and scanning electron microscopy,
- x-ray analysis and surface science facilities,
- photonics and optoelectronics device development laboratory,
- molecular beam epitaxy,
- lithography of thin films, and
- epilayer characterization facilities.

The Submillimeter-Wave Science and Technology Laboratory develops coherent sources, receivers and novel imaging systems for application at terahertz frequencies. Research equipment includes microwave through infrared spectrometers for design and characterization of material dielectric properties, a CO2 and far-infrared laser magnetospectroscopy facility, and submillimeter-wave compact ranges for electromagnetic scattering studies.

Entering Graduate Students

Every entering graduate student is assigned a departmental adviser who will counsel the student on programs of study and other academic requirements serve as registration officer, help the student to become acquainted with research opportunities in the Department, and assist in selecting a research supervisor. In addition to the requirements for admission, applicants must submit the official test score report for the GRE general test; the Physics subject test is recommended, but not required.
Applicants for the M.S. and Ph.D. degrees in Physics are expected to have a sound background in intermediate level mechanics, electricity and magnetism, quantum mechanics, and modern physics. Any student found deficient in any of these areas may be required to take appropriate courses to remove the deficiency. Students in the Radiological Sciences and Protection M.S. program should have adequate preparation in mathematics, chemistry, physics, biology and nuclear and radiological sciences similar to the undergraduate curriculum in Radiological Health Physics at the University of Massachusetts Lowell.

Medical Physics

Overview and Program Goals

The University of Massachusetts Lowell's Department of Physics and Applied Physics offers a M.S. and Ph.D. degrees in Medical Physics, both accredited by the Commission on Accreditation of Medical Physics Educational Program (CAMPEP [http://www.campep.org/]). In collaboration with local and regional hospitals and cancer centers in the Boston area, the program is designed for individuals who wish to be educated in therapeutic and imaging medical physics.

Students gain education and training in fundamental radiation sciences, medical physics and dosimetry, which includes laboratory work and clinical internship. The MS program duration is designed to be two years plus one summer semester, although the typical academic plan may be different due to elective courses and the length of thesis research. The duration of the Ph.D. program depends on the students academic progress, and it is usually between four and six years. Both the MS thesis and Ph.D. dissertation must be based on hypothesis or development-driven research, and the student is expected to submit the results to a peer-reviewed journal.

Program Objectives

The MS Degree in Medical Physics qualifies students for all medical physics specialties and prepares them for residency programs, junior medical physics positions, and future ABR (http://www.theabr.org/) exams. The clinical component provides the students with training dominantly in radiation therapy, but diagnostic imaging traineeships are also available.

The Ph.D. degree program provides the students with fundamental knowledge of physics with a specialization in medical physics. Students receive advanced research training in particular areas of medical physics, which will prepare them for entry-level research positions in academia or industry, or for a medical physics resident position under the supervision of a board-certified medical physicist.

Historically, most students have concentrated on therapy physics but because sometimes faculty and the cooperating hospitals have imaging or nuclear medicine research projects, over the last decade a number of students have focused on other medical physics specialties as well.

Upon graduation, medical physics students are prepared to receive advanced clinical training through working under the direction of a board-certified medical physicist or entering a medical physics residency program. The students will be prepared for a career as:

- A professional clinical medical physicist.
- A medical physicist in a research laboratory.
- A medical physicist in industry.
- For Ph.D. students, career as a medical physicist in an academic environment.
- For MS students, further research training in a Ph.D. medical physics program.

Qualification for Admission

Applicants are expected to have a strong foundation in physics, documented by either a degree in physics or in a related engineering or physical science with the following undergraduate coursework at the minimum:

- Physics: Core physics courses, including two semesters of general physics plus Classical Mechanics, Electricity and Magnetism, and Modern Physics or Quantum Mechanics;
- Mathematics: Three semesters of calculus and one semester of differential equations;
- Computer Science: Proficiency in a scientific/engineering programming language and knowledge of fundamental numerical methods;
- Chemistry (preferred): Two semesters of general chemistry;
- Biology (preferred): One semester of general biology;
- Anatomy (preferred): One semester of human anatomy.

Although Anatomy is not a requirement for admission, completion of an appropriate anatomy course is a requirement before graduation.

Successful applicants typically have an undergraduate major in physics, engineering, or a similar technical field. Students with other undergraduate degrees may be accepted if the prerequisite coursework is satisfied. Applicants with minor deficiencies, such as the undergraduate anatomy course, may
be admitted with the provision of satisfying the prerequisite during the first year of graduate study.

The application deadline is normally the last day of February. Further information on the graduate admission process, including on-line and downloadable application forms, may be accessed at the UMass Lowell Graduate Admission website (https://www.uml.edu/admissions/default.aspx).

Programs of Study

Master of Science Degree

The MS Degree in Medical Physics requires 31 hours of didactic courses, 2 hours of clinical training (counting as laboratory courses), and a thesis of publishable quality that includes a minimum of 6 hours of thesis research. Elective courses may be taken to meet particular educational needs, especially for the students research.

Doctor of Philosophy Degree

There are two paths towards earning a Ph.D. degree in Medical Physics at UMass Lowell: Via the Department of Physics and Applied Physics Ph.D. Program with Medical Physics option and via the University’s interdisciplinary doctoral program in Biomedical Engineering Biotechnology (BMEBT) with Medical Physics specialization. The Ph.D. in Physics path invariably appeals to traditional physics students. Students with engineering background often choose the BMEBT path. While retaining their respective Physics and Biomedical Engineering ancestry, these programs offer a common Medical Physics curriculum, which is based on the required courses in the MS curriculum.

Both Ph.D. programs, via Physics or BMEBT, offer an en-route MS degree option: Students who entered the program with a BS or non-Medical Physics MS degree and pass the Comprehensive Examination may be eligible for the MS degree in Medical Physics if they have satisfied the relevant MS degree requirements as detailed above.

Detailed description of the programs of study is published each year by the Department of Physics and Applied Physics, which includes the Medical Physics Programs, and it is available from the Physics Graduate Coordinator. For further information, the Medical Physics Program can be reached at:
MED_PHYS@uml.edu

Statistics on Medical Physics Program Students and Graduates


Medical Physics Faculty, Research and Resources

- Faculty (https://www.uml.edu/Sciences/physics/Programs-of-Study/Medical-Physics/Medical-Physics-Faculty.aspx)
- Resources (http://www.uml.edu/centers/radlab/default.html)

Masters of Science Degree Program

The Department of Physics and Applied Physics offers the following M.S. degrees:

- M.S. Degree in Physics (General, Thesis or non-thesis)
- M.S. Degree in Physics, Optical Sciences Option
- M.S. Degree in Radiological Science and Protection
- M.S. Degree in Medical Physics, a subplan of M.S. Degree in Radiological Science and Protection

All M.S. degrees require, at the minimum, 30 credit hours, as well as completion of a research component

1. Academic Advising Committee and Research Supervisor

All students in the Physics graduate program will be assigned an Academic Committee that consists of the student’s Research Supervisor and at least two other faculty members selected by mutual agreement between the student and the Research Supervisor. One of these members should be outside the direct research area of the Research Supervisor. Until one is officially assigned, the relevant Graduate Coordinator will serve as the Academic Advisor. Students meet with the Academic Advising Committee at least once per semester prior to course registration decisions. The Committee reviews students’ adequate progress towards their Graduate Degree and reports to the Graduate Coordinator. Committee members external to the department or institution could be chosen, especially in cases where the research extends beyond the department, but they would have to be in addition to the three members from the department.

The Research Supervisor is responsible for research guidance, and his/her approval is required to register for Dissertation, Thesis, or Project Research credits.

2. Research

Although no schedule is imposed, if you enter the M.S. program without undergraduate deficiencies you should have
found a Research Supervisor, formed an Academic Advising Committee, and have started investigation of a proposed research topic by the end of your first year. The choice of a research topic is often accomplished by matching your interests with topics suggested by a prospective supervisor or with research projects presently in progress. After forming an Academic Advising Committee, a student electing the Thesis track must defend a proposal, which shall be a brief description of the research problem you propose to investigate for your Thesis, or a description of the Project you wish to undertake. A student who elects the Project track must obtain the approval of the Research Supervisor for the Project Proposal. An M.S. project must be completed and defended in one semester.

After completing the research, you must submit to the Physics Department a thesis or project report in the format specified by the UML Thesis and Dissertation Guide (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf). Students are required to submit a printed copy of their thesis to the Department in addition to the electronic submission to the Library. Thesis students must then pass an oral defense conducted by an Academic Advising Committee. This examination will be primarily based on, but not necessarily restricted to, the subject of your thesis. A student submitting a Physics M.S. Project Report must pass an oral defense of the Project, which will be primarily based on, but not necessarily restricted to, the subject of the Project.

3.Grades Below B

As per University Policy, no more than 6 credits of grades below B may be counted towards the fulfillment of the M.S. degree. No graduate degree will be awarded to any student whose overall cumulative grade point average falls below 3.0

4. Time Limit

All requirements for the M.S. degree must be completed within five years after entrance into the graduate program. After five years, subsequent registration in that program will not be permitted without special permission. M.S. candidates must maintain continuous matriculation. Students who do not register for a semester must apply for readmission to the Graduate Admission Office.

5.BS/MS program

Under BS/MS track (see www.uml.edu/b2m (https://www.uml.edu/Academics/undergraduate-programs/bachelors-masters.aspx)) the University allows students who meet certain GPA requirements and are otherwise admissible to MS program to double-count up to 6 graduate credits, taken during their undergraduate course of study towards both MS and BS degrees

M.S. Degree in Physics (General, Thesis and Non-thesis pathways)

M.S. Degree in Physics requires a minimum of 30 credit hours with at most 3 credit hours from colloquium or seminar courses.

All students are expected to have completed as part of their undergraduate studies: a two-semester course in electromagnetic theory (PHYS.5530/40 (https://www.uml.edu/catalog/courses/PHYS) or equivalent) and a two-semester course in introductory quantum mechanics (PHYS.5350/60 (https://www.uml.edu/catalog/courses/PHYS) or equivalent).

- Degree Pathway for the MS in Physics, General (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

M.S. Degree in Physics: Optical Sciences Option

This is a terminal Masters Program for students who have completed a bachelor’s degree program in Physics, Engineering, or other sciences and wish to specialize in electro-optical phenomena, lasers, applications of optics to telecommunication and information processing, fiber optics, and other optical materials and devices. It is offered in cooperation with the Department of Electrical and Computer Engineering, which offers an allied option in opto-electronics.

- Degree Pathway for the MS in Physics, Optical Sciences Option (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

**Seminars/Colloquia**

All full-time candidates are required to register for Physics Colloquium, PHYS.7010/7020 (https://www.uml.edu/catalog/courses/PHYS), at least one Physics Seminar every semester. After attending the general Graduate Seminar, PHYS.7110/7120 (https://www.uml.edu/catalog/courses/PHYS), for one year, students may elect take one of the specialized seminars instead.

Up to a total of 3 credits for colloquia/seminars can be counted forward a graduate degree.

Medical Physics Master of Science Degree

The MS Degree in Medical Physics requires 31 hours of didactic courses, 2 hours of clinical training (counting as laboratory courses), and a thesis of publishable quality that includes a minimum of 6 hours of thesis research. Elective courses may be taken to meet particular educational needs, especially for the students research.

- Sample degree pathway leading to the MS Degree in
Medical Physics (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Doctor of Philosophy Degree Program

The Department offer the following Ph.D. degree:

- Ph.D. Degree in Physics
- Ph.D. Degree in Physics, Applied Physics Options
  - Atmospheric Science Option (collaboration with Dept. of Earth and Atmospheric Science)
  - Energy Engineering Option (collaboration with Dept. of Chemical Engineering)
  - Applied Mechanics Option (collaboration with Dept. of Mechanical Engineering)
  - Medical Physics Option
  - Radiological Science Option

All Ph.D. Degree require, at the minimum

- 60 credit hours beyond the bachelors’ degree, including
- at least 15 and at most 24 credit hours of Ph.D. dissertation research (PHYS.7560)
- at least 36 credit hours of non-research and non-project courses
- at most 3 credit hours can be from colloquium or seminar courses

Academic Advising Committee and Research Supervisor

All students in the Physics graduate program will be have assigned an

Academic Committee

that consists of the students Research Supervisor and at least two other faculty members selected by mutual agreement between the student and Research Supervisor. One of these members should be outside the direct research area of the research supervisor. Until one is officially assigned, the relevant Graduate Coordinator will play the role of the Academic Advisor. Students meet with the Academic Advising Committee at least once per semester prior to course registration decisions. The Committee reviews students adequate progress towards their Graduate Degree and reports to the Graduate Coordinator. Committee members external to the department or institution could be chosen, especially in cases where the research extends beyond the department, but they would have to be in addition to the three members from the department.

The

Research Supervisor

is responsible for research guidance, and his/her approval is required to register for Dissertation, Thesis, or Project Research credits.

Comprehensive Examination

Ph.D. candidates for all Physics and Applied Physics programs must take the Physics Ph.D. Comprehensive Examination, which consists of both written and oral parts, and is administered twice a year, at the beginning of Fall and Spring semesters. Students are required to take the exam by the beginning of their second Fall semester at UML (e.g. students entering in a Fall semester must take the exam by the beginning of the following Fall semester). Those who do not take the exam at the proper time will be considered to fail their first Comprehensive Examination and may lose their TA support.

1. Written Part

The Written Part of the exam has three sections:

Sec. I   Classical Mechanics with introductory level Thermodynamics

Sec. II   Electricity and Magnetism with introductory level Optics

Sec. III (a) Modern Physics and Quantum Mechanics with Statistical Mechanics,
  or (b) Radiological Sciences Health Physics (topics in Health Physics)
  or (c) Medical Physics (topics in Medical Physics)
  or (d) Atmospheric Sciences (topics in Atmospheric Sciences)

Note

: Students who pass the Comprehensive Exam and switch degree options/tracks must repeat Section III in the area to which they have switched.

The level of the questions in mechanics, statistical mechanics, quantum mechanics, and electromagnetism is advanced undergraduate. The written part is given at the beginning of each semester, three hours per section (usually with a two-day interval between sections). Past exams, as well as the topics covered during the written examinations, are available online.
The results of the written part of the exam are reviewed by the Physics Graduate Committee, which decides if a student is eligible to continue to the oral part of the Comprehensive Exam.

2. Oral Part

Students who have been recommended by the Physics Graduate Committee to continue beyond the written part of the Ph.D. Comprehensive Exam will take the oral part. The Department will form several specialty-based Oral Committees. Each specialty committee should have representation from outside the specialty. The Physics Graduate Committee will announce starting points of discussion to each student. These could be either problems or scientific publications, based on the material studied by the students in their first year at UML. Each student will be examined by two Oral Committees for approximately one hour each.

3. Exam Pass/Fail

Oral examination committees will submit reports to the Physics Graduate Committee, which, after deliberation, will submit a recommendation to the entire Physics Faculty on whether a student passes or fails the exam. The final decisions shall be made at the Physics Faculty meeting. Students who fail the Comprehensive Exam may take the exam a second time in the following semester. A student who fails the Comprehensive Exam twice may be eligible for an M.S. degree if they satisfy the requirements for that degree.

Graduate Research Admission

Each doctoral candidate must demonstrate the ability to carry out graduate-level research before embarking on Ph.D. dissertation research. This requirement can be satisfied by:

1. completing an M.S. Thesis at UML
2. passing two semesters of Advanced Projects in Physics
3. a waiver of the above requirements for a student who has completed a master’s thesis to earn an M.S. in physics or a related discipline (e.g. at another university) to their Academic Advising Committee

The M.S. Thesis defense, or Advanced Project oral defense, or oral presentation of previous M.S. work, constitutes the Graduate Research Admission Examination, and must be completed before the student may register for Ph.D. Dissertation Research.

To receive a satisfactory grade in Advanced Projects, a student must:

1. Submit a written Progress Report to the Academic Advising Committee the end of the first semester of work in Advanced Projects I (PHYS.7310 (https://www.uml.edu/catalog/courses/PHYS/7310)).
2. Submit a final written Advanced Project Report to the Academic Advising Committee on completion of the Project.
3. Make an oral presentation of the Advanced Project before the Academic Advising Committee.

Dissertation

When ready to engage in M.S. thesis or Ph.D. dissertation research, a student must first choose a research supervisor (a member of the Physics Department), obtain an SIS permission number to enroll in either PHYS.7460 (https://www.uml.edu/catalog/courses/PHYS/7460) or PHYS.7560 (https://www.uml.edu/catalog/courses/PHYS/7560), respectively, and form the Academic Advising Committee. The Academic Advising Committee shall track students progress towards their degree. In the semester in which they FIRST register for PHYS.7460/7560 (https://www.uml.edu/catalog/courses/PHYS), the student must prepare and defend a dissertation proposal to the Academic Advising Committee (see section IX, p.18 for the format of a proposal). Students who did not successfully defend their proposal have an option of revising and re-defending the proposal at a later time, with an approval of the Academic Advising Committee. Upon completion of the research, the student must prepare a thesis or dissertation following the guidelines and regulations of the University of Massachusetts Lowell Dissertation and Thesis Guide (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf). For the accepted style specifically of a physics dissertation, thesis or project report, the the AIP Style Manual (http://www.aip.org/pubservs/style/4thed/toc.html) is to be followed. In the few cases where the two are in disagreement, the latter document takes precedence. Once the written thesis or dissertation is sufficiently complete the Academic Advising Committee will schedule a defense/oral examination. This oral examination will be based on, but not necessarily restricted to, the subject of students research. Upon completion of the oral examination, the Committee will recommend whether the thesis or dissertation is acceptable or not. If it is not acceptable the Committee may make recommendations on how to amend it to make it acceptable. After these recommendations have been carried out, an amended thesis or dissertation may be prepared and, if so stipulated, a new oral examination will be scheduled. The student must order printed copies of the thesis/dissertation for the Department and Advisor in addition to online submission to the library.

Course requirements for the Physics Ph.D.

- PHYS.6070 (https://www.uml.edu/catalog/courses/PHYS/6070)
  Mathematical Methods of Physics (3)
- PHYS.5630
• PHYS.5210
(https://www.uml.edu/catalog/courses/PHYS/5210)
Statistical Thermodynamics (3)
• PHYS.6110
(https://www.uml.edu/catalog/courses/PHYS/6110)
Classical Mechanics (3)
• PHYS.6165
(https://www.uml.edu/catalog/courses/PHYS/6165)
Graduate Quantum Mechanics (3)
• PHYS.6570/6580
(https://www.uml.edu/catalog/courses/PHYS)
Electromagnetic Theory I/II (3+3)
• PHYS.7310/7320
(https://www.uml.edu/catalog/courses/PHYS) Advanced Projects in Physics I/II* (3+3)
• PHYS.7010/7012
(https://www.uml.edu/catalog/courses/PHYS) Physics Colloquium (0...1)
• PHYS.7110/7120
(https://www.uml.edu/catalog/courses/PHYS) Graduate Seminar (0...1)
• PHYS.7560
(https://www.uml.edu/catalog/courses/PHYS/7560)
Doctoral Dissertation in Physics (15...24)

At least one elective at 6xxx level

Course Requirements for Applied Physics Options

Every student in an Applied Physics Ph.D. Option must satisfy the following course requirements:

1. Common course requirement for all options:
   - PHYS.6070
     (https://www.uml.edu/catalog/courses/PHYS/6070)
     Mathematical Methods of Physics (3)
   - PHYS.5130
     (https://www.uml.edu/catalog/courses/PHYS/5130)
     Classical Mechanics (3)
   - PHYS.5530/5540
     (https://www.uml.edu/catalog/courses/PHYS)
     Electromagnetism I/II (3+3)
   - PHYS.5350
     (https://www.uml.edu/catalog/courses/PHYS/5350) Intro Quantum Mechanics I (3)
   - PHYS.
     (https://www.uml.edu/catalog/courses/PHYS/6050/7310
     /7320) Advanced Project in Physics(3+3)

*This may be waived for students who have completed a master’s thesis

2. Six electives as appropriate for each area of concentration

Physics/Energy Engineering Option

In addition to the general requirements, students in this option must take:
   - PHYS.5360
     (https://www.uml.edu/catalog/courses/PHYS/5360) Intro Quantum Mechanics II (3)

At least eight additional courses from among the Physics, Energy Engineering, and Mechanical Engineering offerings at the graduate level. These eight courses should include required courses appropriate to the field of study.

Applied Mechanics Option

In addition to the general requirements, students in this option must take:
   - PHYS.5360
     (https://www.uml.edu/catalog/courses/PHYS/5360) Intro Quantum Mechanics II (3)

At least two graduate courses from the Mechanical Engineering Department, the courses to be determined by the students Academic Advising Committee.

Atmospheric Sciences Option

In addition to the general requirements, students in this area must take 9 credits of the following core course:
   - MECH.5810
     (https://www.uml.edu/catalog/courses/MECH/5810)
Fluid Mechanics (3)
- PHYS.6570
  (https://www.uml.edu/catalog/courses/PHYS/6570)
Electromagnetic Theory I (3)
- PHYS.5550
  (https://www.uml.edu/catalog/courses/PHYS/5550)
Introduction to Space Physics (3)
- PHYS.5380
  (https://www.uml.edu/catalog/courses/PHYS/5380)
Astronomy and Astrophysics (3)

Plus 9 credits from the following courses:

PHYS.5210
  (https://www.uml.edu/catalog/courses/PHYS/5210)
Statistical Thermodynamics (3)

PHYS.6110
  (https://www.uml.edu/catalog/courses/PHYS/6110)
Classical Mechanics (3)

PHYS.6580
  (https://www.uml.edu/catalog/courses/PHYS/6580)
Electromagnetic Theory II (3)

PHYS.6650
  (https://www.uml.edu/catalog/courses/PHYS/6650)
Space Physics (3)

PHYS.5690
  (https://www.uml.edu/catalog/courses/PHYS/5690)
Plasma Physics (3)

PHYS.5560
  (https://www.uml.edu/catalog/courses/PHYS/5560)

Radiative Processes in Astrophysics (3)

**Colloquia and Seminars**
All full-time candidates are required to register for Physics Colloquium, PHYS.7010/7020
(https://www.uml.edu/catalog/courses/PHYS), and at least one Physics Seminar every semester. After attending the general Graduate Seminar, PHYS.7110/7120
(https://www.uml.edu/catalog/courses/PHYS), for one year, students may elect to take one of the specialized seminars instead.

Up to a total of 3 credits for colloquia/ seminars can be counted towards a graduate degree

Medical Physics Option

Radiological Science Option

(https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

**Medical Physics Doctor of Philosophy Degree**

There are two paths towards earning a Ph.D. degree in Medical Physics at UMass Lowell: Via the Department of Physics and Applied Physics Ph.D. Program with Radiological Sciences Medical Physics option and via the University's interdisciplinary doctoral program in Biomedical Engineering/Biotechnology (BMEBT) with Medical Physics/Radiological Sciences specialization. The Ph.D. in Physics path invariably appeals to traditional physics students. Students with engineering background often choose the BMEBT path. While retaining their respective Physics and Biomedical Engineering ancestry, these programs offer a common Medical Physics curriculum, which is based on the required courses in the MS curriculum.

Both Ph.D. programs, via Physics or BMEBT, offer an en-route MS degree option: Students who entered the program with a BS or non-Medical Physics MS degree and pass the Comprehensive Examination may be eligible for the MS degree in Medical Physics if he/she has satisfied the relevant MS degree requirements as detailed above.

Sample curricula

- Leading to the Ph.D. Degree in Physics  Medical Physics Option, entering with BS in Physics
  (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)
Leading to the Ph.D. Degree in Physics Medical Physics Option, entering with MS in Physics (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Leading to the Ph.D. Degree in Physics Medical Physics Option, entering with MS in Medical Physics (https://www.uml.edu/catalog-AY21/pdf/Graduate.pdf)

Detailed description of the programs of study is published each year by the Department of Physics and Applied Physics, which includes the Medical Physics Programs, and it is available from the Physics Graduate Coordinator.

Graduate Certificates in Physics

The Department of Physics offers two Graduate Certificates

- Medical Physics
- Photonics & Opto-Electronic Devices
- Radiological Health Physics & General Work
- Environment Protection

Medical Physics

Department of Physics

Contact: Erno Sajo (mailto:erno_sajo@uml.edu), Ph.D., 978-934-3288

This 12-credit certificate is open to matriculated students who have completed the required core courses for the M.S. in Radiological Sciences. Students who have a graduate degree in Radiological Health Physics or Physics may apply to the certificate program if they meet the core requirements.

Required Courses:

- RADI.5960 Medical Physics
- RADI.6760L Graduate Medical Physics Internship
- RADI.5330 External Radiation Dosimetry and Shielding
- RADI.5340 Internal Radiation Dosimetry and Bioassay Assessment

Photonics & Opto-Electronic Devices

Physics Department and Electrical Engineering & Computer Engineering Department (Interdisciplinary)

Contact: Partha Chowdary, Ph.D., 978-934-3730
partha_chowdary@uml.edu

This certificate is offered jointly by the Electrical & Computer Engineering & Physics Departments and reflects the strong interests in the physics and technologies of electro-optics. Extensive research facilities include: new materials growth (molecular beam epitaxy) and device fabrication and testing laboratories.

Required Courses:

- PHYS.5770 Solid State Electronic & Opto-electronic Devices and
- PHYS.5390 Electro-optics
  OR
- EECE.5950 Solid State Electronics and
- EECE.5680 Electro-optics

Elective Courses (choose 2):

- EECE.5070 Electromagnetic Waves and Materials
- EECE.5080 Quantum Electronics
- EECE.5900 Fiber Optic Communications
- EECE.6070 Electromagnetix of Complex Media
- EECE.6690 Opto Electronic Devices
- PHYS.5470 Laser Physics & Applications
- PHYS.6310 Nonlinear Optics
- PHYS.5780 Integrated Optics: Wave Guides & Lasers

Gainful Employment Disclosure Information


Radiological Health Physics and General Work Environment Protection

Contact: Mark Tries, Ph.D. (mailto:mark_tries@uml.edu), 978-934-3353

This certificate is open to matriculated students who have completed the required core courses for the MS in Radiological Sciences. Students who already hold a graduate degree in Radiological Health Physics or Physics may also apply to this certificate program if they meet the core requirements.
The program is a collaborative endeavor between the University's Physics and Radiological Sciences Program and the Work Environment Program. No other college or university in New England offers this type of program.

This certificate requires 14 credits of course work earned by taking four courses.

**Required Courses:**
- RADI.5010L Radiation Safety and Control I (4 credits)
- RADI.5020L Radiation Safety and Control II (4 credits)
- PUBH.5250 Introduction to Industrial Hygiene/Ergonomics (3 credits)

**Elective Courses (Choose one approved elective course):**
- PUBH.5400 Occupational Safety and Health Engineering

**Gainful Employment Disclosure Information**

PHYS.4780 Integrated Optics: Wave Guides and Lasers (Formerly 95.478/578) - Credits: 3

This course is a continuation of 95.477 and serves as an introduction to solid state electronic and optoelectronic devices. The course will cover bipolar junction transistors, field effect transistors, integrated circuits, lasers, switching devices, and negative conductance microwave devices. Three or four practical demonstrations will also be performed with the analysis of the generated data assigned as homework. (offered as 95.548 for graduate credit)

PHYS.5010 Energy, Force and Motion (Formerly 95.501) - Credits: 3

An introduction to the most fundamental area of physics: the nature of motion, what affects it, and how it is measured. We examine Newton's laws, including the law of gravity, and how forces produce acceleration. The course also examines the nature of energy - potential and kinetic - and how it relates to motion and forces. We will concentrate on how to analyze physical situations and solve the basic equations of motion. This course is intended to help teachers develop their understanding of the physics of motion.

PHYS.5170 Space Science Mission Design (Formerly 95.417/517) - Credits: 3

This one-semester, 3-credit course intended for junior level science and engineering majors, is centered around the conceptual design of a spaceflight mission. In this project-based and team-based class, students will apply their science and technical knowledge to develop a spacecraft and mission concept tailored to answer a specific science question. Students will perform quantitative trade studies consistent with real-life constraints such as cost, schedule, manufacturability, team-expertise, operational environment, mission lifetime, etc. Students will 1) learn the fundamentals of key subsystems involved in a space flight mission and 2) apply their skills of inquiry, research, critical thinking to design a complete space science mission to solve a real-world problem while working within a multidisciplinary team.

PHYS.5210 Statistical Thermodynamics (Formerly 95.421/521) - Credits: 3

An integrated study of the thermodynamics and statistical mechanics, review of the experimental foundations and historical development of classical thermodynamics; probability and statistical methods of studying macroscopic systems; atomic basis of the laws of thermodynamics and microscopic definitions of thermodynamics quantities using the method of ensembles; entropy and related quantities; TdS equations, Maxwell relations, equation of state, and applications: canonical and grand canonical ensembles; phase transitions; quantum statistics; application to radiation, magnetism, specific heats. (offered as 95.521 for graduate credit)

PHYS.5360 Introductory Quantum Mechanics II (Formerly 95.536) - Credits: 3

The three-dimensional Schroedinger equation, the deuteron nucleus, angular momentum, spin, the hydrogen atom, spin-orbit interaction, Zeeman effect, Pauli exclusion principle, atomic structure, multi-electron atoms, the Fermi gas, X-rays.

PHYS.5370 Geometric Optics - Credits: 3

This course will cover the use of lenses, mirrors, and other optics to construct optical systems. Topics will include paraxial optics, aberrations, two element systems (such as telescopes), and dispersive optics (such as diffraction gratings and binary optics). We will discuss transfer functions, zernike polynomials, ray tracing procedures, and other analysis techniques in order to understand the performance of systems and their aberrations. As time allows we will discuss wave effects including diffraction, interferometry, and other physical effects.

PHYS.5380 Physical Optics and Waves (Formerly 95.538) - Credits: 3

Wave nature of light, mathematics of wave motion, electromagnetic theory of light propagation, reflection and refraction, Fresnel coefficients, polarization, interference, Young's experiment, fringe visibility and coherence, various interferometers, Newton's rings and applications, Fraunhofer diffraction by single and multiple apertures and diffraction gratings, Fresnel diffraction.

PHYS.5390 Electro-Optics (Formerly 95.439/539) - Credits: 3

Optical properties of materials, including dispersion, absorption, reflection and refraction at the boundary of two media. Crystal optics and induced birefringence and optical activity. Polarization states and Jones matrices. Applications to electro-optic devices. Experiments and projects involving the study of optical sources and detectors, spectroscopy, polarization, birefringence, pockels' effect, optical fibers, and optical communication. (offered as 95.539 for graduate credit)

PHYS.5550 Introduction to Space Physics (Formerly 95.555) - Credits: 3

The course introduces the present knowledge of space phenomena and the physical understanding of the plasma environment from the sun to the earth's ionosphere and in the
heliosphere. Regions in space to be discussed include the solar surface, solar wind, bow shock, magnetosheath, magnetosphere, magnetotail, radiation belts, ring currents, and the ionosphere. Among space plasma physic theories, single particle theory, kinetic theory, and magnetohydrodynamics, which describe charged particle motion in electromagnetic fields and its consequences, are introduced and applied to the space environment.

**PHYS.5560 Radiative Processes in Astrophysics**  
(Formerly 95.456/556) - Credits: 3

Our knowledge of the universe beyond the Solar System is derived almost entirely from our interpretation of the radiation we receive from the universe; Our knowledge of the Earth’s upper atmosphere and the atmospheres of other solar system objects is heavily dependent on observations of electromagnetic radiation. To understand the atmospheres of Earth and other planets, stars, galaxies and the universe, we need to understand the processes which produce electromagnetic radiation, and how radiation interacts with matter and propagates through space. This course describes the basic processes which create and alter such electromagnetic radiation before it's detected here in the Solar System. The course will consist of a combination of lectures, problem sets and class discussion sessions. The lectures will be expanded from the material in the text and will include additional material on the astrophysical and planetary context of radiative processes, drawn primarily from the following list of references. The discussion sessions will often be based on recent problem sets - regular participation of students in class discussions is expected.

**PHYS.5630 Computational Methods in Physics**  
Credits: 3

The course aims to provide an overview of the main and common computational methods currently used in physics research. The course will cover the topics of basic concepts of computational physics, first and second order methods of integration of advection equations, kinetic methods and N-body methods, Monte Carlo and Particle in Cell (PIC) methods, finite elements, finite volume and Computational Fluid Dynamics (CFD), spectral methods, girding methods and Adaptive Mesh Refinement (AMR), and introduction to parallel computing.

**PHYS.5640 Particle Astrophysics**  
(Formerly 95.464/564) - Credits: 3


**PHYS.5670L Automation Techniques**  
(Formerly 95.567) - Credits: 3

**PHYS.5690 Plasma Physics**  
Credits: 3

The course aims to provide upper level undergraduate and graduate students from Physics and Engineering background in plasma physics, focusing on the fundamental physics principles, not any specific application or field of research. The course will cover the topics of basic plasma concepts, single-particle motion in an electromagnetic field, magnetohydrodynamics, plasma waves, plasma instabilities, plasma kinetics, and some advanced topics in plasma physics.

**PHYS.5830 Astronomy and Astrophysics I**  
(Formerly 95.583) - Credits: 3

Physics based introduction to modern Astronomy and Astrophysics. Aimed at students who have already studied E&M Modern Physics, and Calculus. Focus on fundamentals of Stellar Astrophysics and Galactic Astronomy.

**PHYS.5870 Cloud Physics**  
Credits: 3

This course explores the essentials of cloud physics, beginning with the basic laws of thermodynamics of both dry and moist atmospheres. Condensation, nucleation, and drop growth are studied in detail at an advanced level.

**PHYS.5930L Graduate Physics Laboratory**  
(Formerly 95.593) - Credits: 2

Experiments in various branches of physics including optics, atomic physics, solid state physics and nuclear physics.
PHYS.6050 Mathematical Methods of Physics I
(Formerly 95.605) - Credits: 3
Vector analysis; matrices and determinants; theory of analytical functions; differential equations, Fourier series, Laplace transforms, distributions, Fourier transforms. Students taking PHYS.6050/6060 cannot get credit for PHYS.6070.

PHYS.6060 Mathematical Methods of Physics II
(Formerly 95.606) - Credits: 3
Partial differential equations, boundary value problems, and special functions; linear vector spaces; Green's functions; selected additional topics; numerical analysis. Students taking PHYS.6050/6060 cannot get credit for PHYS.6070.

PHYS.6070 Mathematical Methods of Physics - Credits: 3
Vector and tensor analysis; Linear spaces; Special functions; Fourier transforms; Theory of complex variables. Students taking PHYS.6070 cannot get credit for PHYS.6050/6060.

PHYS.6110 Classical Mechanics (Formerly 95.611) - Credits: 3

PHYS.6150 Quantum Mechanics I (formerly 95.615) - Credits: 3

PHYS.6160 Quantum Mechanics II (formerly 95.616) - Credits: 3

PHYS.6165 Graduate Quantum Mechanics - Credits: 3
This single-semester course assumes prior exposure to quantum mechanics and is designed to train students in more complex concepts and tools of quantum mechanics. The topics include mathematical framework of complex vector spaces, exactly solvable systems such as harmonic oscillator and spin-half, path integral formalism, continuous and discrete symmetries, gauge invariance and quantum Hall effect, time-independent and time-dependent perturbation theory, second quantization of many-body quantum systems. The aim of the course is to provide foundational conceptual and technical background requisite for advanced elective courses, such as quantum Information, quantum optics, quantum field theory, and/or quantum many-body physics. Students can get credit for either PHYS.6165 or for PHYS.6150/PHYS.6160 Sequence.

PHYS.6170 Advanced Quantum Mechanics I (formerly 95.617) - Credits: 3
Dirac equation as a single particle wave equation, free particle spinors and plane waves, matrices and relativistic covariance, nonrelativistic approximation and the fine-structure of the H atom. Quantization of the e.m. field in the coulomb gauge; interaction of an atom with the quantized radiation field; radiative transitions in atoms; Thomson scattering; classical and quantized Lagrangian field theory; symmetries and conservation laws: quantization of the real and complex Klein-Gordon field; Dirac Field and the covariant quantization of the e.m. field; Feynman propagators; the interaction picture and the S-matrix expansion in perturbation theory and the Wick's Rule. Feynman diagrams and rules for calculating S-matrix elements in QED; formulas for cross-section and spin and photon polarization sums; calculation of cross-sections for (1) e++- l++ l - (2) e++e- e++e- (3) Compton scattering and (4) scattering of electrons by an external e.m. field.

PHYS.6190 Physics of Quantum Information - Credits:
Introduction of physical concepts behind quantum information processing; Quantum description of physical systems, such as a harmonic oscillator and a single qubit, from an information processing point of view; More complex systems composed of entangled qubits; General tools, rooted in density-matrix formalism, used to describe entanglement and decoherence; Quantum error correction and how it can correct for qubit decoherence to realize fault tolerant computation; Recent advances in engineering quantum information processing platforms, teleportation, and quantum annealing.

PHYS.6310 Nonlinear Optics (formerly 95.631) - Credits: 3

Wave propagation in a linear anisotropic medium; Wave propagation in a nonlinear optical medium. Classical model for the origin of nonlinear optical effects; Second order nonlinear optical effects - second harmonic generation, sum and difference frequency generation, linear electro-optical effect; Third order nonlinear optical effects, Kerr effect and intensity dependent nonlinear index of refraction, stimulated Raman and Brillouin scattering; Photorefraction; Nonlinear optical devices.

PHYS.6570 Electromagnetic Theory I (formerly 95.657) - Credits: 3

Electrostatics and magnetostatics with special attention to boundary value problems. Quasistatic fields and displacement currents. Maxwell's equations, special relativity, wave-guides, scattering, radiation from accelerated charges, propagation in material media and plasmas, Kramers-Kronig relations.

PHYS.6580 Electromagnetic Theory II (Formerly 95.658) - Credits: 3

Electrostatics and magnetostatics with special attention to boundary value problems. Quasistatic fields and displacement currents. Maxwell's equations, special relativity, wave-guides, scattering, radiation from accelerated charges, propagation in material media and plasmas, Kramers-Kronig relations.

PHYS.6620 Nuclear Physics II (Formerly 95.662) - Credits: 3

The nucleon-nucleon force; nuclear models; nuclear reaction theory and partial wave analysis of scattering; fast neutron physics.

PHYS.6650 Space Physics (Formerly 95.665) - Credits: 3

This course provides in depth knowledge of space phenomena and physical understanding of the plasma environment form the sun to the earth's ionosphere and in the heliosphere. Regions in space include solar surface, solar wind, bow shock, magnetosheath, magnetosphere, magnetotail, radiation belts, ring currents, and upper ionosphere. Among space plasma physics theories, single particle theory and magnetohydrodynamics are discussed in depth.

PHYS.6830 General Relativity - Credits: 3

Special relativity and Lorentz transformations; Scalar and electromagnetic fields; Curved spacetime and the metric tensor; The equivalence principle; Geodesics, covariant derivatives, and Killing vectors; Einstein's field equations; The energy conditions; Relativistic cosmology and the expanding Universe; (Special topics: Schwarzschild solution and black holes; Penrose-Carter diagrams; Quantum gravity)

PHYS.6840 Theoretical Cosmology - Credits: 3

Geometry, kinematics, and dynamics in an expanding Universe; Thermal history; Generation of standard model particles; Phase transitions; Inflation; quantum origin of primordial inhomogeneities; Scalar, vector, and tensor perturbations; Gravitational instability; Choice of gauge; Matter distribution; Galaxy bias; Redshift space distortions; Cosmic microwave background anisotropies; Baryon acoustic oscillations; Polarization.

PHYS.7010 Physics Colloquium (Formerly 95.701) - Credits: 0-1

A series of invited lectures on current research topics in Physics. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7020 Physics Colloquium (Formerly 95.702) - Credits: 0-1

A series of invited lectures on current research topics in Physics. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7040 Seminar in Nuclear Physics (Formerly 95.704) - Credits: 0-1

involve presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7050 Seminar in Solid State/Optics (Formerly 95.705) - Credits: 0-1
involve presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7051 Supervised Teaching - Physics (Formerly 96.705) - Credits: 0

PHYS.7060 Seminar in Solid State/Optics (Formerly 95.706) - Credits: 0-1

involve presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7090 Seminar in Accelerator Physics (Formerly 95.709) - Credits: 0-1

A weekly series of presentations and discussions by students and faculty concerning research in progress and planned research at the 5.5 MV Van de Graaff Accelerator. Enrollment in the course is limited to students whose research projects involve the Van de Graaff accelerator. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7100 Seminar in Experimental Optics (Formerly 95.710) - Credits: 0-1

A weekly series of presentations and discussions concerning experimental optics research in the University of Massachusetts Lowell Department of Physics and Applied Physics. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7110 Graduate Seminar in Physics (Formerly 95.711) - Credits: 0-1

Presentations by students of progress in their research projects. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7120 Graduate Seminar in Physics (Formerly 95.712) - Credits: 0-1

Presentations by students of progress in their research projects. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7130 Seminar in Theoretical Research (Formerly 95.713) - Credits: 0-1

"Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7140 Seminar in Experimental Research (Formerly 95.714) - Credits: 0-1

"Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7150 Seminar in Terahertz Technology (Formerly 95.715) - Credits: 0-1

Course involves presentations by students, faculty members, and visiting scientists of advanced topics, original research for journal articles relevant to technologies at terahertz frequencies. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7160 Seminar in Biomedical Optics (Formerly 95.716) - Credits: 0-1

Seminar in Biomedical Optics, offered at the Advanced Biophotonics Laboratory by Dr. Anna N. Yaroslavsky, covers topics related to recent advances in biomedical optics. Examples include, but are not limited to, the development of individualized, image-based methods of light dosimetry and planning for cancer treatments, concepts and implementation of full inverse Monte Carlo technique for reconstruction of tissue optical properties, investigation of light scattering by complex biological structures and live tissues, development of steady-state and time-resolved polarization, fluorescence and elastic scattering methods for diagnostics and treatment of pathology. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7160L Special Problems In Physics (Formerly 96.716) - Credits: 1-9

Reading in preparation for research, or research not for thesis. If results of the research are to be subsequently incorporated into a thesis, credits earned in this course may be used to satisfy thesis credit requirements in M.S. or Ph.D. Thesis Research with the written permission of the thesis supervisor, provided such permission is granted at the time of registration for this course. If the results are incorporated in an M.S. project, not more than 3 credits are allowed.

PHYS.7170 Seminar in Heavy Ion Physics (Formerly 95.717) - Credits: 0-1

Involves presentations by students, faculty members, and research scientists on advanced topics in heavy-ion spectroscopy, including both original research and journal articles. "Variable credit course, student chooses appropriate
PHYS.7180 Seminar in Space Physics (formerly 95.718) - Credits: 0-1
This course is a weekly seminar covering the areas of conventional "space physics" and extending to "astrophysics" and "Upper atmospheric physics". Each seminar is focused on a topic that is currently at the cutting edge in these fields while an extended introduction will be given based on diverse background knowledge at graduate level in physics and engineering. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7190 Seminar in Nanoscale Physics and Technology (formerly 95.719) - Credits: 0-1
Students will study the scientific literature on topics and concepts in nanoscale physics and technology, including nanoscale thermal properties, micro- and nano-fluidity, nano-optics, quantum confinement to electronic states, and other phenomena. Students will make presentations and lead discussions on these studies at the frontiers of the field. The presentations will help them to generate new ideas for their own graduate research. Every student will have the opportunity to lead more than one discussion session. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7200 Medical Physics Seminar - Credits: 0-1
Current research topics in medical physics, discussed by faculty, students and invited speakers. "Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7210 Selected Topics in Physics (formerly 95.721) - Credits: 3
Selected topics courses cover recent advances and more advanced topics, not covered in the regular courses in these areas. Subject matter varies, depending on the interests of the instructor and the needs of the students. Subject matter varies sufficiently that these courses may be taken more than once for credit without repeating topics.

PHYS.7250 Selected Topics in Solid State (formerly 95.725) - Credits: 3
Selected topics courses cover recent advances and more advanced topics, not covered in the regular courses in these areas. Subject matter varies, depending on the interests of the instructor and the needs of the students. Subject matter varies sufficiently that these courses may be taken more than once for credit without repeating topics.

PHYS.7270 Selected Topics in Theoretical Physics (formerly 95.727) - Credits: 3
Selected topics courses cover recent advances and more advanced topics, not covered in the regular courses in these areas. Subject matter varies, depending on the interests of the instructor and the needs of the students. Subject matter varies sufficiently that these courses may be taken more than once for credit without repeating topics.

PHYS.7310 Advanced Projects In Physics I (formerly 96.731) - Credits: 3
Research project leading to the Graduate Research Admission Examination (for Ph.D. candidates only.)

PHYS.7320 Advanced Projects In Physics II (formerly 96.732) - Credits: 3
Research project leading to the Graduate Research Admission Examination (for Ph.D. candidates only.)

PHYS.7330 Graduate Project - Physics (formerly 96.733) - Credits: 3

PHYS.7460 Master's Thesis Research Physics (formerly 96.746) - Credits: 0-9
"Variable credit course, student chooses appropriate amount of credits when registering."

PHYS.7560 Doctoral Dissertation/Physics (formerly 96.756) - Credits: 1-9
Note: Courses with 98 prefix are described in the Radiological Sciences and Protection section of this catalog.

PHYS.7610 Continued Grad Research (formerly 96.761) - Credits: 1
Continued Grad Research

PHYS.7710 Physics Systems Analysis I (formerly 95.771) - Credits: 3
PHYS.7720 Physics Systems Analysis II (formerly 95.772) - Credits: 3
PHYS.7730 Physics Systems Analysis III (formerly 95.773) - Credits: 3
PHYS.8000 Cooperative Education in Physics (formerly 96.800) - Credits: 0-1

Cooperative Education in Physics. "Variable credit course, student chooses appropriate amount of credits when registering."
PSMA.5000 Professional Science Master's (PSM) Professional Development (Formerly PSM 500) - Credits: 0

Professional Science Master's students who are preparing to participate in an internship enroll in this Professional Development Seminar prior to the semester of their work period. This seminar will provide them with resources and skills to manage an internship search, secure a position and work successfully in a professional environment.

PSMA.5010 Professional Science Master's (PSM) Reflective Seminar. (Formerly PSM 501) - Credits: 1

Reflective seminar following the internship which will enable Professional Science Master's (PSM) students to share and learn from the experiences of colleagues in other settings. The seminar is be conducted on campus and will include writing and oral presentation of experience.

PSMA.5100 Professional Science Master's (PSM) Internship (Formerly PSM 510) - Credits: 0

The internship component is expected to be 350 hour minimum and 3-6 month duration. The student will work within a business, government agency or research institute directly related to their area of study. Through this experience the student engages in real world work situations involving technical problems, teamwork, communication skills and decision-making. A student must have completed a minimum of 18 credit hours before commencing the internship. This course records the internship experience and carries zero credits.

PSMA.5350 Project Management for Scientists (Formerly PSM 535) - Credits: 3

This course is designed to provide skills to prepare students to take on the role of project manager. The necessity for project Management is now realized by most companies where the entire business including most of the routine activities can be regarded as a series of projects. Project Management principles provide a systematic approach to running a business; both large and small businesses as well as a scientific laboratory.

PSMA.5550 Professional Leadership in Science and Engineering (PSM 555) - Credits: 3

This course is designed to provide awareness and skills to prepare students to take on the role of leader. Part of a technically competent professional's responsibilities or opportunities for advancement may include leading small projects or work groups. This course will be organized around thematic video interviews with industry leaders to impart knowledge of and experience in leadership topics that support professional development.
Radiological Sciences and Protection

The Profession of Radiological Health Physics

Radiological Health Physics (RHP) involves the study of the effects of radiation and radioactivity on life processes. It also can be called radiation protection science and is particularly involved with the effects of radiation on the human body and the control of such radiation.

Many graduates of this curriculum at the University of Massachusetts Lowell (UML) enter the profession of health physics, which is devoted to the protection of man and the environment from the harmful effects of radiation while at the same time making it possible for our advancing civilization to enjoy all of the benefits resulting from uses of radiation.

Radiation control in its professional aspects requires the skills and knowledge from many disciplines. It has common scientific interests with many areas of specialization: biophysics, physics, biochemistry, chemistry, biology, genetics, ecology, nuclear engineering, metallurgy, medicine, physiology, industrial hygiene, and toxicology.

Other aspects of the profession include a working knowledge of labor relations, public relations, teaching, philosophy, and administration. The wide spectrum of knowledge required of the health physicist makes this profession both challenging and rewarding.

The Profession of Medical Physics

Medical Physics (MP) involves the application of physics to the diagnosis and treatment of disease. The use of radiation producing devices and radioactivity in medical physics is extensive. Many graduates of the Radiological Sciences and Protection curriculum at the University of Massachusetts Lowell (UML) enter the profession of medical physics.

Graduate students who intend to enter this profession are encouraged to seek internships and research venues at nearby hospitals for which they can receive graduate credit towards the masters degree.

Employment and Scholarship Opportunities

Health physicists are employed by federal agencies (such as the Nuclear Regulatory Commission and Department of Energy) at

- research, production, and testing facilities;
- state, and local government agencies responsible for regulating the use of radiation sources and radioactive materials;
- the military services;
- electric utilities operating nuclear power plants and many related industries such as engineering support companies;
- industries which use radioisotopes or x-ray equipment to detect flaws or defects in manufactured products, prepare or reprocess nuclear fuels, control nuclear wastes, or produce or use radioactive materials or devices;
- universities (in teaching, research, and equipment monitoring);
- hospitals and medical centers that use radionuclides, x-ray equipment, and accelerators in the diagnosis and treatment of patients; and
- consulting firms which advise the organizations that do not employ full-time health physicists.

Scholarships are available for graduate students who choose the Radiological Sciences Program. These are available from

- the Nuclear Regulatory Commission (NRC),
- the Department of Energy (DOE),
- the National Academy for Nuclear Training,
- the Health Physics Society (HPS),
- the American Nuclear Society (ANS), and
- other organizations concerned with radiation protection.

Teaching Assistantships and Research Assistantships are available on a limited basis for UML graduate students.

Students may gain valuable applied work experience while also earning graduate credit and money through various summer internship programs. They also may gain experience and academic credit through an internship course at the UML Radiation Laboratory. This course is conducted under the direction of the health physics staff who have responsibility for the radiation safety programs at the nuclear reactor facility; accelerator facility, radioisotope research laboratories and x-ray facilities at the University of Massachusetts Lowell.

Radiological Sciences and Protection - Master of Science Degree Program

With the increasing use of radiation and radioactive material in society, there is a growing need for research and advanced education in Radiological Sciences and Protection.

The excellent facilities, equipment and supporting staff available at the University of Massachusetts Lowell’s Radiation Laboratory and faculty in the Radiological Sciences Program
and in other allied departments give students at the University of Massachusetts Lowell (UML) a unique opportunity to obtain rewarding careers in and make significant research contributions to the radiation protection field and to the use of radiation physics in medicine.

The Master of Science Degree Program in Radiological Sciences and Protection is interdisciplinary in nature and should be attractive to engineering students and students in the biological and physical sciences.

Master of Science - Radiological Sciences and Protection

Master of Science in Radiological Sciences and Protection - Professional Science Master’s Option

Admission Requirements

A student should have a reasonable minimum preparation, including courses in mathematics, chemistry, physics, biology and in nuclear and radiological sciences similar to the University of Massachusetts Lowell Radiological Health Physics undergraduate curriculum. Because there is no advanced test in the field of Radiological Sciences and Protection, and because various undergraduate backgrounds are suitable for graduate study in the program, students are not required to take the Advanced GRE tests. The GRE Aptitude Test, however, is required. It is important that the mathematical preparation of students include differential and integral calculus through differential equations. Physics preparation up to and including Modern Physics is required. Preparatory courses are available at UMass Lowell for applicants who are deficient in these areas.

Master of Science in Radiological Sciences and Protection

Plan of Study

The program allows a student to select courses and a research project consistent with his/her desired area of professional development. Various opportunities for research and professional development are possible through the use of the Radiation Laboratory of the University and through cooperative programs with hospitals, nuclear reactor facilities, government laboratories, and other radiation facilities. A research advisor, other than a University of Massachusetts Lowell faculty member, may be approved for the conduct of research at facilities outside the University. Two M.S. degree options are available: thesis option or project option. In addition to a core curriculum, a master’s thesis or project report must be submitted and approved.

Thesis Option

Under the thesis option, a student must complete a minimum of 21 credits of formal courses and a minimum of 9 credits of graduate research. The master’s thesis generally will consist of a scholarly laboratory or theoretical investigation in the field of Radiological Sciences and Protection. Proposed research must be approved by the Program Graduate Committee. The format for the final written thesis shall conform to the requirements of the University. The thesis proposal and report requirements may be obtained from the Program Coordinator.

Project Option

Under the project option, a student must complete a minimum of 27 credits of formal courses and 3 credits of graduate research to yield a total of 30 credits. In addition to the project report, the student must pass a comprehensive examination. The master’s project consists of a scholarly investigation such as a review, report, design, etc., in the field of Radiological Sciences and Protection. The subject of the project must be approved by the student’s advisor in advance. The final report must be approved by the Program Graduate Committee and conform to the format specified by the University.

Oral Defense of Thesis

A thesis committee is appointed to read a student’s thesis and to listen to an oral presentation and defense by the student. In general, the committee will include the thesis advisor and two additional members chosen from the Physics faculty or from other departments in which the candidate has taken graduate studies.

Comprehensive Examination for the Project Option

Degree candidates electing the project option are required to pass a Comprehensive written examination administered by the Program Graduate Committee. This examination normally will be administered during the semester in which the student completes his/her course requirements for the M.S. degree. The comprehensive examination may be waived for a student who can document that he/she has passed Part I of the American Board of Health Physics Certification Examination.

Residency and Foreign Language Requirements

No residency or foreign language requirements are specified by the Department.

Core Curriculum

A core curriculum consisting of seven courses and Thesis Research or Graduate Project in Radiological Sciences and Protection are required of all students pursuing the Master’s Degree in Radiological Sciences and Protection. These core courses are listed below. If a student has already had a course or courses similar to those listed, then the requirement for such courses may be waived. Courses in Nuclear Engineering, Physics and Applied Physics, Environmental Studies, Biology, Mathematics, Meteorology, Chemistry, Work Environment, and others may be selected for graduate credit with the approval of the Department.
Required Core Courses

- RADI.5060
  (https://www.uml.edu/catalog/courses/RADI/5060)
  Nuclear Instrumentation (4 credits)
- RADI.5010L
  (https://www.uml.edu/catalog/courses/RADI/5010L)
  Radiation Safety and Control I (4 credits)
- RADI.5020L
  (https://www.uml.edu/catalog/courses/RADI/5020L)
  Radiation Safety and Control II (4 credits)
- RADI.5330
  (https://www.uml.edu/catalog/courses/RADI/5330)
  External Radiation Dosimetry and Shielding (3 credits)
- RADI.5340
  (https://www.uml.edu/catalog/courses/RADI/5340)
  Internal Radiation Dosimetry and Bioassay Assessment (3 credits)
- RADI.5620
  (https://www.uml.edu/catalog/courses/RADI/5620)
  Radiation Biology (3 credits)
- RADI.7110/7120
  (https://www.uml.edu/catalog/courses/RADI) Graduate Seminar in Radiological Sciences and Protection 1
- RADI.7330
  (https://www.uml.edu/catalog/courses/RADI/7330)
  Graduate Project in Radiological Sciences and Protection (3 credits), or
  RADI.7430
- Plus departmental electives as required

Total = 30 credits

The Professional Science Master’s Option within the Radiological Sciences Program

The development of Professional Science Masters (PSM) degree programs represents a growing trend in the United States with currently 120 such degrees offered at 60 colleges and universities. PSMs maintain a strong science core while incorporating professional communication (oral, written) skills, multidisciplinary training, management courses, and a professional internship into the curriculum. Applicants to PSMs include individuals with baccalaureate degrees currently employed at companies as well as new bachelor degree recipients from the United States and abroad who desire to combine in-depth science education with workplace skills important for their career development.

The Professional Science Master’s Option within the Radiological Sciences Program in the Department of Physics and Applied Physics shares the same core courses as the current masters degree program and, in lieu of a research component, requires courses selected from the foundation courses of the MBA degree program, a communications course, and a professional internship in Radiological Sciences.

Core Courses for Radiological Sciences and Protection

The required core courses for all options for the M.S. Degree in Radiological Sciences and Protection are:

- RADI.5060
  (https://www.uml.edu/catalog/courses/RADI/5060)
  Nuclear Instrumentation (4 credits)
- RADI.5010L
  (https://www.uml.edu/catalog/courses/RADI/5010L)
  Radiation Safety and Control I (4 credits)
- RADI.5020L
  (https://www.uml.edu/catalog/courses/RADI/5020L)
  Radiation Safety and Control II (4 credits)
- RADI.5330
  (https://www.uml.edu/catalog/courses/RADI/5330)
  External Radiation Dosimetry and Shielding (3 credits)
- RADI.5340
  (https://www.uml.edu/catalog/courses/RADI/5340)
  Internal Radiation Dosimetry and Bioassay Assessment (3 credits)
- RADI.5620
  (https://www.uml.edu/catalog/courses/RADI/5620)
  Radiation Biology (3 credits)
- RADI.7110/7120
  (https://www.uml.edu/catalog/courses/RADI) Graduate Seminar in Radiological Sciences and Protection (3 credits)
- RADI.7330
  (https://www.uml.edu/catalog/courses/RADI/7330)
  Graduate Project in Radiological Sciences and Protection (3 credits), or
  RADI.7430
- Plus departmental electives as required

The required plus courses for the PSM option to the M.S. Degree in Radiological Sciences and Protection are:
Graduate Certificate Programs in Radiological Sciences:

- Medical Physics
- Radiological Health Physics and General Work Environment Protection

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

Medical Physics Certificate Program

Erno Sajo  
Tel. 978-934-3288  
Erno_Sajo@uml.edu (mailto:erno_sajo@uml.edu)

Program Description and Requirements.

Radiological Health Physics and General Work Environment Protection

Mark Tries  
Tel. 978-934-3353  
Mark_Tries@uml.edu (mailto:mark_tries@uml.edu)

Program Description and Requirements.

Bachelor's-Master's Program

In recognition of the need for advanced training beyond the bachelor of science level in radiological sciences, the following represents a program by which outstanding undergraduates can pursue an accelerated course of study leading to the B.S. and M.S. degrees in Radiological Sciences and Protection.

1. Undergraduate students who express an interest in this program will be evaluated by the graduate selection committee. Those students deemed commendable by the committee will be advised relative to the correct procedure for successful completion of their B.S. degree as well as a course of study toward the M.S. degree.

2. The first three years of undergraduate study is identical to that specified for students enrolled in the current four year B.S. program.

3. During the second semester of the junior year and upon approval and recommendation by the graduate selection committee, the student will file formal application to the Graduate School. This does not require the student to have taken the Graduate Record Examination. The committee decision will be based on (a) overall grade-point average, (b)
grade-point average in selected subjects, (c) recommendations by program faculty, and (d) a one year minimum enrollment requirement at the University of Massachusetts Lowell. Upon approval, the student may be conditionally accepted to the Master’s on Physics, Radiological Health Physics option pending successful completion of the bachelor’s degree with a minimum 3.0 cumulative GPA.

4. During the senior year, the student is permitted to take up to six graduate-level courses (two three-credit courses) which can be double-counted towards the M.S. degree, provided the courses have an earned grade of B or better.

5. Upon completion of the fourth year of bachelors study, assuming that all program and University requirements have been met, and the student has filed for graduation with the baccalaureate degree, the student will be awarded the B.S. degree and then may be recommended for full matriculation status by the graduate selection committee prior to the full matriculation status by the graduate selection committee prior to the full matriculation into the Master’s program. For University policy regarding to the BS?MS degree, please see

6. Although the options exist for taking an overload in any semester and/or registering for one or more summer sessions, they are not a requirement of this program. However, students wishing to gain a full research experience will be encouraged to initiate their research as early as possible (e.g., during the junior to senior year summer session), which is a distinct advantage of this accelerated program.

7. During the fifth year, as in the standard M.S. degree program, the student may choose the thesis option (9 semester hours of graduate research) or the project option (3 semester hours of graduate project). In either case, the student is required to take two one-credit graduate seminar courses and other courses required for the M.S. degree in radiological sciences that satisfy the 30 credit minimum M.S. degree requirement. Upon completion of all program and graduate school requirements, the student will be awarded the M.S. degree in Radiological Sciences and Protection.

More information on the Bachelor’s/Master's Program
RADI.5010L Radiation Safety and Control I (Formerly 98.501) - Credits: 3-4
This course provides a theoretical basis for radiological sciences and protection, with a rigorous review of the fundamentals of radiation physics including nuclear reactions, radioactivity and the kinetics of radioactive decay, natural and man-made radiation sources, the characteristics of ionizing radiation, radioactivity analysis, radiation dose quantities and measurement, external and internal radiation dosimetry, and radiation protection techniques.

RADI.5020L Radiation Safety and Control II (Formerly 95.420/98.502) - Credits: 3-4
This course provides a continuation of the theoretical and practical aspects of radiation protection provided in Radiation Safety and Control I (98.501). Topics include the statistical analyses and data reduction techniques that are used to analyze radiation measurements pertaining to the field of radiation protection. Laboratory sessions on alpha and gamma radiation measurements and air sampling will reinforce class lectures. Students also will experience applied radiation protection and dose assessment through a contamination control exercise that involves the use of protective clothing and respiratory protection.

RADI.5060 Nuclear Instrumentation (Formerly 98.506) - Credits: 3
This course provides the operating principles and applications of nuclear radiation detection systems, including detector theory, electronic signal processing, and measurement and data reduction techniques. The systems covered include gas-filled detectors (ion chambers, proportional counters, and Geiger-Mueller counters), inorganic and organic scintillators, and high-purity germanium detectors, for the detection of alpha, beta, gamma, and neutron radiation. This course also covers hypothesis testing, detection limits, and detector dead time.

RADI.5090 Nuclear Instrumentation (Formerly 96.409) - Credits: 3
This course provides the operating principles and applications of nuclear radiation detection systems, including detector theory, electronic signal processing, and measurement and data reduction techniques. The systems covered include gas-filled detectors (ion chambers, proportional counters, and Geiger-Mueller counters), inorganic and organic scintillators, and high-purity germanium detectors, for the detection of alpha, beta, gamma, and neutron radiation. This course also covers hypothesis testing, detection limits, and detector dead time. This course is adapted for Nuclear Engineering and Medical Physics majors. (offered as 98.509 for graduate credit).

RADI.5240 Environmental Health Physics (Formerly 98.524 & 94.424) - Credits: 3
Natural and man-made sources of environmental radioactivity and radiation; environmental transport in air, water, and soil; exposure pathways; environmental standards and regulations; environmental monitoring and surveys (MARSSIM); contaminated site characterization, and site remediation; environmental radiological impact of industry, accidents, and natural and man-made disasters.

RADI.5330 External Dosimetry and Shielding (Formerly 98.533) - Credits: 3
This course provides the theory and application of dosimetry and shielding for ionizing radiation sources outside the human body. Differential cross-sections, energy transfer and absorption coefficients, kerma, attenuation, and buildup are discussed for photons. Cross-sections, kerma factors, removal coefficients, diffusion, and point-source dose functions for fissioning sources are discussed for neutrons. Beta dosimetry concepts include stopping power, point-source dose functions, and the effects of attenuating materials. Heat generation and temperature profiles are discussed for irradiated materials and radioactive substances. Dosimetry concepts and barrier requirements also are described for particle accelerators, radiotherapy facilities, and medical x-ray imaging facilities.

RADI.5340 Internal Dosimetry and Bioassay (Formerly 98.534) - Credits: 3
RADI.5410 Radiochemistry (Formerly 98.541) - Credits: 3
This course provides the theory and application of several analytical techniques, including precipitation, solvent extraction, ion exchange chromatography, and electrodeposition, to the separation and analysis of radioactive substances in various samples. This course also covers some common radiation detection systems, measurement and data reduction techniques, radiotracer and isotope dilution techniques, neutron activation analysis, and radioimmunoassay.

RADI.5620 Radiation Biology (Formerly 98.562) - Credits: 3
Effects of ionizing radiation on cellular, molecular and organ systems levels of biological organization; Study of x-rays, gamma rays, accelerator beams, and neutrons in interaction with living systems; Cohesive treatment of radiation biophysics with applications in health physics and radiation oncology.
RADI.5650 Introduction to Radiation Therapy Physics  
(Formerly 98.565) - Credits: 3
Introduction to the fundamental physics of radiation therapy, with emphasis on external beam photon and electron therapy and on brachytherapy. For these modalities, the basic operation of delivery equipment, treatment planning principles, methods of dose calculations, determination of time of irradiation from dose prescription, dose measurements, and quality assurance will be studied. This knowledge will prepare the student for an introduction to the practice of clinical physics in radiation therapy, for advanced radiation therapy physics, and research in radiation therapy physics.

RADI.5750 Certification Preparation in Radiological Sciences  
(Formerly 98.575) - Credits: 3
Advanced problem solving in radiological sciences including strategies for preparing for and taking professional certification examinations.

RADI.5820 Numerical Methods In Radiological Sciences  
(Formerly 98.582) - Credits: 3
This course provides a more advanced mathematical treatment of the topics covered in 98.481, with extensive application of computer techniques to numerical problem solving that is applicable to radiological sciences and protection.

RADI.5980 Medical Imaging I  
(Formerly 98.598) - Credits: 3
Medical Imaging I is the first part of a two course sequence. Medical Imaging I provides an overview of the medical imaging modalities, teaches basic underlying physics and mathematics of medical imaging, describes key modalities in radiographic imaging, including general x-ray radiography, fluoroscopy, and mammography.

RADI.6050 Radiation Interactions and Transport  
(Formerly 98.605) - Credits: 3
Photon, neutron, and electron interactions and energy deposition; the Boltzmann equation, elementary analytical solutions; deterministic computational methods, including spherical harmonics and discrete ordinates techniques; continuous slowing down and Fokker Planck approximations.

RADI.6060 Monte Carlo Simulation of Radiation Transport  
(Formerly 98.606) - Credits: 3
Radiation transport simulation by the Monte Carlo method: phase space tracking, dose response estimators, biasing methods; integral form of the Boltzmann equation; condensed history method for charged particles; neutron, photon, and electron transport calculations for medical physics and health physics applications.

RADI.6310L Professional Health Physics Internship  
(Formerly 98.631) - Credits: 1-3
The student will be introduced to the physics of advanced treatment techniques used in radiation therapy, which include external beam electron, proton, and photon therapy and internal brachytherapy. For these techniques, the principles of the techniques such as clinical applications, radiation delivery equipment, treatment planning methods, methods of dose calculations, determination of time of irradiation from dose prescription, dose measurements, and quality assurance will be studied. This knowledge will prepare the student for an introduction to the clinical practice of medical physics applied to complex treatment techniques used in radiation therapy. Also, this should help prepare the student for research in radiation therapy physics.

RADI.6710L Graduate Accelerator HP Internship  
(Formerly 98.671) - Credits: 3
Clinical Rotation under the direction of clinical staff. This course provides the student with exposure to medical physics responsibilities in a radiation oncology department, including simulation, treatment planning and preparation, monitor unit calculations, dose measurements and calculations, treatment delivery techniques, quality assurance, and radiation safety.
RADI.6790L Graduate HP Internship (Formerly 98.679) - Credits: 1-3
RADI.6830L Graduate HP Internship (Formerly 98.683) - Credits: 3
RADI.6850L Advanced Medical HP Internship (Formerly 98.685) - Credits: 3
RADI.6860L Advanced Medical Physics Internship (Formerly 98.686) - Credits: 1-9

Clinical Rotation under the direction of clinical staff. This course involves the student in one or more projects that require skill development, extended involvement, and project completion, which includes planning and delivery of advanced radiation therapy treatments.

RADI.6870L Advanced Medical Physics Internship (Formerly 98.687) - Credits: 3
RADI.6890L Advanced Graduate HP Internship (Formerly 98.689) - Credits: 1
RADI.6900L Advanced Graduate HP Internship (Formerly 98.690) - Credits: 2
RADI.6910L Advanced Graduate HP Internship (Formerly 98.691) - Credits: 2
RADI.6920L Advanced Graduate HP Internship (Formerly 98.692) - Credits: 3
RADI.6930L Advanced Graduate HP Internship (Formerly 98.693) - Credits: 3
RADI.6980 Medical Imaging II (Formerly 98.599) - Credits: 3

Medical Imaging II is the second part of a two course sequence. Medical Imaging II focuses on the fundamental principles, instrumentation, image reconstruction and applications of computed tomography, radioactive tracer imaging, magnetic resonance imaging, ultrasound imaging, and new emerging imaging technologies.

RADI.7050 Supervised Teaching in Radiological Sciences (Formerly 98.705) - Credits: 0
RADI.7110 Graduate Seminar in Radiological Sciences (Formerly 98.711) - Credits: 0-1

"Variable credit course, student chooses appropriate amount of credits when registering."

RADI.7120 Graduate Seminar in Radiological Sciences (Formerly 98.712) - Credits: 0-1

"Variable credit course, student chooses appropriate amount of credits when registering."

RADI.7310L Advanced Project in Radiological Sciences I (Formerly 98.731) - Credits: 3-6
RADI.7320L Advanced Project in Radiological Sciences II (Formerly 98.732) - Credits: 3
RADI.7330 Graduate Project in Radiological Sciences and Protection (Formerly 98.733) - Credits: 3-6
RADI.7430 Master's Thesis in Radiological Sciences and Protection (Formerly 98.743) - Credits: 3
RADI.7460 Master's Thesis in Radiological Sciences and Protection (Formerly 98.746) - Credits: 1-9
RADI.7490 Master's Thesis Research in Radiological Sciences (Formerly 98.749) - Credits: 9
RADI.7530L Doctoral Dissertation in Radiological Sciences and Protection (Formerly 98.753) - Credits: 3
RADI.7560 Doctoral Dissertation in Radiological Sciences and Protection (Formerly 98.756) - Credits: 1-9
RADI.7590L Doctoral Dissertation in Radiological Sciences and Protection (Formerly 98.759) - Credits: 9
RADI.7690 Continued Graduate Research (Formerly 98.769) - Credits: 9