College of Sciences

The UMass Lowell College of Sciences, led by Dr. Mark Hines, 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 College of Sciences (pdf)

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

Graduate Programs Offered

Master of Science (MS) - degree awarded in the following fields:

- Biological Science
- Biotechnology Option
- Professional Science Master's Options (Applied Biotechnology, Biosafety, Environmental Biotechnology, Project Management for Life Sciences)
- 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
- Professional Science Master's Option (Radiological 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
Medical Physics

Overview and Program Goals

The University of Massachusetts Lowell’s Department of Physics and Applied Physics offers a Master of Science degree in Medical Physics and a Ph.D. in Radiological Sciences with Medical Physics Concentration. A Ph.D. in Biomedical Engineering and Biotechnology with Medical Physics Specialization is also available. In collaboration with local and regional hospitals and cancer centers in the Boston area, the program is designed for individuals who seek the MS or Ph.D. degree and 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 student’s 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 exams. The clinical component provides the students with training dominantly in radiation therapy.

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 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.

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.

Further information on the graduate admission process, including on-line and downloadable application forms, may be accessed at the UMass Lowell Graduate Admission website.

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 student’s research.

- Sample curriculum leading to the MS Degree in 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
- Leading to the Ph.D. Degree in Physics – Medical Physics Option, entering with MS in Physics
- Leading to the Ph.D. Degree in BMEBT – Medical Physics Specialization, entering with BS in a technical discipline

For the latest course information please visit the UMass Lowell Online Academic Catalog.

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.

Medical Physics and Radiological Science Faculty, Research and Resources

- Faculty
- Resources

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 student’s research.

- Sample curriculum leading to the MS Degree in Medical Physics

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.

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Sample curricula available as pdfs

- Leading to the Ph.D. Degree in Physics – Medical Physics Option, entering with BS in Physics
- Leading to the Ph.D. Degree in Physics – Medical Physics Option, entering with MS in Physics
- Leading to the Ph.D. Degree in BMEBT – Medical Physics Specialization, entering with BS in a technical discipline

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81.500 Professional Experience

Course ID: 7536

Course Details: 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

Max Credits: 3

Min Credits: 3
**81.506 Environmental Microbiology Laboratory**

Course ID: 7542
Course Details:
Max Credits: 1
Min Credits: 1

**81.508 Cell Biology for Teachers**

Course ID: 33596
Course Details: This online course will examine the structure and function of cells and the regulation of cellular processes characteristic 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.
Max Credits: 3
Min Credits: 3

**81.509 Photobiology**

Course ID: 36854
Course Details: 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.
Max Credits: 3
Min Credits: 3

**81.513 Invertebrate Zoology II**

Course ID: 36646
Course Details: An in depth exploration of the deuterostome phyla with a focus on anatomy, ecology and evolution of the lophophorates, Echinodermata, Chaetognatha, Hemichordata and Chordata. Includes readings from the primary literature.
Max Credits: 3
Min Credits: 3

**81.515 Invertebrate Zoology Lab II**

Course ID: 36647
Course Details: The laboratory study of live and preserved specimens of invertebrate animals with a focus on anatomy and functional morphology.
Max Credits: 1
Min Credits: 1

**81.516 Climate Change: Science, Communication, and Solutions**

Course ID: 36712
Course Details: Climate change offers one of the greatest challenges yet faced by society and scientists. The scientific consensus is clear that climate change is occurring, its pace is accelerating, its impacts on human society will be largely negative, and it is largely caused by anthropogenic greenhouse gas emissions. Yet, despite strong scientific evidence for the enormous challenges that society may face, scientists' attempts to disseminate that evidence beyond their peers have not yet been successful. Indeed in today's media world of blogs, YouTube video clips, and sound-bites, confusion over the scientific reality of climate change frequently dominates the discourse in classrooms and communities. This course will provide students with the tools and knowledge that they need to develop their own well-informed view of climate change. Because climate change is both impacted by humans and will increasingly impact society,
this course takes a cross-disciplinary approach, integrating science, policy solutions, and media literacy as they relate to climate change.

Max Credits: 4
Min Credits: 4

81.519 Biochemistry I

Course ID: 7547

Course Details: 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.

Max Credits: 3
Min Credits: 3

81.520 Biochemistry II

Course ID: 7548

Course Details: This course is a continuation of 81-519 and will include discussions on all aspects of amino acid and nucleic acid metabolism and protein biosynthesis.

Max Credits: 3
Min Credits: 3

81.521 Biochemistry Techniques

Course ID: 7549

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

Max Credits: 2
Min Credits: 2

81.523 Biology of Global Change

Course ID: 7551

Course Details:

Max Credits: 3
Min Credits: 3

81.526 Evolutionary Biology

Course ID: 36581

Course Details: 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.

Max Credits: 3
Min Credits: 3

81.528 Molecular Biotechnology: Recombinant Protein Production

Course ID: 37368

Course Details: Proteins are major targets of Pharmaceuticals, and are themselves increasingly used as therapeutics. 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.

Max Credits: 3
Min Credits: 3

81.529 Recombinant Protein Production Techniques

Course ID: 38228

Course Details: This course introduces students to the principles and practice of recombinant protein expression and purification. 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.

Max Credits: 4
Min Credits: 4

81.532 Genomics

Course ID: 37681

Course Details: 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.

Max Credits: 3
Min Credits: 3

81.534 Genomics Laboratory

Course ID: 37680

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

Max Credits: 1
Min Credits: 1

81.537 Biology and Evolution of Arthropoda

Course ID: 37356

Course Details: 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.

Max Credits: 3
Min Credits: 3

81.539 Biology and Evolution of Arthropoda Laboratory

Course ID: 37355

Course Details: 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.

Max Credits: 1
Min Credits: 1
81.540 Advances in Plant Biology

Course ID: 32944

Course Details: 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.

Max Credits: 3
Min Credits: 3

81.541 Topics in Cell Biology

Course ID: 7555

Course Details: Structure and function of the cell: a) cellular membranes, b) transport mechanisms, c) motility, d) excitable cells, and e) energy transduction mechanisms. May be repeated for credit when content varies.

Max Credits: 3
Min Credits: 3

81.542 Cell Biology

Course ID: 7556

Course Details: Ultrastructure and biochemistry of eukaryotic cells; cell membranes and organelles; energy capture and transduction; histochemical and biochemical studies of organelles at the optical and electron microscopic level; cytogenetics; brief discussion of prokaryotic cells. A substantial library investigation is required.

Max Credits: 3
Min Credits: 3

81.545 Isolation and Purification

Course ID: 1236

Course Details: Efficient isolation and purification of biological products, especially proteins, from complex natural mixtures.

Max Credits: 3
Min Credits: 3

81.547 Evolution in Context for Teachers

Course ID: 30381

Course Details: 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 some of 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.

Max Credits: 3
Min Credits: 3

81.552 Quantitative Physiology

Course ID: 7561

Course Details:

Max Credits: 3
Min Credits: 3

81.557 Advanced Invertebrate Zoology
Course ID: 36648
Course Details: Comparative functional morphology, life histories, and phylogeny of a particular taxon (Crustacea, Molusca) of invertebrates.
Max Credits: 3
Min Credits: 3

81.559 Advanced Invertebrate Zoology Laboratory
Course ID: 36650
Course Details: Classification, identification, anatomy and physiology of selected invertebrates.
Max Credits: 1
Min Credits: 1

81.560 Stem Cell Biology
Course ID: 36651
Course Details: 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.
Max Credits: 3
Min Credits: 3

81.561 Electron Microscopy
Course ID: 7564
Course Details:
Max Credits: 3
Min Credits: 3

81.567 Molecular Biology
Course ID: 36652
Course Details: A study of the principles and specialized techniques of cloning, purifying, and manipulating recombinant DNA molecules.
Max Credits: 3
Min Credits: 3

81.569 Molecular Biology
Course ID: 7567
Course Details: 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.
Max Credits: 4
Min Credits: 4

81.572 Virology
Course ID: 7568
Course Details: 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.

Max Credits: 3  
Min Credits: 3

81.576 Cell Culture

Course ID: 36653

Course Details: 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.

Max Credits: 4  
Min Credits: 4

81.580 Developmental Biology

Course ID: 7571

Course Details: 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.

Max Credits: 3  
Min Credits: 3

81.582 Cancer Biology

Course ID: 36654

Course Details: 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.

Max Credits: 3  
Min Credits: 3

81.588 Structural Biology

Course ID: 37679

Course Details: 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.

Max Credits: 3  
Min Credits: 3

81.589 Practical Protein Crystallography

Course ID: 38015

Course Details: 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.

Max Credits: 4
Min Credits: 4

81.590 Human Neurobiology

Course ID: 31890
Course Details: A study of cellular and systems neurobiology with a focus on how these relate to human health and disease. Particular attention will be given to illustrating functional neuroanatomy and neurophysiology of the human CNS using investigations into the pathogenic mechanisms of a variety of human neurodegenerative diseases including epilepsy, Alzheimer's Disease, Huntington's Disease, ALS among others. Note: Graduate level enrollees will be responsible for additional reading and writing.

Max Credits: 3
Min Credits: 3

81.593 Immunology

Course ID: 1231
Course Details: A study of the nature of the immune response with sections on antibody structure, function and production; antigen-antibody reactions; immunogenetics; and immune regulation, protection and injury.

Max Credits: 3
Min Credits: 3

81.601 Graduate Seminar Biology

Course ID: 7573
Course Details: Assists students in developing effective writing and speaking skills required for preparation of research papers, grants and professional presentations. Disclosure and conflict of interest, publishing ethics, publishing censorship/fraud, and electronic collaborations are also reviewed through outside readings.

Max Credits: 3
Min Credits: 3

81.603 Graduate Colloquium Biology

Course ID: 35237
Course Details: Presentations of current topics by visiting scientists and staff. Required of all graduate students.

Max Credits: 1
Min Credits: 1

81.604 Professional Communication in Science and Technology

Course ID: 35820
Course Details: 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.

Max Credits: 3
Min Credits: 3

81.666 Selected Topics in Molecular and Cellular Biology

Course ID: 37198
Course Details: 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.

Max Credits: 3
Min Credits: 3

81.707 Internship Biology

Course ID: 35831

Course Details:

Max Credits: 1
Min Credits: 1

81.708 Graduate Course Review

Course ID: 35575

Course Details: Internship or co-op.

Max Credits: 1
Min Credits: 1

81.721 Special Problems In Biology

Course ID: 7584

Course Details:

Max Credits: 3
Min Credits: 1

81.731 M.S. Project in Biology

Course ID: 7587

Course Details:

Max Credits: 9
Min Credits: 1

81.743 Master's Thesis - Biology

Course ID: 7592

Course Details:

Max Credits: 9
Min Credits: 1

81.753 PhD Dissertation Biochemistry

Course ID: 7597

Course Details:

Max Credits: 9
Min Credits: 3
**84.502 Matter in Context**

Course ID: 30762

Course Details: This is the first course of a two-semester chemistry program that provides teachers with everyday experiences that are directly related to fundamental chemical concepts. As such, it emphasizes the need to make careful observations, collect data, formulate conclusions and make predictions based on those findings. Teachers gain knowledge and skills by observing local chemical phenomena that allow them to then examine more complex chemical systems like global warming, ozone depletion, and the greenhouse effect; air and water quality; ecosystems; environmental factors in evolution and biodiversity; the earth, and the food web. Inherent in this process is an exposure to modeling, both developing and using physical and mathematical models to describe observed chemical phenomena. Teachers will practice inquiry methods, enhance their critical thinking skills and learn to use a variety of technical and laboratory skills to design, perform and interpret experiments.

Max Credits: 3
Min Credits: 3

**84.514 Advanced Analytical Chemistry**

Course ID: 7701

Course Details: 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.

Max Credits: 3
Min Credits: 3

**84.516 Advanced Techniques**

Course ID: 7703

Course Details:

Max Credits: 3
Min Credits: 3

**84.520 Chronatography**

Course ID: 7706

Course Details:

Max Credits: 3
Min Credits: 3

**84.523 Organic Reaction Mechanisms**

Course ID: 7708

Course Details: Provides insight into how reactions occur and how reaction mechanisms are studied. Emphasis is placed on bonding, structure and reactivity. Conformational analysis and stereoelectronic effects, including an introduction to the application of computational chemistry to these subjects.

Max Credits: 3
Min Credits: 3

**84.524 Organic Synthesis**

Course ID: 7709

Course Details: 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.
Max Credits: 3
Min Credits: 3

**84.526 Chromatography**

Course ID: 7711

Course Details: Coverage directed to the performance of packed and capillary column for gas chromatography and HPLC. Modern injection, detector and pumping systems used in chromatography are also discussed.

Max Credits: 3
Min Credits: 3

**84.532 Advanced Physical Chemistry**

Course ID: 7715

Course Details: 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.

Max Credits: 3
Min Credits: 3

**84.538 Biochemical Mechanisms**

Course ID: 7720

Course Details: 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.

Max Credits: 3
Min Credits: 3

**84.543 Modern Inorganic Chemistry**

Course ID: 7722

Course Details: 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.

Max Credits: 3
Min Credits: 3

**84.550 Biochemistry I**

Course ID: 7726

Course Details: 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.

Max Credits: 3
Min Credits: 3

**84.551 Biochemistry II**

Course ID: 7727

Course Details: 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.

Max Credits: 3
Min Credits: 3
84.560 Advanced Physical Biochemistry

Course ID: 7732

Course Details: 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.

Max Credits: 3
Min Credits: 3

84.562 Pharmaceutical Biochemistry

Course ID: 36766

Course Details: 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 (energetus), as well as crystallographic and computational approaches.

Max Credits: 3
Min Credits: 3

84.563 Chemistry Of Natural Products

Course ID: 7733

Course Details: Covers the proof of structure of various types of natural products, approaches to the total synthesis of these products and the biosynthetic pathways.

Max Credits: 3
Min Credits: 3

84.566 Nanomaterials and Nanostructures

Course ID: 37645

Course Details: 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 various methods 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.

Max Credits: 3
Min Credits: 3

84.567 Computational Biochemistry

Course ID: 7735

Course Details: This course will provide an 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 and biophysics of single biomolecules. The course will be useful for senior undergraduates and beginning graduate students. Chem/Bioinformatics 84.567 will attempt to cultivate computational skills, which on needs to tackle current scientific problems of biology and biophysics.

Max Credits: 3
Min Credits: 3
84.568 Structural Analysis

Course ID: 7736

Course Details: 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.

Max Credits: 3  
Min Credits: 3

84.570 Protein Chemistry

Course ID: 7737

Course Details: 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.

Max Credits: 3  
Min Credits: 3

84.580 Bioanalytical Chemistry

Course ID: 7739

Course Details: 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.

Max Credits: 3  
Min Credits: 3

84.601 Chemistry Seminar

Course ID: 7741

Course Details: Required of all graduate students. Presentation of current topics by graduate students.

Max Credits: 2  
Min Credits: 2

84.602 Chemistry Seminar

Course ID: 7742

Course Details: Required of all graduate students. Presentation of current topics by graduate students.

Max Credits: 2  
Min Credits: 2

84.603 Chemistry Colloquium

Course ID: 7743

Course Details: Required of all graduate students. Presentation of current topics by visiting scientists and staff.

Max Credits: 1  
Min Credits: 1

84.604 Chemistry Colloquium

Course ID: 7744
Course Details: Required of all graduate students. Presentation of current topics by visiting scientists and staff.

Max Credits: 1
Min Credits: 1

84.641 Co-Op Internship

Course ID: 35199

Course Details: Practical training for International Students in a Co-operative agreement with Industry or a Government Laboratory for 1 semester.

Max Credits: 1
Min Credits: 0

84.651 Selected Topics: Chemistry

Course ID: 7746

Course Details: 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.

Max Credits: 3
Min Credits: 3

84.652 Selected Topics: Chemistry

Course ID: 7747

Course Details:

Max Credits: 3
Min Credits: 3

84.653 Chemical Oceanography

Course ID: 7748

Course Details:

Max Credits: 3
Min Credits: 3

84.672 Surface and Colloid Chemistry

Course ID: 33615

Course Details: 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.

Max Credits: 3
Min Credits: 3

84.705 Supervised Teaching Ch & Ps

Course ID: 7750

Course Details:

Max Credits: 0
Min Credits: 0

84.731 Graduate Project in Chemistry

Course ID: 35693

Course Details: Continued research project supplementing the research credits for a doctoral student. This course will require special permission from the Graduate Coordinator.

Max Credits: 1
Min Credits: 1

84.741 Master's Thesis - Chemistry

Course ID: 36421

Course Details: Master's Thesis - Chemistry

Max Credits: 1
Min Credits: 1

84.743 Master's Thesis - Chemistry

Course ID: 7754

Course Details:

Max Credits: 3
Min Credits: 3

84.746 Master's Thesis - Chemistry

Course ID: 7755

Course Details:

Max Credits: 6
Min Credits: 6

84.749 Master's Thesis - Chemistry

Course ID: 7756

Course Details:

Max Credits: 9
Min Credits: 9

84.751 Graduate Doctoral Research Credit

Course ID: 35659

Course Details:

Max Credits: 1
Min Credits: 1

84.753 Doctoral Dissertation/Chemistry

Course ID: 7757

Course Details:

Max Credits: 3
84.756 Doctoral Dissertation/Chemistry
Course ID: 7758
Course Details:
Max Credits: 6
Min Credits: 6

84.759 Doctoral Dissertation/Chemistry
Course ID: 7759
Course Details:
Max Credits: 9
Min Credits: 9

84.763 Continued Graduate Research
Course ID: 7760
Course Details:
Max Credits: 3
Min Credits: 3

84.769 Continued Graduate Research
Course ID: 7762
Course Details:
Max Credits: 9
Min Credits: 9

85.501 Boundary Layer Meteorology
Course ID: 7796
Course Details: 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.
Max Credits: 3
Min Credits: 3

85.502 Advanced Synoptic Meteorology
Course ID: 7797
Course Details: 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.
Max Credits: 3
Min Credits: 3

85.503 Remote Sensing
Course ID: 7798
Course Details: 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.

Max Credits: 3
Min Credits: 3

85.508 The Climate System

Course ID: 33556
Course Details: 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 climatic change are considered.

Max Credits: 3
Min Credits: 3

85.510 Regional Weather and Climate Modeling

Course ID: 37957
Course Details: 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.

Max Credits: 3
Min Credits: 3

85.513 Physical Meteorology

Course ID: 34585
Course Details: 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.

Max Credits: 3
Min Credits: 3

85.515 Atmospheric Structure and Dynamics

Course ID: 7801
Course Details: 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.

Max Credits: 3
Min Credits: 3

85.518 Forecasting and Synoptic Techniques I

Course ID: 34590
Course Details: 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.
85.519 Forecasting and Synoptic Techniques II

Course ID: 34914

Course Details: 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 stimulates 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.

Max Credits: 3
Min Credits: 3

85.524 Simple Atmospheric Models

Course ID: 35197

Course Details: 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.

Max Credits: 3
Min Credits: 3

85.529 Advanced Forecasting

Course ID: 34915

Course Details: 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.

Max Credits: 3
Min Credits: 3

85.540 Tropical Meteorology

Course ID: 37879

Course Details: An introduction to the tropical atmosphere, including tropical climatology, structure and dynamics of easterly waves, tropical cyclones and monsoon circulation's.

Max Credits: 3
Min Credits: 3

85.550 Satellite and Rad Meteorology

Course ID: 7803
Course Details:
Max Credits: 3
Min Credits: 3

85.571 Air Pollution Phenomenology

Course ID: 7804
Course Details: 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.

Max Credits: 3
Min Credits: 3

85.581 Meteorology for Teachers

Course ID: 30388

Course Details: 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.

Max Credits: 3
Min Credits: 3

85.591 Directed Study

Course ID: 7808

Course Details:
Max Credits: 3
Min Credits: 3

85.701 Graduate Research Seminar

Course ID: 7813

Course Details:
Max Credits: 1
Min Credits: 1

85.732 Graduate Research

Course ID: 7814

Course Details:
Max Credits: 2
Min Credits: 2

85.733 Master's Research in Atmospheric Sciences

Course ID: 7815

Course Details:
Max Credits: 3
Min Credits: 1

85.743 Master's Thesis in Atmospheric Sciences

Course ID: 7817

Course Details:
Max Credits: 6
Min Credits: 1
85.753 Doctoral Dissertation in Atmospheric Sciences

Course Details:
Max Credits: 8
Min Credits: 3

85.760 Continuing Graduate Research (PhD)

Course Details: Continuing Graduate Research at the PhD level. May be taken for variable credit.
Max Credits: 9
Min Credits: 1

85.761 Continuing Graduate Research (PhD)

Course Details: Research on dissertation or other research areas as required by the program and the student's advisor.
Max Credits: 1
Min Credits: 1

85.763 PhD Research in Atmospheric Sciences

Course Details:
Max Credits: 2
Min Credits: 2

85.765 Doctoral Dissertation

Course Details:
Max Credits: 8
Min Credits: 1

85.768 Doctoral Dissertation

Course Details:
Max Credits: 8
Min Credits: 8

87.504 Geographic Information Systems

Course Details: 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.
Max Credits: 3
87.520 Methods in Environmental Impact Assessment and Analysis

Course ID: 37684

Course Details: 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.

Max Credits: 3
Min Credits: 3

87.572 Energy and Environment

Course ID: 7869

Course Details: 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.

Max Credits: 3
Min Credits: 3

89.501 Paleoclimatology

Course ID: 37512

Course Details: 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.

Max Credits: 3
Min Credits: 3

89.502 Quantitative Geomorphology

Course ID: 37733

Course Details: 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.

Max Credits: 3
Min Credits: 3

89.504 Igneous and Metamorphic Petrology

Course ID: 37892

Course Details: The origin and evolution of igneous and metamorphic rocks. Emphasis will be on physical and chemical processes, magma transport and crystallization, phase equilibria, development of metamorphic facies, open and closed system behavior, and the development of metamorphic fabric.

Max Credits: 3
Min Credits: 3

89.506 Igneous and Metamorphic Petrology Laboratory

Course ID: 37891
Course Details: Identification and classification of igneous and metamorphic rocks. Emphasis is on thin section identification and use of rock textures and compositions as guides to petrogenesis.

Max Credits: 1
Min Credits: 1

89.510 Glacial and Pleistocene Geology

Course ID: 7923
Course Details:
Max Credits: 3
Min Credits: 3

89.520 Structural Geology

Course ID: 37890
Course Details: 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.

Max Credits: 3
Min Credits: 3

89.522 Structural Geology Laboratory

Course ID: 37895
Course Details: A survey of the graphical techniques used to convert field measurement into the information needed in the construction of geologic maps, cross-sections, and crustal stress-strain histories.

Max Credits: 1
Min Credits: 1

89.524 Regional Hydrogeology

Course ID: 7925
Course Details: Concentrating on the storage and steady state flow of ground water at a basin-wide scale, the course studies flow nets, fluid potential, and numerical modeling of flow controlled by basin geometry 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.

Max Credits: 3
Min Credits: 3

89.540 Mass Transit Modeling

Course ID: 7929
Course Details:
Max Credits: 3
Min Credits: 3

89.541 Environmental and Engineering Geology

Course ID: 37928
Course Details: Fundamentals of geology applied to environmental and engineering problems. Topics include minerals and rocks, soil properties, rock mechanics, active tectonics and earthquake hazards, slope stability and landslides, groundwater, rivers and flood hazards, coastal processes, and site assessment. Student project.
89.552 Sedimentation & Stratigraphy

Course ID: 37894

Course Details: Principles and processes of sedimentation: erosion, mechanics of transport, diagenesis and lithification, models for sedimentary environments. Development of the stratigraphic record, relative and absolute time, and seismic stratigraphy.

Max Credits: 3
Min Credits: 3

89.554 Sedimentation and Stratigraphy Laboratory

Course ID: 37893

Course Details: Determination of mass properties of sediments with emphasis on mechanical and statistical analysis, identification and description of sedimentary rocks, facies models and stratigraphic cross-sections.

Max Credits: 1
Min Credits: 1

89.556 Applied Geophysics

Course ID: 37897

Course Details: Application of geophysics to problems in geology and environmental science. Principles and techniques of gravity, magnetic, electrical, and seismic methods. Field projects and surveys.

Max Credits: 3
Min Credits: 3

89.558 Advanced Geochemistry

Course ID: 37896

Course Details: Application of chemical principles to geological and environmental problems. Topics include abundance and distribution of elements in the earth, Crystal chemistry, stable and radiogenic isotopes, radiogenic dating, isotopic and elemental tracers, water-rock interactions.

Max Credits: 3
Min Credits: 3

89.585 Oceanography for Teachers

Course ID: 37519

Course Details: 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.

Max Credits: 3
Min Credits: 3

89.599 Advanced Rocks

Course ID: 7931

Course Details:
Max Credits: 3
Min Credits: 3
89.702 Graduate Seminar Biology

Course ID: 7932
Course Details:
Max Credits: 3
Min Credits: 3

89.731 Master's Research in Environmental Geoscience

Course ID: 37926
Course Details:
Max Credits: 6
Min Credits: 1

89.741 Master's Thesis in Environmental Geoscience

Course ID: 37925
Course Details:
Max Credits: 6
Min Credits: 1

91.500 Fundamental of Computer Science

Course ID: 8132
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.502 Foundations of Computer Science

Course ID: 8134
Course Details: An advanced introduction to theoretical computer science. This course will cover the fundamentals of automata, formal languages, and computability theory.
Max Credits: 3
Min Credits: 3

91.503 Algorithms

Course ID: 8135
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.504 Advanced Algorithms: Computational Geometry
Course ID: 8136
Course Details: Advanced algorithms topics, such as design and analysis of geometric and combinatorial algorithms, computability and complexity.
Max Credits: 3
Min Credits: 3

91.508 Analysis Of Algorithms

Course ID: 8138
Course Details: Topics in algorithm design and analysis; mapping and modeling; issues in complexity, lower bounds; models of parallel computation.
Max Credits: 3
Min Credits: 3

91.510 Computational Complexity Theory

Course ID: 8139
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.513 Internet And Web Systems I

Course ID: 8142
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.514 Internet & Web Systems II

Course ID: 8143
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.515 Operating Systems I

Course ID: 8144
Course Details: 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.
Max Credits: 3
Min Credits: 3
91.516 Operating Systems II

Course ID: 8145

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.520 Digital Storage Architectures

Course ID: 8149

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.522 Object Oriented Analysis

Course ID: 8151

Course Details: Object-oriented techniques for analysis, specification, and design. Static information models and state-based dynamic behavior models applied to rapid prototyping projects that both use and implement object-oriented CASE tools.

Max Credits: 3
Min Credits: 3

91.527 Human Computer Interaction

Course ID: 8155

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.528 Evaluation of Human-Computer Interaction

Course ID: 30391

Course Details: 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.

Max Credits: 3
Min Credits: 3
91.530 Special Topics
Course ID: 8156
Course Details: Topics of mutual interest to the instructor and student(s).
Max Credits: 3
Min Credits: 3

91.531 Design of Program Languages
Course ID: 8157
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.534 Compiler Construction I
Course ID: 8160
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.540 Visual Analytics
Course ID: 8164
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.541 Data Visualization
Course ID: 8165
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.543 Artificial Intelligence
Course ID: 8167
Course Details: Search and games, knowledge representation paradigms, natural language understanding, planning, perception. Use of the LISP language for one or more programming projects.
Max Credits: 3
91.544 Data Mining

Course ID: 8168

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.545 Machine Learning

Course ID: 8169

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.546 Computer Graphics I

Course ID: 8170

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.547 Computer Graphics II

Course ID: 8171

Course Details: Lighting models, photo-realism, animation, constructive solid geometry, and distributed graphics.

Max Credits: 3
Min Credits: 3

91.548 Robot Design

Course ID: 8172

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.550 Topics

Course ID: 8174

Course Details: Topics of mutual interest to the instructor and student(s).

Max Credits: 3
Min Credits: 3
**91.553 Parallel Processing**

Course ID: 8177

Course Details: A survey of parallel computer architectures, parallel programming languages, and parallel algorithms, with emphasis on solving practical problems with parallel computers. A final project, typically a substantial parallel program, is required. Usually offered during the Spring semester.

Max Credits: 3

Min Credits: 3

**91.561 Computer & Network Security I**

Course ID: 8183

Course Details: 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.

Max Credits: 3

Min Credits: 3

**91.563 Data Communications I**

Course ID: 8185

Course Details: 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.

Max Credits: 3

Min Credits: 3

**91.564 Data Communications II**

Course ID: 8186

Course Details: Continuation of 91.563

Max Credits: 3

Min Credits: 3

**91.568 Seminar in Human-Computer Interaction**

Course ID: 8189

Course Details: 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.

Max Credits: 3

Min Credits: 3

**91.570 Topics**

Course ID: 8190

Course Details: Topics of mutual interest to the instructor and student(s).

Max Credits: 3
Min Credits: 3

**91.573 Data Base I**

Course ID: 8192

Course Details: 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.

Max Credits: 3

Min Credits: 3

**91.574 Data Base II**

Course ID: 8193

Course Details: Continuation of Data Base I. Various issues in the implementation of database systems will be covered.

Max Credits: 3

Min Credits: 3

**91.580 Topics in Computer Science**

Course ID: 8194

Course Details: Topics of mutual interest to the instructor and student(s).

Max Credits: 3

Min Credits: 3

**91.592 Special Topics: Computer Science**

Course ID: 8203

Course Details:

Max Credits: 3

Min Credits: 3

**91.593 Cooperative Education**

Course ID: 8204

Course Details:

Max Credits: 1

Min Credits: 0

**91.604 Network Optimization**

Course ID: 35779

Course Details: 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.

Max Credits: 3

Min Credits: 3

**91.613 Advanced Topics in Information Retrieval and Mining**

Course ID: 34993
Course Details: 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.

Max Credits: 3
Min Credits: 3

91.640 Advanced Research Topics in Data Visualization

Course ID: 34857

Course Details: This course will cover modern information visualization research. Student will read and summarize current research and published papers. If a student already has a thesis topic or is already doing research, the student will participate in the development of a proposal for external funding related to their thesis topic or research. If a student does not have a thesis topic, the student will develop their thesis proposal.

Max Credits: 3
Min Credits: 3

91.641 Advanced Topics in Visualization

Course ID: 35415

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.644 Topics in Data Mining

Course ID: 37056

Course Details: 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.

Max Credits: 3
Min Credits: 3

91.650 Advanced Research Topics in Wireless Networks

Course ID: 34770

Course Details: This course will cover state-of-art wireless networking research topics, including communications, management, security, sensors, and mobile applications. Students will read and summarize current research and published papers, and do experimental projects. This course allows subtitle (topics), and students can take this course multiple times with different subtitle (topics). The subtitle (topic) of this course is to be determined when the course is offered.

Max Credits: 3
Min Credits: 3

91.661 Advanced Topics in Network Security

Course ID: 34625

Course Details: 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.

Max Credits: 3
Min Credits: 3
91.673 Advanced Database Systems
Course ID: 35041
Course Details: 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.
Max Credits: 3
Min Credits: 3

91.691 International Finance
Course ID: 8211
Course Details:
Max Credits: 3
Min Credits: 3

91.701 Computer Science Research
Course ID: 8212
Course Details:
Max Credits: 3
Min Credits: 3

91.702 Computer Science Research
Course ID: 8213
Course Details:
Max Credits: 6
Min Credits: 6

91.703 Computer Science Research
Course ID: 8214
Course Details:
Max Credits: 3
Min Credits: 3

91.706 Directed Research
Course ID: 8217
Course Details:
Max Credits: 6
Min Credits: 6

91.710 Approximation Algorithms
Course ID: 36940
Course Details: 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.
91.711 Combinatorial Optimization
Course ID: 36941
Course Details: This covers advanced topics in computational combinatorial optimization. Topics will be drawn from practical applications in various areas, including wireless sensor networks, different types of complex networks, online social networks, bioinformatics, and computational medicine.
Max Credits: 3
Min Credits: 3

91.741 Thesis Review
Course ID: 35269
Course Details:
Max Credits: 1
Min Credits: 1

91.743 Master's Thesis - Computer Science
Course ID: 8223
Course Details:
Max Credits: 3
Min Credits: 3

91.746 Master's Thesis - Computer Science
Course ID: 8226
Course Details:
Max Credits: 6
Min Credits: 6

91.749 Master's Thesis - Computer Science
Course ID: 8227
Course Details:
Max Credits: 9
Min Credits: 9

91.751 Doctoral Thesis Research
Course ID: 8228
Course Details:
Max Credits: 3
Min Credits: 1

91.753 Doctoral Dissertation/Computer Science
Course ID: 8229
91.756 Doctoral Dissertation/Computer Science

Course Details:
Max Credits: 3
Min Credits: 3

Course ID: 8231

91.757 Doctoral Thesis Research

Course Details:
Max Credits: 6
Min Credits: 6

Course ID: 8232

91.759 Doctoral Dissertation/Computer Science

Course Details:
Max Credits: 12
Min Credits: 12

Course ID: 8233

91.769 Continued Graduate Research

Course Details:
Max Credits: 9
Min Credits: 9

Course ID: 8236

92.500 Discrete Structures

Course Details: 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.

Max Credits: 3
Min Credits: 3

Course ID: 8402

92.501 Real Analysis

Course Details: 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.

Max Credits: 3
Min Credits: 3

Course ID: 8403
92.503 Mathematical Analysis

Course ID: 8405

Course Details: Development of number systems, including axiomatic and constructive treatment of the integers and the reals; sequences and series; functions of a real variable and their properties, including continuity, derivatives and integrals; functions of several real variables, including partial derivatives and multiple integration; differential equations and applications; metric spaces. Masters degree credit for the Teacher Option only.

Max Credits: 3
Min Credits: 3

92.507 Applied Functional Analysis I

Course ID: 8408


Max Credits: 3
Min Credits: 3

92.509 Probability and Mathematical Statistics

Course ID: 8409

Course Details: 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.

Max Credits: 3
Min Credits: 3

92.510 Computers and Calculators in Classroom

Course ID: 8410

Course Details: 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.

Max Credits: 3
Min Credits: 3

92.511 Complex Variables I

Course ID: 1227

Course Details: Discusses complex numbers, functions of a complex variable, mappings, derivatives, analytic functions, elementary functions. Laurent series, residues and poles, contour integration.

Max Credits: 3
Min Credits: 3

92.513 Number Theory

Course ID: 8412

Course Details: Study of primes, congruences, number-theoretic functions, Diophantine approximation, quadratic forms and quadratic number fields. Additional topics as time permits.

Max Credits: 3
92.519 Introduction to Probability and Statistics II

Course ID: 30831

Course Details: The course combines theory with applications and covers both fundamental topics in statistical inference and their applications in data analysis. Discussions of the theoretical topics of statistical estimation and hypotheses testing will be complemented by analyzing simulated and real data sets. The course is taught at the computer lab equipped with MINITAB, SAS and other packages. Students will learn how statistical theory helps using statistical software, how to choose the right tool for the problem at hand and how to interpret the output. Topics to be covered include point and interval estimation, hypotheses testing, maximum likelihood estimation, likelihood ratio and related tests, applications of statistical inference to commonly used statistical models, such as one-sample, two-sample and many-sample (ANOVA) models, linear regression models, goodness-of-fit tests and contingency tables, and elements of statistical quality control and experimental design. Time permitting, topics in nonparametric and robust statistics will also be covered. Pre-requisite: 92.386, 92.509 or equivalent.

Max Credits: 3
Min Credits: 3

92.520 Mathematical Problem Solving

Course ID: 1226

Course Details: Focuses on: mathematical resources, ability to use heuristics, the student's beliefs about the use of mathematics to solve problems, and the student's self-confidence as a problem solver. Effective strategies for incorporating problem solving in the curriculum will also be discussed.

Max Credits: 3
Min Credits: 3

92.521 Abstract Algebra I

Course ID: 1225

Course Details: Elementary group theory, groups, cosets, normal subgroups, quotient groups, isomorphisms, homomorphisms, applications.

Max Credits: 3
Min Credits: 3

92.523 Linear Algebra

Course ID: 8418

Course Details: Sets and maps, vector spaces and linear maps, matrix of linear maps, solving systems of equations, scalar products and orthogonality, eigenvalues and applications. Masters degree credit for Teachers Option Only.

Max Credits: 3
Min Credits: 3

92.526 Topology

Course ID: 33480

Course Details: Metric spaces, topological spaces, connectedness, compactness, the fundamental group, classifications of surfaces, Brouwer's fixed point theorem.

Max Credits: 3
Min Credits: 3

92.527 Geometry

Course ID: 1224

Course Details: This course is designed for current and prospective geometry teachers. In addition to the development of Euclidean
geometry, students will become familiar with geometry applications in Geometer’s Sketchpad software, and to a lesser degree with other geometry software applications including Geogebra, Cabri, Maple and/or Mathematica. There will be an introduction to spherical and hyperbolic geometry and triangle measurements will be computed for each. Calculus based derivations of area and volume for surfaces and solids will be generated and related to Euclidean geometry topics.

Max Credits: 3
Min Credits: 3

92.529 Differential Geometry

Course ID: 8421

Course Details: Differential geometry involving curves and surfaces in 3-space. Curvature, torsion, Frenet equations, intrinsic equations, involutes and evolutes.

Max Credits: 3
Min Credits: 3

92.530 Applied Mathematics I

Course ID: 8422

Course Details: Ordinary and partial differential equations; Fourier series and Fourier integrals; Laplace transform; matrix theory.

Max Credits: 3
Min Credits: 3

92.531 Applied Mathematics II

Course ID: 8423

Course Details: Vector analysis and vector calculus; Gauss, Green, and Stokes theorems; complex analysis; calculus of variations; special functions; orthogonal functions.

Max Credits: 3
Min Credits: 3

92.532 Advanced Geometry

Course ID: 38483

Course Details: Historical perspectives: Euclid’s synthetic geometry, Descartes’ analytic geometry, attempts to prove parallel postulate, emergence of non-Euclidean geometry’s, axiomatic development of geometry, Klein’s Erlanger Programm; projective, affine, and metric geometries; non-Euclidean geometry’s; foundations of geometry; algebraic geometry; finite geometry. Requires knowledge of linear algebra, abstract algebra for groups and fields including Galois fields, some familiarity with propositions and set-theoretic topology as covered in a course on Discrete Mathematics.

Max Credits: 3
Min Credits: 3

92.535 History of Mathematics

Course ID: 1223

Course Details: Examines ancient numeral systems, Babylonian and Egyptian mathematics, Pythagorean mathematics, duplication, trisection, and quadrature, Euclid’s elements and Greek mathematics after Euclid, Hindu and Arabian mathematics, European mathematics from 500 to 1600, origins of modern mathematics, analytic geometry, the history of calculus. Also covers the transition to the twentieth century and contemporary perspectives.

Max Credits: 3
Min Credits: 3

92.548 Mathematics Of Signal Processing

Course ID: 8430
Course Details: Representation of signals: Fourier analysis, fast Fourier transforms, orthogonal expansions. Transformation of signals: linear filters, modulation; band-limited signals; sampling; uncertainty principle; Windows and extrapolation.

Max Credits: 3
Min Credits: 3

92.550 Mathematical Modeling

Course ID: 8431

Course Details: 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.

Max Credits: 3
Min Credits: 3

92.551 Calculus of Variations

Course ID: 8432


Max Credits: 3
Min Credits: 3

92.552 Wavelet Analysis

Course ID: 8433

Course Details: Introduction to time-frequency localization of signals; frames; windowed Fourier transforms; continuous and discrete wavelet transforms; time frequency sampling theorems; orthonormal bases of wavelets; algebraic wavelet theory; applications to electrodynamics and optics.

Max Credits: 3
Min Credits: 3

92.555 Applied Math for Life Scientists

Course ID: 8436

Course Details: 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).

Max Credits: 3
Min Credits: 3

92.563 Computational Mathematics

Course ID: 8439


Max Credits: 3
Min Credits: 3

92.564 Applied Linear Algebra

Course ID: 8440
Course Details: Use of iterative algorithms to find exact or approximate constrained solutions to large, and often spares, 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.

Max Credits: 3
Min Credits: 3

**92.568 Approximation Theory**

Course ID: 31893

Max Credits: 3
Min Credits: 3

**92.570 Probability and Statistics**

Course ID: 8444

Course Details: Overview of descriptive statistics, data analysis, probability of events, discrete random variables, continuous random variables, normal, binomial and other probability distributions, central limit theorem, survey sampling, estimation, hypothesis testing, regression, experimental design, analysis of categorical data, nonparametric statistics. Masters degree credit for Teachers Option Only.

Max Credits: 3
Min Credits: 3

**92.572 Optimization**

Course ID: 8446

Course Details: 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.

Max Credits: 3
Min Credits: 3

**92.576 Statistical Programming using SAS**

Course ID: 8449

Course Details: 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.

Max Credits: 3
Min Credits: 3

**92.578 Statistical Inference and Data Mining**

Course ID: 31943

Course Details: Topics in nonasymptotic direct computational methods for statistical inference in data mining. Background in probability and statistics required.

Max Credits: 3
Min Credits: 3

**92.582 Time Series Analysis**

Course ID: 8454

Course Details: Building models for discrete time series and dynamic systems and their use in forecasting and control. Stationary and
non-stationary time series models. Box-Jenkins (ARMA) and other techniques.

Max Credits: 3
Min Credits: 3

92.584 Stochastic Process

Course ID: 8456

Course Details: Markov chains and processes, random walks, stationary, independent increments, and Poisson processes. Ergodicity. Examples (e.g., diffusion, queuing theory, etc.).

Max Credits: 3
Min Credits: 3

92.587 Probability Theory

Course ID: 8459

Course Details: This is a course in mathematical probability that gives rigorous proofs to various limit theorems in probability (zero-one laws, laws of large numbers, central limit theorems) that, in particular, constitute a basis for most of the statistical techniques. Tentative topics are: Sigma-algebras of random events, probability measures; Random variables and their distributions, moments; Independent events and sigma-algebras, independent random variables; infinite products of probability spaces; Zero-One Laws and Laws of Large Numbers; Characteristic functions and their properties; Weak convergence of measures and central Limit Theorem; Radon-Nikodim theorem and conditional expectations. Prerequisites: 92.502 Measure and Integration or equivalent

Max Credits: 3
Min Credits: 3

92.588 Mathematical Statistics

Course ID: 8460

Course Details: Random variables, densities, joint and conditional distributions, expectations, variance, estimation, sufficiency and completeness, hypothesis testing, limiting distributions.

Max Credits: 3
Min Credits: 3

92.591 Linear Statistics Modeling and Regression

Course ID: 8463


Max Credits: 3
Min Credits: 3

92.592 Multivariate Statistics

Course ID: 8464

Course Details: 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.

Max Credits: 3
Min Credits: 3

92.593 Experimental Design

Course ID: 8465

Course Details: How to design, carry out, and analyze experiments. Randomized block designs, randomization, blocking, matching,
analysis of variance and covariance, control of extraneous variables.

Max Credits: 3
Min Credits: 3

**92.651 Selected Topics in Mathematics**

Course ID: 8467

Course Details: Intended to satisfy individual student needs. Topics include various fields of mathematics.

Max Credits: 3
Min Credits: 3

**92.653 Selected Topics**

Course ID: 8469

Course Details: 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.

Max Credits: 3
Min Credits: 3

**92.742 Thesis Review**

Course ID: 35257

Course Details:

Max Credits: 1
Min Credits: 1

**92.965 Introduction To Pascal**

Course ID: 11633

Course Details:

Max Credits: 3
Min Credits: 3

**94.511 Network and Systems Administration**

Course ID: 35873

Course Details: 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.

Max Credits: 3
Min Credits: 3

**94.514 Systems Security and Auditing**

Course ID: 37843

Course Details: This course examines the strategies for deploying and auditing secure systems. IT auditors primarily study computer systems and networks form the point of vies 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 situations objectively., Make informed, if difficult decisions., Implement corrective actions, changes and improvements where needed.

Max Credits: 3
**94.517 Operating Systems Foundations**

Course ID: 35776

Course Details: 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 behaviour 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.

Max Credits: 3

Min Credits: 3

**94.518 Large Scale application Deployment**

Course ID: 35874

Course Details: This course will develop a systematic framework for the lifecycle 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.

Max Credits: 3

Min Credits: 3

**94.519 Virtual Systems**

Course ID: 35875

Course Details: 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. Paravirtualized 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.

Max Credits: 3

Min Credits: 3

**94.531 Project Management**

Course ID: 37828

Course Details: 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 outsourcing. Practical examples will be used to demonstrate the concepts and techniques, plus you will receive hands on experience by working on a case study.

Max Credits: 3

Min Credits: 3

**94.532 Managing and Mining Large Data Sets**

Course ID: 37827

Course Details: 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).

Max Credits: 3
Min Credits: 3

94.535 Agile and Iterative Project Management

Course ID: 38319

Course Details: 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 stakeholders, and recognize the key success criteria for implementing Agile Projects.

Max Credits: 3
Min Credits: 3

94.541 Information Security, Privacy and Regulatory Compliance

Course ID: 37842

Course Details: This course focuses on enterprise-level information security risk management, audit, and regulatory compliance, and
on developing the skills required for creating a new culture of information management compliance (IMC) by incorporating and IMS
philosophy into a corporate governance structure. Expert advice and insight reveals the proven methodology that adopts the principles,
controls, and discipline upon which many corporate compliance programs are built and explains how to apply this methodology to
develop and implement IMC programs that anticipate problems and take advantage of opportunities. You'll learn how to measure
information management compliance through the use of auditing and monitoring, following the proper delegation of program roles and
components, and creating a culture of information management awareness.

Max Credits: 3
Min Credits: 3

94.543 Intrusion Detection Systems

Course ID: 37841

Course Details: 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.

Max Credits: 3
Min Credits: 3

94.560 Network Infrastructures

Course ID: 35876

Course Details: 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.

Max Credits: 3
Min Credits: 3

94.561 Computer Network Security

Course ID: 35785
Course Details: 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.

Max Credits: 3
Min Credits: 3

94.562 Digital Forensics
Course ID: 35877

Course Details: 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.

Max Credits: 3
Min Credits: 3

94.563 Secure Mobile Networks
Course ID: 35878

Course Details: 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, securing 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.

Max Credits: 3
Min Credits: 3

94.565 Cloud Computing
Course ID: 37437

Course Details: 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 ecommerce applications. Designing systems as web services. Principles of cloud computing using examples from open-source and commercial applications.

Max Credits: 3
Min Credits: 3

94.566 Advanced Cloud Computing
Course ID: 38140

Course Details: 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.

Max Credits: 3
Min Credits: 3

95.501 Energy, Force and Motion
Course ID: 30760
Course Details: 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.

Max Credits: 3
Min Credits: 3

95.513 Mechanics

Course ID: 1221


Max Credits: 3
Min Credits: 3

95.521 Statistical Thermodynamics

Course ID: 1220

Course Details: 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)

Max Credits: 3
Min Credits: 3

95.535 Introductory Quantum Mechanics I

Course ID: 1219

Course Details: De Broglie waves, the Schroedinger equation, wave functions, wave packets, Heisenberg uncertainty principle, expectation values, particle in a box, the simple harmonic oscillator, free particles, step barrier, barrier penetration, square well potential, time independent perturbation theory. (offered as 95.535 for graduate credit)

Max Credits: 3
Min Credits: 3

95.536 Introductory Quantum Mechanics II

Course ID: 8589

Course Details: 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.

Max Credits: 3
Min Credits: 3

95.538 Physical Optics and Waves

Course ID: 8591

Course Details: Wave nature of light, mathematics of wave motion, electro-magnetic 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.

Max Credits: 3
Min Credits: 3

95.539 Electro-Optics
Course ID: 1218

Course Details: 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)

Max Credits: 3
Min Credits: 3

95.540 Image Processing

Course ID: 8592

Course Details: Basic physics of television and other imaging systems: representation and manipulation of images in digital form; Fourier analysis and filtering of images: detection of image features such as edges and regions, pattern recognition, three-dimensional visual perception in man and machine, examples of image processing tasks from such areas as medicine, industrial inspection and robotics. Ability to program a computer is required.

Max Credits: 3
Min Credits: 3

95.547 Laser Physics and Applications

Course ID: 1217

Course Details: Spontaneous and stimulated emission line broadening processing, rate equations, laser oscillation condition, spectral output of lasers. Gaussian beam propagation and resonator design parameters. Key features of ultraviolet through far infrared laser systems. Application to spectroscopy, radar, welding. (offered as 95.547 for graduate credit)

Max Credits: 3
Min Credits: 3

95.552 Contemporary Physics

Course ID: 8593

Course Details:
Max Credits: 3
Min Credits: 3

95.553 Electromagnetism I

Course ID: 1216

Course Details: The theory of electromagnetic fields using vector analysis: electrostatic fields and potentials in vacuum, conductors, and dielectric media, magnetic effects of steady currents in nonmagnetic media, magnetic induction and time varying currents and fields. (offered as 95.553 for graduate credit)

Max Credits: 3
Min Credits: 3

95.554 Electromagnetism II

Course ID: 1215

Course Details: Magnetic materials, electric multipoles, solutions to Laplace’s equation, boundary conditions, image charge problems, Maxwell's equations; propagation of electromagnetic waves in vacuum, conductors and dielectrics; reflection and refraction of electromagnetic waves; radiation from dipoles and antennas. (offered as 95.554 for graduate credit).

Max Credits: 3
Min Credits: 3
**95.555 Introduction to Space Physics**

Course ID: 33625

Course Details: 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 physics 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.

Max Credits: 3
Min Credits: 3

**95.557 Electromagnetic Theory I**

Course ID: 8594

Course Details:

Max Credits: 4
Min Credits: 4

**95.561 Nuclear Physics I**

Course ID: 1214

Course Details: Nuclear properties including size, mass, binding energy, electromagnetic moments, parity and statistics; nuclear shell model, collective structure, deformed shell model, radioactive decay law and the Bateman equations, radioactive dating, counting statistics, energy resolution, coincidence measurements and time resolution, lifetime measurements; nuclear barrier penetration; angular momentum, Coulomb barrier, alpha decay and systematics, fission. (offered as 95.561 for graduate credit).

Max Credits: 3
Min Credits: 3

**95.572 Solid State Physics**

Course ID: 1213

Course Details: Crystal structures, x-ray diffraction, crystal binding, lattice vibrations, free electron and band models of metals. (offered as 95.572 for graduate credit).

Max Credits: 3
Min Credits: 3

**95.577 Solid State Electronic and Optoelectronic Devices**

Course ID: 1212

Course Details: This course is an introduction to solid state electronic and optoelectronic devices for undergraduate science students (i.e. biology, chemistry, mechanical engineering, electrical engineering, physics, etc.) graduate students just entering a scientific endeavor which utilizes solid state devices, and practical engineers and scientists whose understanding of modern electronics and optoelectronics needs updating. The course is organized to bring students with a background in sophomore physics to a level of understanding which will allow them to read much of the current literature on new devices and applications. The course will cover fundamental crystal properties, atoms and electrons, energy bands and charge carriers, excess carriers, junctions and p-n junction diodes (includes photodiodes and light-emitting diodes). Three or four practical demonstrations will also be performed with the analysis of the generated data assigned as homework. (offered as 95.577 for graduate credit)

Max Credits: 3
Min Credits: 3

**95.578 Integrated Optics: Wave Guides and Lasers**

Course ID: 1211

Course Details: 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)

Max Credits: 3
Min Credits: 3

95.583 Astronomy and Astrophysics I

Course ID: 8599

Course Details: 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.

Max Credits: 3
Min Credits: 3

95.587 Cloud Physics

Course ID: 38461

Course Details: 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.

Max Credits: 3
Min Credits: 3

95.605 Mathematical Methods of Physics I

Course ID: 8606

Course Details: Vector analysis; matrices and determinants; theory of analytical functions; differential equations, Fourier series, Laplace transforms, distributions, Fourier transforms.

Max Credits: 3
Min Credits: 3

95.606 Mathematical Methods of Physics II

Course ID: 8607

Course Details: Partial differential equations, boundary value problems, and special functions; linear vector spaces; Green's functions; selected additional topics; numerical analysis.

Max Credits: 3
Min Credits: 3

95.611 Classical Mechanics

Course ID: 8611

Course Details: Knowledge of Lagrangian mechanics assumed. Central force problem, scattering, rigid-body mechanics, normal modes and special relativity. Hamiltonian dynamics, canonical transformations, Hamilton-Jacobi theory and action-angle variables. Continuous systems and fields. Simplectic formulation, stochastic processes, and chaos theory.

Max Credits: 3
Min Credits: 3

95.615 Quantum Mechanics I

Course ID: 8613

Course Details: The representation of quantum states as abstract vectors, Superposition of states, Quantum operators and their matrix representations, Angular momentum operator as the generator of rotations. Eigenvalues and eigenstates of angular momentum. The uncertainty principle. Spin one-half and spin one as examples. Addition of angular momentum. The Hamiltonian operator and the
Schrodinger equation. One dimensional examples. The momentum operator, eigenstates of position. Operator solution of the harmonic
oscillator. IQM I
The representation of quantum states as abstract vectors. Superposition of states. Quantum
operators and their matrix representations. Angular momentum operator as the generator of rotations. Eigenvalues and eigenstates of
angular momentum. The uncertainty principle. Spin one-half and spin one as examples. Addition of angular momentum. The Hamiltonian
operator and the Schrodinger equation. One dimensional examples. The momentum operator, eigenstates of position. Operator solution
of the harmonic oscillator.

Max Credits: 3
Min Credits: 3

95.616 Quantum Mechanics II

Course ID: 8614

Course Details: Quantum mechanics in three dimensions. translational and rotational invariance and conservation of linear and angular
momentum, center-of-mass coordinates. Position-space representation of the angular momentum operator, orbital angular momentum
eigenfunctions. Bond states of central potentials, including the Coulomb potential and the hydrogen atom. Approximation methods:
time-independent perturbations, applications to the Stark effect, the Zeeman effect, spin-orbit coupling in hydrogen. The variational
interactions: emission and absorption of radiation.

Max Credits: 3
Min Credits: 3

95.617 Advanced Quantum Mechanics I

Course ID: 8615

Course Details: 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++e- l++ l - (2) e++e- e++e- (3) Compton scattering and (4) scattering of
electrons by an external e.m. field.

Max Credits: 3
Min Credits: 3

95.631 Nonlinear Optics

Course ID: 8617

Course Details: 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; Photorefractivity; Nonlinear optical devices.

Max Credits: 3
Min Credits: 3

95.657 Electromagnetic Theory I

Course ID: 8625

Course Details: 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.

Max Credits: 3
Min Credits: 3

95.658 Electromagnetic Theory II

Course ID: 8626
Course Details: Electrostatics and magnetostatics with special attention to boundary value problems. Quasistatic fields and displacement currents. Maxwell's equations, special relativity, waveguides, scattering, radiation from accelerated charges; propagation in material media and plasmas, Kramers-Kronig relations.

Max Credits: 3
Min Credits: 3

95.662 Nuclear Physics II

Course ID: 8629

Course Details: The nucleon-nucleon force; nuclear models; nuclear reaction theory and partial wave analysis of scattering; fast neutron physics.

Max Credits: 3
Min Credits: 3

95.665 Space Physics

Course ID: 37731

Course Details: 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.

Max Credits: 3
Min Credits: 3

95.701 Physics Colloquium

Course ID: 8632

Course Details: A series of invited lectures on current research topics in Physics.

Max Credits: 1
Min Credits: 0

95.702 Physics Colloquium

Course ID: 8633

Course Details: A series of invited lectures on current research topics in Physics.

Max Credits: 1
Min Credits: 0

95.704 Seminar in Nuclear Physics

Course ID: 8635

Course Details: involve presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles.

Max Credits: 1
Min Credits: 0

95.705 Seminar in Solid State/Optics

Course ID: 8636

Course Details: involve presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles.
95.706 Seminar in Solid State/Optics

Course ID: 8637

Course Details: involve presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles.

Max Credits: 1
Min Credits: 0

95.709 Seminar in Accelerator Physics

Course ID: 8640

Course Details: 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.

Max Credits: 1
Min Credits: 0

95.710 Seminar in Experimental Optics

Course ID: 8641

Course Details: A weekly series of presentations and discussions concerning experimental optics research in the University of Massachusetts Lowell Department of Physics and Applied Physics.

Max Credits: 1
Min Credits: 0

95.711 Graduate Seminar in Physics

Course ID: 8642

Course Details: Presentations by students of progress in their research projects.

Max Credits: 1
Min Credits: 0

95.712 Graduate Seminar in Physics

Course ID: 8643

Course Details: Presentations by students of progress in their research projects.

Max Credits: 1
Min Credits: 0

95.713 Seminar in Theoretical Research

Course ID: 8644

Course Details:

Max Credits: 1
Min Credits: 0

95.714 Seminar in Experimental Research
95.715 Seminar in Terahertz Technology

Course ID: 33227

Course Details: Course involves presentations by students, faculty members, and visiting scientists of advanced topics, original research for journal articles relevant to technologies at terahertz frequencies.

Max Credits: 1
Min Credits: 0

95.716 Seminar in Biomedical Optics

Course ID: 36767

Course Details: 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.

Max Credits: 1
Min Credits: 0

95.717 Seminar in Heavy Ion Physics

Course ID: 33691

Course Details: Involves presentations by students, faculty members, and research scientists on advanced topics in heavy-ion spectroscopy, including both original research and journal articles.

Max Credits: 1
Min Credits: 0

95.718 Seminar in Space Physics

Course ID: 37671

Course Details: 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.

Max Credits: 1
Min Credits: 0

95.719 Seminar in Nanoscale Physics and Technology

Course ID: 8647

Course Details: 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.

Max Credits: 1
Min Credits: 0

95.721 Selected Topics in Physics
Course ID: 8648

Course Details: 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.

Max Credits: 3
Min Credits: 3

**95.723 Selected Topics in Nuclear Physics**

Course ID: 8650

Course Details: 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.

Max Credits: 3
Min Credits: 3

**95.725 Selected Topics in Solid State**

Course ID: 8652

Course Details: 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.

Max Credits: 3
Min Credits: 3

**95.727 Selected Topics in Theoretical Physics**

Course ID: 8654

Course Details: 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.

Max Credits: 3
Min Credits: 3

**95.771 Physics Systems Analysis I**

Course ID: 8663

Course Details:
Max Credits: 3
Min Credits: 3

**95.772 Physics Systems Analysis II**

Course ID: 8664

Course Details:
Max Credits: 3
Min Credits: 3

**95.773 Physics Systems Analysis III**

Course ID: 8665
Course Details: Max Credits: 3
Min Credits: 3

96.545 Characterization of Materials

Course ID: 35486
Course Details: A one-semester course designed to teach the student several of the important techniques for characterizing the structural, optical, and electronic properties of materials. Experiments will include x-ray diffractometry, hardness measurements, ellipsometry, visible and near infrared spectroscopy, far infrared spectroscopy, and raman spectroscopy.
Max Credits: 2
Min Credits: 2

96.567 Automation Techniques

Course ID: 8724
Course Details:
Max Credits: 3
Min Credits: 3

96.593 Graduate Physics Laboratory

Course ID: 8726
Course Details: Experiments in various branches of physics including optics, atomic physics, solid state physics and nuclear physics.
Max Credits: 2
Min Credits: 2

96.705 Supervised Teaching - Physics

Course ID: 8728
Course Details:
Max Credits: 0
Min Credits: 0

96.716 Special Problems In Physics

Course ID: 8732
Course Details: 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.
Max Credits: 9
Min Credits: 1

96.731 Advanced Projects In Physics I

Course ID: 8734
Course Details: Research project leading to the Graduate Research Admission Examination (for Ph.D. candidates only.)
Max Credits: 3
Min Credits: 3
96.732 Advanced Projects In Physics II
Course ID: 8735
Course Details: Research project leading to the Graduate Research Admission Examination (for Ph.D. candidates only.)
Max Credits: 3
Min Credits: 3

96.733 Graduate Project - Physics
Course ID: 8736
Course Details:
Max Credits: 3
Min Credits: 3

96.746 Master's Thesis Research Physics
Course ID: 8742
Course Details:
Max Credits: 9
Min Credits: 1

96.756 Doctoral Dissertation/Physics
Course ID: 8747
Course Details: Note: Courses with 98 prefix are described in the Radiological Sciences and Protection section of this catalog.
Max Credits: 9
Min Credits: 1

96.800 Cooperative Education in Physics
Course ID: 35615
Course Details: Cooperative Education in Physics
Max Credits: 1
Min Credits: 0

97.503 Polymer Science I
Course ID: 8752
Course Details: 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.
Max Credits: 3
Min Credits: 3

97.504 Polymer Science II
Course ID: 8753
Course Details: 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.
Max Credits: 3
Min Credits: 3

97.511 Biopolymers

Course ID: 8756

Course Details: 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, polysaccarides and polynucleotides, and examination of relationships between synthetic polymers and naturally occurring polymers.

Max Credits: 3
Min Credits: 3

97.553 Macromolecules Organic Chemistry

Course ID: 8759

Course Details: An advanced study in polymer science concerned with the synthesis of macromolecules and their mechanisms of formation.

Max Credits: 3
Min Credits: 3

97.601 Polymer Science Seminar

Course ID: 8760

Course Details: Required of all Polymer Science graduate students. Presentation of current topics in polymer science by graduate students.

Max Credits: 2
Min Credits: 2

97.602 Seminar in Polymer Science

Course ID: 8761

Course Details: Required of all Polymer Science graduate students. Presentation of current topics in polymer science by graduate students.

Max Credits: 2
Min Credits: 2

97.603 Polymer Science Colloquium

Course ID: 8762

Course Details: Required of all Polymer Science graduate students. Presentation of current topics in polymer science by visiting scientists and staff.

Max Credits: 1
Min Credits: 1

97.604 Polymer Science Colloquium

Course ID: 8763

Course Details: Required of all Polymer Science graduate students. Presentation of current topics in polymer science by visiting scientists and staff.

Max Credits: 1
Min Credits: 1
97.649 Introduction to Conjugated Polymers

Course ID: 8764

Course Details: 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.

Max Credits: 3
Min Credits: 3

97.705 Supervised Teaching in Polymer Science

Course ID: 8767

Course Details: 

Max Credits: 0
Min Credits: 0

97.743 Master's Thesis in Polymer Science

Course ID: 8771

Course Details: 

Max Credits: 3
Min Credits: 3

97.746 Master's Thesis in Polymer Science

Course ID: 8772

Course Details: 

Max Credits: 6
Min Credits: 6

97.749 Master's Thesis in Polymer Science

Course ID: 8773

Course Details: 

Max Credits: 9
Min Credits: 9

97.751 Thesis Review

Course ID: 35642

Course Details: This is a one credit thesis review course.

Max Credits: 1
Min Credits: 1

97.753 Doctoral Dissertation in Polymer Science

Course ID: 8774

Course Details:
Max Credits: 3
Min Credits: 3

97.756 Doctoral Dissertation in Polymer Science

Course ID: 8775
Course Details:
Max Credits: 6
Min Credits: 6

97.759 Doctoral Dissertation in Polymer Science

Course ID: 8776
Course Details:
Max Credits: 9
Min Credits: 1

97.769 Continued Graduate Research

Course ID: 8779
Course Details:
Max Credits: 9
Min Credits: 9

98.500 Introduction to Radiological Sciences

Course ID: 36770
Course Details: This course is designed to introduce students to the working practices encountered in the health physics and medical physics profession. This is accomplished through field trips to local facilities that use radioactive materials, use and calibrations of radiological instrumentation, laboratory exercises, and class discussions. This class exposes the student to basic health and medical physics procedures, vocabulary, and equipment.
Max Credits: 3
Min Credits: 3

98.501 Radiation Safety and Control I

Course ID: 1209
Course Details: 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.
Max Credits: 4
Min Credits: 3

98.502 Radiation Safety and Control II

Course ID: 8802
Course Details: 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.
Max Credits: 4
98.506 Nuclear Instrumentation

Course ID: 8806

Course Details: 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.

Max Credits: 4
Min Credits: 3

98.509 Nuclear Instrumentation

Course ID: 37351

Course Details: 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).

Max Credits: 3
Min Credits: 3

98.522 Environmental Radiation and Nuclear Site Criteria

Course ID: 8815

Course Details: This course provides an overview of the sources, distribution, environmental transport, dose projections, and environmental impact of radiations associated with the nuclear fuel cycle.

Max Credits: 3
Min Credits: 3

98.523 Air Resource Management

Course ID: 8816

Course Details:

Max Credits: 3
Min Credits: 3

98.524 Environmental Health Physics

Course ID: 37592

Course Details: 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.

Max Credits: 3
Min Credits: 3

98.533 External Dosimetry and Shielding

Course ID: 8822
Course Details: 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.

Max Credits: 3
Min Credits: 3

98.534 Internal Dosimetry and Bioassay

Course Details:

Max Credits: 3
Min Credits: 3

98.541 Radiochemistry

Course Details: 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 radio-immunoassay.

Max Credits: 3
Min Credits: 3

98.562 Radiation Biology

Course Details: 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. (offered as 98.562 for graduate credit)

Max Credits: 3
Min Credits: 3

98.565 Introduction to Radiation Therapy Physics

Course Details: 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.

Max Credits: 3
Min Credits: 3

98.575 Certification Preparation in Radiological Sciences

Course Details: Advanced problem solving in radiological sciences including strategies for preparing for and taking professional certification examinations.

Max Credits: 3
Min Credits: 3
98.581 Mathematical Methods of Radiological Sciences

Course ID: 1207

Course Details: This course provides an overview of applied mathematical concepts that are useful in radiological sciences and protection, including special techniques for radiation physics, radiation dosimetry, and radiation shielding, with emphasis on computer applications.

Max Credits: 3
Min Credits: 3

98.582 Numerical Methods In Radiological Sciences

Course ID: 8836

Course Details: 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.

Max Credits: 3
Min Credits: 3

98.598 Introduction to Medical Imaging

Course ID: 36752

Course Details: Key topics of modern medical imaging: principles of medical imaging, image formation, Fourier analysis, image reconstruction, digital image processing with applications in computed tomography, radioisotope imaging, magnetic resonance imaging, positron emission tomography, ultrasound imaging, and optical imaging. Strengths and limitations of imaging modalities.

Max Credits: 3
Min Credits: 3

98.599 Advanced Medical Imaging

Course ID: 37216

Course Details: Advanced Medical Imaging course presents the key topics of modern medical imaging in a systematic program structured as follows: principles of medical imaging, computer tomography, radioactive traces imaging, magnetic resonance imaging, ultrasound imaging, and optical imaging. The purpose of this course is to outline the breadth and depth of scientific knowledge underlying Medical Imaging. It describes the core physics related to medical imaging that a physicist should know when graduating from an accredited Medical Physics program. The course will aid him/her in understanding the strengths and limitations of the available medical imaging tools.

Max Credits: 3
Min Credits: 3

98.605 Radiation Interactions and Transport

Course ID: 8841

Course Details: 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.

Max Credits: 3
Min Credits: 3

98.606 Monte Carlo Simulation of Radiation Transport

Course ID: 36753

Course Details: 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.
98.616 Data Redn for RSP

Course ID: 8847
Course Details:
Max Credits: 3
Min Credits: 3

98.631 Professional Health Physics Internship

Course ID: 36584
Course Details:
Max Credits: 1
Min Credits: 1

98.665 Advanced Radiation Therapy Physics

Course ID: 37215
Course Details: 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.
Max Credits: 3
Min Credits: 3

98.671 Graduate Accelerator HP Internship

Course ID: 8857
Course Details:
Max Credits: 3
Min Credits: 3

98.672 Graduate Reactor HP Internship

Course ID: 8858
Course Details:
Max Credits: 3
Min Credits: 1

98.673 Graduate Reactor HP Internship

Course ID: 8859
Course Details:
Max Credits: 3
Min Credits: 3

98.675 Graduate Medical HP Internship
Course ID: 8861
Course Details:
Max Credits: 3
Min Credits: 3

98.676 Graduate Medical Physics Internship

Course ID: 8862
Course Details: 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.
Max Credits: 3
Min Credits: 1

98.677 Graduate Medical Physics Internship

Course ID: 8863
Course Details:
Max Credits: 3
Min Credits: 3

98.678 Graduate HP Internship

Course ID: 8864
Course Details:
Max Credits: 3
Min Credits: 1

98.679 Graduate HP Internship

Course ID: 8865
Course Details:
Max Credits: 3
Min Credits: 1

98.683 Graduate HP Internship

Course ID: 8869
Course Details:
Max Credits: 3
Min Credits: 3

98.685 Advanced Medical HP Internship

Course ID: 8871
Course Details:
Max Credits: 3
Min Credits: 3
98.686 Advanced Medical Physics Internship

Course ID: 8872

Course Details: 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.

Max Credits: 3
Min Credits: 3

98.687 Advanced Medical Physics Internship

Course ID: 8873

Course Details:

Max Credits: 3
Min Credits: 3

98.689 Advanced Graduate HP Internship

Course ID: 8875

Course Details:

Max Credits: 1
Min Credits: 1

98.690 Advanced Graduate HP Internship

Course ID: 8876

Course Details:

Max Credits: 2
Min Credits: 2

98.691 Advanced Graduate HP Internship

Course ID: 8877

Course Details:

Max Credits: 2
Min Credits: 2

98.692 Advanced Graduate HP Internship

Course ID: 8878

Course Details:

Max Credits: 3
Min Credits: 3

98.693 Advanced Graduate HP Internship

Course ID: 8879

Course Details:

Max Credits: 3
Min Credits: 3
Advanced Medical Imaging

Course ID: 37216

Course Details: Advanced Medical Imaging course presents the key topics of modern medical imaging in a systematic program structured as follows: principles of medical imaging, computer tomography, radioactive traces imaging, magnetic resonance imaging, ultrasound imaging, and optical imaging. The purpose of this course is to outline the breadth and depth of scientific knowledge underlying Medical Imaging. It describes the core physics related to medical imaging that a physicist should know when graduating from an accredited Medical Physics program. The course will aid him/her in understanding the strengths and limitations of the available medical imaging tools.

Max Credits: 3
Min Credits: 3

Supervised Teaching in Radiological Sciences

Course ID: 8886

Course Details:
Max Credits: 0
Min Credits: 0

Graduate Seminar in Radiological Sciences

Course ID: 8887

Course Details:
Max Credits: 1
Min Credits: 0

Graduate Seminar in Radiological Sciences

Course ID: 8888

Course Details:
Max Credits: 1
Min Credits: 0

Advanced Project in Radiological Sciences I

Course ID: 8889

Course Details:
Max Credits: 6
Min Credits: 3

Advanced Project in Radiological Sciences II

Course ID: 8890

Course Details:
Max Credits: 3
Min Credits: 3

Graduate Project in Radiological Sciences and Protection

Course ID: 8891
Course Details:
Max Credits: 6
Min Credits: 3

98.743 Master's Thesis in Radiological Sciences and Protection
Course ID: 8895

Course Details:
Max Credits: 3
Min Credits: 3

98.746 Master's Thesis in Radiological Sciences and Protection
Course ID: 8896

Course Details:
Max Credits: 9
Min Credits: 1

98.749 Master's Thesis Research in Radiological Sciences
Course ID: 8897

Course Details:
Max Credits: 9
Min Credits: 9

98.753 Doctoral Dissertation in Radiological Sciences and Protection
Course ID: 8900

Course Details:
Max Credits: 3
Min Credits: 3

98.756 Doctoral Dissertation in Radiological Sciences and Protection
Course ID: 8901

Course Details:
Max Credits: 9
Min Credits: 1

98.759 Doctoral Dissertation in Radiological Sciences and Protection
Course ID: 8902

Course Details:
Max Credits: 9
Min Credits: 9

98.769 Continued Graduate Research
Course ID: 8905

Course Details:
Max Credits: 9
Min Credits: 9

99.501 Biomedical Engineering and Biotechnology Seminar

Course ID: 8917
Course Details:
Max Credits: 1
Min Credits: 1

IB.770 CPT - Co-op Training

Course ID: 35548
Course Details: Course required to perform CPT
Max Credits: 1
Min Credits: 1

IM.630 Biological Oceanography

Course ID: 20118
Course Details:
Max Credits: 3
Min Credits: 3

IM.650 Physical Oceanography

Course ID: 20119
Course Details:
Max Credits: 3
Min Credits: 3

IM.743 Master's Thesis

Course ID: 35705
Course Details:
Max Credits: 3
Min Credits: 3

IM.746 Master's Thesis

Course ID: 35706
Course Details:
Max Credits: 6
Min Credits: 6

IM.749 Master's Thesis

Course ID: 35707
Course Details:
Max Credits: 9
Min Credits: 9

**IM.751 Doctoral Dissertation**

Course ID: 33675
Course Details: Doctoral Dissertation Research
Max Credits: 9
Min Credits: 1

**IM.752 Doctoral Dissertation**

Course ID: 33676
Course Details: Doctoral Dissertation Research
Max Credits: 2
Min Credits: 2

**IM.753 Doctoral Dissertation**

Course ID: 33677
Course Details: Doctoral Dissertation Research
Max Credits: 3
Min Credits: 3

**IM.754 Doctoral Dissertation**

Course ID: 33678
Course Details: Doctoral Dissertation Research
Max Credits: 4
Min Credits: 4

**IM.755 Doctoral Dissertation**

Course ID: 33679
Course Details: Doctoral Dissertation Research
Max Credits: 5
Min Credits: 5

**IM.756 Doctoral Dissertation**

Course ID: 33680
Course Details: Doctoral Dissertation Research
Max Credits: 6
Min Credits: 6

**IM.757 Doctoral Dissertation**

Course ID: 33681
Course Details: Doctoral Dissertation Research
Max Credits: 7
Min Credits: 7

**IM.758 Doctoral Dissertation**

Course ID: 33682
Course Details: Doctoral Dissertation Research
Max Credits: 8
Min Credits: 8

**IM.759 Doctoral Dissertation**

Course ID: 33683
Course Details: Doctoral Dissertation Research
Max Credits: 9
Min Credits: 9

**IM.769 Continuing Graduate Research**

Course ID: 37339
Course Details: Graduate Research.
Max Credits: 9
Min Credits: 9

**PSM.500 Professional Science Master's (PSM) Internship**

Course ID: 37165
Course Details: 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.
Max Credits: 0
Min Credits: 0

**PSM.501 Professional Science Master's (PSM) Reflective Seminar.**

Course ID: 37168
Course Details: Reflective seminar concurrent with 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 may be conducted online, and campus, or in a blended mode and will include writing and oral presentation of experience.
Max Credits: 1
Min Credits: 0

**PSM.535 Project Management for Scientists**

Course ID: 37833
Course Details: 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.
Max Credits: 3
Min Credits: 3
PSM.545 Professional and Scientific Communication

Course ID: 37732

Course Details: This course will help you improve your professional communication. A science professional who can communicate quickly, clearly and effectively will be most successful in the workplace. In this course, you will gain a fuller understanding of the communication process, and will practice the application of effective communication skills. You will develop both written and oral communication within the context of your professional area. Students will prepare and present a variety of short to moderate length presentations and written assignments. These assignments simulate those encountered in the "real-world" including persuasive presentations, oral and written reports, media interviews, memoranda, and crisis situations. This class will also display the impact of newer technologies such as e-mail and presentational software and the opportunities they present and constraints they place on effective communication. Supplemental course reading and materials included as appropriate.

Max Credits: 3
Min Credits: 3

PSM.555 Professional Leadership in Science and Engineering

Course ID: 37832

Course Details: 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.

Max Credits: 3
Min Credits: 3

Facilities

Special Facilities

Special facilities of the UMass Lowell College of Sciences include science laboratories, computer laboratories, undergraduate and graduate research facilities, a greenhouse, a nuclear reactor and a linear accelerator.

Departmental Facilities

The faculty offices, including those of department chairpersons, are housed in the following locations:

On UMass Lowell North:

<table>
<thead>
<tr>
<th>Department</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological Sciences</td>
<td>Olsen Hall</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Olsen Hall</td>
</tr>
<tr>
<td>Computer Science</td>
<td>Olsen Hall</td>
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<tr>
<td>Environmental, Earth, and Atmospheric Sciences</td>
<td>Olsen Hall</td>
</tr>
<tr>
<td>Mathematics</td>
<td>Olsen Hall</td>
</tr>
<tr>
<td>Physics</td>
<td>Olsen Hall</td>
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</tbody>
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Honor & Professional Societies

Several departments with the College of Sciences host chapters of national honor societies in their disciplines. These honor societies encourage and acknowledge high achievement by students. Departments hosting honor or professional societies include:

- Association for Computing Machinery (Computer Science)
- American Chemical Society
- American Meteorological Society
- Optical Society of America (Physics)
- Pi Mu Epsilon (Mathematics)
- Radiological Health Physics Society
- Sigma Gamma Epsilon (Earth Sciences Honor Society)
- Sigma Xi (Scientific Research)

Mission of the College of Sciences

The mission of the College of Sciences is to foster 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. Faculty members emphasize quality instruction, research, and creative activity as well as service to the community. Through activities, such as applied research and student
internships in which students and faculty use their expertise in the community, the College serves the economic and social needs of the Merrimack Valley region and beyond.

**Organization and Governance**

The College of Sciences contains six departments.

Dean’s Office
Olney Hall, Room 524
978-934-3840

**Policies & Requirements**

To qualify for University degrees, baccalaureate candidates are required to obtain a 2.00 (C) average in their total course of study; to complete a minimum of 120 semester credits; to fulfill the minimum residency requirement designated for University day courses and for each major; to satisfy the regulations and academic standards of the colleges that exercise jurisdiction over the degrees for which they are matriculating; to complete all curriculum requirements and minimum averages in majors specified by the college in which they are enrolled and department(s) in which they are majoring; and to complete the University general education requirements.

- Second Majors and Minors
- Approved Minors
- Declaring and Changing Major
- Transfer Policies
- Courses from Other Institutions
- Repetition of Transfer Courses
- Intercollegiate Transfer
- Pre-Professional Training
- Law School Requirements
- Medical/Dental School Requirements
- Teaching Careers

**Second Majors and Minors**

Options for second majors and minor studies are permitted as specified below:

1. Students may elect a second major that is offered by the College of Sciences or, upon approval of the Dean, they may elect a second major that is offered by other colleges of the University.

2. Students who elect academic majors in more than one college are candidates for one degree only, and they are considered to be degree candidates in the college of their initial major unless they indicate to the contrary at the time they make a declaration of second major by filing for intercollegiate transfer. Accordingly, a student who pursues academic majors in the College of Sciences and another college is subject to all degree requirements as specified by the college of his or her initial major and is subject only to major course requirements (including any collateral and prerequisite courses for the major) as specified by the department of his or her second major. For a full discussion of University requirements concerning second majors, students should consult the relevant section of this publication, which appears under the heading .

3. In accordance with the requirements of established minor programs, students who matriculate for degrees in the College of Sciences may undertake a minor from those areas cited below that are distinct from the disciplines comprising their majors. The curriculum committee of the College will from time to time review and, when appropriate, approve new minors in addition to those listed below. Students should consult with their advisors concerning additions to the approved listing of minors. Specific options for minor programs will depend on the major field that a student has elected to pursue and the collateral course requirements that have been specified by their major departments. Students are advised that an aggregation of courses that total 18 or more credits does not constitute a minor area and they are referred to University policies, which appear elsewhere in this publication under the heading for further discussion. Students who wish to elect a minor program in colleges other than the College of Sciences should refer to the appropriate section of this publication concerning prerequisites, restrictions, and prescribed sequences of courses.

4. With the approval of their faculty advisors, matriculating students in the College of Sciences may develop programs of elective courses for the purpose of providing greater personal and professional relevance to their major fields. Such programs may be developed from among those disciplines that are listed above as areas in which elective courses may be authorized for matriculating students of the College of Sciences.

5. Matriculating students in the College of Sciences who do not choose to take a second major or a minor must present at least six semester credits in courses that are on or above the 7300? level among those elective courses offered in fulfillment of collateral degree requirements. These courses may not be taken on a pass/fail basis.

**Declaring and Changing Major**

Students who are matriculating for degrees in the College of Sciences are required to designate degree majors in the college. Students who are admitted to Bachelor of Science programs in the sciences or mathematics are advised to declare their major fields during their freshman year and are required to make such declaration at the end of the sophomore year. Students should consult policies listed elsewhere in this publication under the heading for a complete discussion of declaration of major, declaration of second major, and
change of major with intercollegiate transfer.

Transfer Policies

Students transferring to the College of Sciences from other colleges of the University or from other institutions may expect recognition of previously completed college level courses that are applicable to the degree requirements of the college. Courses of a professional nature that are not relevant to the academic orientation of the student’s major program may not be credited to the minimum degree requirement of 120 credits, and, regardless of any previous recognition by the Office of Admissions or by other colleges of the University, they may not be credited to degree requirements in the College of Sciences. Students wishing to transfer Bachelor of Music programs are required to demonstrate their vocal or instrumental ability during an audition before the music faculty and are required to complete placement testing in music theory.

Courses from Other Institutions

The Office of Admissions initially evaluates courses that are transferred from other institutions when a student is admitted to the University. Courses are evaluated by major departments in terms of college and program requirements. Courses that are transferred to the University under provisions of the Commonwealth Transfer Compact and that are not creditable to requirements of the College of Sciences or as unrestricted elective courses will be listed on the student’s permanent record but will not apply to the minimum degree requirements. In the event that a student who has transferred to the University subsequently makes an intercollegiate transfer to the College of Sciences, all previously completed courses, including transferred courses from other institutions, will be reevaluated in terms of their applicability to degree requirements of the College of Sciences.

Repetition of Transfer Courses

A student who has been granted transfer credit, and on this basis has been assigned to advanced courses for which the transferred course is a prerequisite, may be advised to repeat such transferred work at the University or to take a more elementary course than that which has been transferred when the competence of the student has been demonstrably inadequate. Permission to repeat the transferred course is granted by filing an academic petition form through the office of the college dean. Since credit may not be granted more than once for the completion of any course, a condition for filing such a petition is the simultaneous filing of a request to revoke recognition of the previously transferred course.

Intercollegiate Transfer to the College of Arts and Sciences

Students wishing to transfer from another college of the University or from baccalaureate continuing education programs of the evening school must file an academic petition, together with a transcript, with the appropriate chairperson and the Dean of Sciences by November 1 for spring semester transfer and by April 1 for fall semester transfer. Students are referred to University policies concerning intercollegiate transfers, which appear elsewhere in this publication under the heading for further procedural details. Records of students who are approved for transfer are reviewed by the Office of the Dean of the College of Sciences and, irrespective of grades previously received in other college programs, all courses that may not be applied to college or program requirements are deleted from the student’s cumulative grade-point average.

Pre-Professional Training

The curricula for the Bachelor of Science degrees do not prescribe patterns of courses for specific vocational goals. The students in these programs receive a broad general education in the sciences that will prepare them for further study in professional fields at the graduate level. Students planning to enter professional fields should seek the advice of faculty advisors in the area in which they are interested, as listed below.

Law School Requirements

Pre-law work should include social sciences (especially history, economics, and political science), humanities (especially literature and philosophy), and basic courses in physical sciences and mathematics. Law schools do not specify particular majors for applicants and the field of concentration is not a determinant in admissions. Law schools do, however, vary in specific requirements and the student should, therefore, become familiar with those requirements of the schools to which he or she is planning to apply. The pre-law advisors are Dr. Francis Talty, Director of Academic Programs and Advisor to the Pre-law Society, and Professor William Burke, Legal Studies Coordinator, Falmouth Hall, 302.

Medical/Dental School Requirements

The Council and Association of American Medical Colleges have established minimum requirements for admission to an approved medical school. These include general and organic chemistry, biology, physics, and mathematics. These are minimums and many medical colleges require course work beyond the minimum. For this reason, it is imperative that a pre-medical student plan his or her college program in close consultation with the faculty advisor for pre-medical students. The advisor for pre-medical students is located in the Department of Biological Sciences, Olsen Hall 604.

Most medical and dental schools prefer a broad, liberal education in addition to specific course requirements. They do not advocate a particular major or majors and the field of concentration is not a determining factor in admission as long as the specified course requirements are met. Many pre-medical students will major in biology or chemistry, but a major in the areas of humanities and social sciences allows sufficient electives to meet the requirements of most schools. Medical and dental schools require an aptitude examination, which is ordinarily taken in the spring semester of the junior year.

Teaching Careers

The Department of Music offers an undergraduate concentration in music studies for teacher preparation and the degree of Master of
Music in Teaching, leading to initial licensure for teaching music in the Massachusetts public schools. More information about this program is available from Dr. Gena Greher or Dr. Alex Ruthmann in the Department of Music.

For those students interested in teaching subjects other than music, the Graduate School of Education offers graduate degree programs designed to prepare elementary and secondary school teachers. These programs provide the course work and the apprentice teaching experience required for initial licensure in Massachusetts and in many other states. See the Graduate Catalog, the web site, or the Office of the Dean, Graduate School of Education, for programs and the requirements for admission.

Policies

Information about the College of Sciences:

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