Advanced Graduate Certificate in
Data & Computational Science
Course Catalog

There are three types of courses: core, on-ramp, and general. The three core courses are JRN 501; JRN 503; AMS 561. On-ramp courses are intended to serve as an introduction to a discipline for a student from another area of study. Credit is only given within the certificate to students taking an on-ramp course outside of their own field of study. General courses may be counted as credit toward the certificate by any student from any discipline. Any of the CDCS catalog courses that satisfy a home departmental requirement can count toward both the certificate and the degree. Course selection must be approved by the home department’s Graduate Program Director and the certificate’s Graduate Certificate Director.

CORE

**JRN 501: Communicating Science: Distilling Your Message**
Students learn to speak clearly and vividly about their work and why it matters, in terms non-scientists can understand. Includes a video interview with a journalist.

**JRN 503: Communicating Science: Improvisation for Scientists**
This innovative course uses improvisational theater techniques to help students communicate more directly and responsively. It’s not about acting; it’s about connecting with an audience.

**AMS 561: Introduction to Data and Computational Science**
This course intends to teach the basics of applying modern computing instruments effectively to studying diverse areas in physics, chemistry, biology, and engineering, as well as economics. We will introduce relevant computer science topics (architectures, operating systems, programming languages) and relevant applied mathematics topics (numerical algorithms, data analysis, error analysis) and parallel computing. 3 credits, Letter graded (A, A-, B+, etc.)

ON-RAMP

**AMS 511: Foundation of Quantitative Finance**
Introduction to capital markets, securities pricing and modern portfolio theory, including the organization and operation of securities market, the Efficient Market Hypothesis and its implications, the Capital Asset Pricing Model, the Arbitrage Pricing Theory and more general factor models. Common stocks and their valuation, statistical analysis, and portfolio selection in a single-period, mean-variance context will be explored along with its solution as a quadratic program. Fixed income securities and their valuation, statistical analysis, and portfolio selection. Discussion of the development and use of financial derivatives. Introduction to risk neutral pricing, stochastic calculus and the Black-Scholes Formula. Whenever practical examples will use real market data. Numerical exercises and projects in a high-level programming environment will also be assigned. 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 535: Introduction to Computational Structural Biology and Drug Design**
This course will provide an introduction to Computational Structural Biology with application to Drug Design. Methods and applications that use computation to model biological systems involved in human
disease will be emphasized. The course aims to foster collaborative learning and will consist of presentations by the instructor, guest lecturers, and by course participants with the goal of summarizing key, methods, topics, and papers relevant to Computational Structural Biology. Grades are based on the quality of the presentations, participation in class discussion, attendance, quizzes, and a final exam. 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 536: Molecular Modeling of Biological Molecules**
This computer-based lab course is designed for students who wish to gain hands-on experience modeling biological molecules at the atomic level. In conjunction with individual interests, Molecular Mechanics, Molecular dynamics, Monte Carlo, Docking (virtual screening), or Quantum Mechanics software packages can be used to study relevant biological systems (s). Projects will include setup, execution, and analysis. Course participants will give literature presentations relevant to the simulations being performed and a final project report will be required. Familiarity with Unix (Linux) is desirable but not mandatory. 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 504: Compiler Design**
This course covers advanced topics in compilation, including memory management, dataflow analysis, code optimization, just-in-time compilation, and selected topics from compilation of object-oriented and declarative languages. Prerequisites: CSE 304 and CSE 307
Spring. 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 508: Network Security**
Principles and practice of Computer Network Security. Cryptography, authentication protocols, public key infrastructures, IP/www/ E-commerce security, firewalls, VPN, and intrusion detection. Limited to CSE graduate students. Others; permission of instructor. Prerequisite: CSE/ISE 310, or CSE 346 or equivalent.
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 509: Computer System Security**
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 526: Principles of Programming Languages**
Discusses programming language concepts and design, with emphasis on abstraction mechanisms. Topics include language paradigms (procedural, object-oriented, functional, and logic), language concepts (values, bindings, types, modules), and foundations (lambda calculus, denotational semantics). Examples will be drawn from several representative languages, such as C, Java, Standard ML, and Prolog.
Prerequisite: CSE 307
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 530: Geometric Foundations**
This course will focus on mathematical tools, geometric modeling techniques, and fundamental algorithms that are relevant to graphics, visualization, and other visual computing areas. The goal is to provide graduate students with a comprehensive knowledge on geometric concepts and demonstrate the significance of these mathematical tools and geometric algorithms in graphics and relevant areas. Course topics include geometric algorithms for both polygonal and curved objects, theory of parametric and implicit representations, modeling methods of curves, surfaces, and solids, in-depth spline theory, rudiments of wavelet theory and multi-resolution shape representations, differential geometry
fundamentals, and other sophisticated topics and latest advances in the field. Prerequisites: CSE 328 and CSE 332
Spring, 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 532: Theory of Database Systems**
The course will cover advanced topics in modern database systems, including object oriented databases, rule-based databases, temporal and active databases, parallel and distributed databases, distributed object model, data mining, online analytical processing, data warehousing, multimedia databases.
Fall and Spring, 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 533: Network Programming**
Topics include Unix and Linux socket API programming at the TCP, UDP, IP (raw sockets) and datalink access (Linux PF_PACKET sockets, libpcap & libnet libraries) levels, in the context of developing and implementing client-server applications, reliable data transfer using TCP-like rdt and flow control mechanisms, routing protocols, address resolution protocols, multicasting, DNS protocols.
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 537: Artificial Intelligence**
A comprehensive introduction to the problems of artificial intelligence and techniques for attacking them. Topics include problem representation, problem-solving methods, search, pattern recognition, natural language processing, learning, expert systems, AI programming languages and techniques. Covers both theoretical methods and practical implementations. Prerequisites: MAT 371 or CSE 541
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 621: Physics-based Modeling for Visual Computing**
A unified approach to various fields such as graphics, visualization, computer-aided geometric design, biomedical imaging, vision, and virtual environment. The course will explore select research topics centered on physics-based modeling methodology and associated computational methods for theoretical and practical problems in widespread areas of visual computing. The emphasis will be on geometric and solid modeling, geometric design techniques, wavelets and multi-resolution analysis deformable models based on mathematical physics, variational analysis, optimization methods, numerical simulation with finite-difference and finite-element algorithms, differential equations for initial-value and boundary-value problems, force-driven interaction with constraints, dynamic sculpting system, and a large variety of applications for visual computing.
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 634: Data Mining Concepts and Techniques**
Data Mining is a new, promising and flourishing interdisciplinary field drawing work from areas including database technology, artificial intelligence, machine learning, pattern recognition, high-performance computing, and data visualization. It focuses on issues relating to the feasibility, usefulness, efficiency and scalability of techniques for automated extraction of patterns representing knowledge implicitly stored in large databases, warehouses, and other massive information repositories. The course gives a broad, yet in-depth overview of the field of data mining and presents one or two techniques in rigorous detail. Prerequisite: Database course
3 credits, Letter graded (A, A-, B+, etc.)

**ESM 513: Strength of Materials**
A unified approach for all solid materials will be used with regard to the correlation between microstructure and their macroscopic mechanical properties. The course deals with various testing techniques for delineating mechanical properties of materials, considering elasticity, inelasticity,
plasticity, dislocation theory, cohesive strength, fracture, and surface wear. Attention is given to strengthening mechanisms for solids, metals, ceramics, and polymers.

Fall, 3 credits, Letter graded (A, A-, B+, etc.)

**ESM 562: Traditional Fossil Fuels**
The course will focus on the original and history of traditional fossil fuels, coal, petroleum and natural gas. Discuss mining methods and the role of fossil fuels play in the post-industrial revolution era. A comparison of the three fossil fuels with respect to their energy content, CO2 output and associated environmental impact tied to global warming.

Fall, 3 credits, Letter graded (A, A-, B+, etc.)

**ESM 569: Biofuels**
The course will focus on biofuels- a promising option to replace fossil fuels. Topics to be covered include crop-growth cycle and its impact on land-use, biomass to various fuel options, their integration into the exiting energy delivery infrastructure and potential benefit in CO2 reduction.

Spring, 3 credits, Letter graded (A, A-, B+, etc.)

**LIN 521: Syntax I**
A study of formal grammar as one aspect of our knowledge of language. Concepts and elements of modern syntactic analysis are introduced and motivated using a variety of grammatical phenomena and processes, across a wide range of languages.

0-3 credits, Letter graded (A, A-, B+, etc.)

**LIN 522: Phonetics**
A study of articulatory phonetics and the international phonetic alphabet, with intensive practice in phonetic transcription from a wide variety of languages. Acoustic phonetics, speech perception, and the applications of phonetics to foreign language teaching.

3 credits, Letter graded (A, A-, B+, etc.)

**LIN 523: Phonology I**
An introduction to the formal study of sound patterns. Problems from various languages serve as the basis for developing a theory of the representation of sound structure.

Prerequisite: Enrollment in LIN program or permission of instructor 0-3 credits, Letter graded (A, A-, B+, etc.)

**LIN 526: Analysis of an Uncommonly Taught Language**
Working from primary and secondary sources, students construct an outline of the phonology, morphology, and syntax of a language previously unknown to them.

3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

**LIN 537: Computational Linguistics I**
A hands-on introduction to practical aspects of computational linguistics. Students learn how to perform common tasks such as tagging and tokenization with a state-of-the-art programming language. Topics include basic data structures and algorithms, n-gram models, regular expressions, and corpus linguistics.

0-3 credits, Letter graded (A, A-, B+, etc.)

**LIN 538: Statistics for Linguists**
A hands-on introduction to statistical methods in linguistics using R. Topics covered include aggregation and summary, descriptive statistics, data visualization, hypothesis testing, regression analysis, and an introduction to hierarchical modeling. Students will gain experience with quantitative analysis of real-
world linguistic data sets, including corpus data and experimental data, with emphasis on a connection to students' own theoretical research. 0-3 credits, Letter graded (A, A-, B+, etc.)

**LIN 539: Mathematical Methods in Linguistics**
An overview of the mathematical foundations of theoretical and computational linguistics. Topics covered include set theory, morphisms, logic and model theory, algebra, lattices, lambda calculus, probability theory, information theory, and basics of formal language theory. A strong emphasis is put on the linguistic application of the mathematical concepts in the student and analysis of natural language data. 0-3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

**LIN 624: Morphology and Word Formation**
The internal structure of words and the place of the word in syntax, phonology, and the lexicon. A variety of analytical methods -- distributional, experimental and computational-- will be introduced. 0-3 credits, Letter graded (A, A-, B+, etc.)

**LIN 625: Semantics**
An investigation of the role of semantics (the theory of meaning) in the overall theory of grammar, structured around such topics as formal semantics, the interaction of syntax and semantics, and lexical semantics. 0-3 credits, Letter graded (A, A-, B+, etc.)

**ESM 575: The Material World**
The evolution of the Material World starting from the Big Bang, the creation of stars and galaxies, the nucleosynthesis of the elements in supernova explosions, formation of the Earth and Solar System, human adaptation of Earth resources to create the Modern World will be discussed. In this process we will discover the fundamental laws governing material behavior and explore the cosmic significance of our existence. 3 credits, Letter graded (A, A-, B+, etc.)

**MAR 505: General Circulation of the Atmosphere**
This course provides an introduction to the general circulation of the atmosphere, covering aspects in observations, data analyses, and basic theories. Spring, alternate years, 3 credits, Letter graded (A, A-, B+, etc.)

**MAR 507: Marine Conservation**
The fundamental concepts of conservation science, a synthetic field that incorporates principles of ecology, biogeography, population genetics, systematics, evolutionary biology, environmental sciences, sociology, anthropology, and philosophy toward the conservation of biological diversity will be presented within the context of the conservation of marine resources. Examples drawn from the marine environment emphasize how the application of conservation principles varies in different environments. Prerequisite: Enrollment in MCP or MAS program or permission of instructor Fall, 3 credits, Letter graded (A, A-, B+, etc.)

**MAR 512: Marine Pollution**
Review of the physical and chemical characteristics and speciation in the marine environment of organic pollutants, metals and radionuclides including bioavailability, assimilation by marine organisms, toxicity, and policy issues. 3 credits, Letter graded (A, A-, B+, etc.)
MAR 514: Environmental Management
This is an introduction to environmental management, and will focus on the interplay between science and public policy. Concepts include problem identification and definition, collection and analysis of relevant data to produce information, and the roles of public perception and action in ultimately determining outcomes when consensus is not reached. Specific fields to which these concepts will be applied will be solid waste management and coastal management. Current local problems will be used to illustrate the broader conceptual issues. Offered as MAR 514, EST 540 and CEY 501. Prerequisite: Permission of instructor. Offered in Spring, 3 credits, Letter graded (A, A-, B+, etc.)

MAR 517: Waves
Theory and observations of surface waves, internal waves, and planetary waves; wave-wave, wave-current, and wave-turbulence interactions; surface wave prediction; beach processes. Spring, alternate years, 3 credits, Letter graded (A, A-, B+, etc.)

MAR 523: Marine Mammal Biology and Conservation
This course provides an introduction to the basic biology of marine mammals, focusing particularly on various adaptations (e.g., morphological, physiological, acoustic) to life in the marine environment, as well as the ecology and behavior of marine mammals, and the conservation and management of marine mammal populations. 3 credits, Letter graded (A, A-, B+, etc.)

MAR 527: Global Change
The course examines the scientific basis behind questions of global change and some of the policy implications of changes to the region and country. Topics include evidence and courses of past climatic changes, greenhouse gases and the greenhouse effect, analogues with other planets, the Gaia hypothesis, climate modeling, and deforestation and the depletion of ozone. Prerequisite: Permission of instructor. Fall, alternate years, 2 credits, Letter graded (A, A-, B+, etc.)

MAR 536: Environmental Law and Regulation
This course covers environmental law and regulations from inception in common law through statutory law and regulations. The initial approach entails the review of important case law giving rise to today's body of environmental regulations. Emphasis is on environmental statutes and regulations dealing with waterfront and coastal development and solid waste as well as New York State's Environmental Quality Review Act (SEQRA) and the National Environmental Policy Act (NEPA). This course is cross-listed with CEY 503. 3 credits, Letter graded (A, A-, B+, etc.)

MAR 539: Economics of Coastal and Marine Ecosystems
Considering the socioeconomic implications of policy decisions involving environmental and natural resources has become increasingly important for ecosystem management. This course will view human interactions with coastal and marine ecosystems through the lens of economics. Topics will include the basics of welfare analysis, the concept of ecosystem services, the challenges associated with public goods, methods for economic valuation of non-market goods and services, and strategies for sustainable use of coastal and marine resources. In addition to exploring the fundamental principles of environmental economics, the course will also evaluate their real-world application through national and international policy examples. Spring, 3 credits, Letter graded (A, A-, B+, etc.)

MAR 558 Remote Sensing
Theory and application of remote sensing and digital image analysis to marine research. Students use standard software and PCs for digital filtering, enhancement, and classification of imagery. Prerequisite: MAR 501, 502, 504, 506, or permission of instructor. Spring, 2 credits, ABCF grading
**PHY 510: Introduction to Nonlinear Dynamics**
This course concentrates on developing the tools used to analyze models of dynamical systems associated with physical phenomena, such as coupled electrical mechanical, chemical and biological oscillators, amplitude equations, symplectic maps, etc. There is a discussion of the basic theorems, as well as methods used to derive perturbation solutions for differential equations and maps using the method of normal forms.
Fall or Spring, 3 credits, Letter graded (A, A-, B+, etc.)

**PHY 521: Stars**
A study of the atmospheres, interiors, and evolution of stars. The contact between theory and observations is emphasized. Stellar atmospheres in hydrostatic and radiative equilibrium described. Models for the calculation of stellar spectra are discussed. Stellar winds are studied. Next, theoretical studies of stellar interiors and evolution, including equations of state, energy transport, and nuclear energy generation, are developed. Structures of main sequence, red giant, premain sequence, and white dwarves are studied and compared to observations. The evolution of single stars up to supernovae and the peculiar evolution of close binary systems are also studied.
Fall, alternate years, 3 credits, Letter graded (A, A-, B+, etc.)

**PHY 523: Galaxies**
A basic course on the observational and theoretical aspects of the content, morphology, kinematics, and dynamics of galaxies. Topics include the size, shape, and location of the sun in the Milky Way; stellar populations; the disk and spheroidal components; galactic rotation; distance determination in the Milky Way and to external galaxies; galaxy classification and the Hubble Law. Theoretical topics center on stellar dynamics, including potential theory; stellar orbits; and spiral structure. The course also includes a brief introduction to cosmology.
Fall, alternate years, 3 credits, Letter graded (A, A-, B+, etc.)

**PHY 529: Quantum Electronics**
Introduction to modern atomic physics for the laser era for graduate students. Emphasis on the interaction between atoms and light, as well as on atomic structure and how it affects this interaction. Modern applications such as laser cooling, atom trapping, precision spectroscopy with frequency comb, quantum information, and others will be discussed. Not for satisfying physics Ph.D. breadth course requirements.
Spring every year, 1-3 credits, ABCF grading 1-3 credits, Letter graded (A, A-, B+, etc.)

**PHY 542: Fundamentals of Accelerator**
Physics and Technology with Simulations and Measurements Lab This course is an introduction to the underlying principles and uses of the nearly 14,000 particle accelerators that are used worldwide in medicine, industry, and scientific research. The course is suitable for senior undergraduate and entry-level graduate students in physics and engineering or students from other fields with a particular interest in accelerator-based science.
Summer, 1-2 credits, Letter graded (A, A-, B+, etc.)

**PHY 682: Special Topics in Solid State**

**PHY 684: Special Topics in Nuclear Physics**
GENERAL

AMS 510: Analytical Methods for Applied Mathematics and Statistics
Review of techniques of multivariate calculus, convergence and limits, matrix analysis, vector space basics, and Lagrange multipliers. Prerequisite: A course in linear algebra and in multivariate calculus. Fall, 3 credits, Letter graded (A, A-, B+, etc.)

AMS 514: Computational Finance
Review of foundations: stochastic calculus, martingales, pricing, and arbitrage. Basic principles of Monte Carlo and the efficiency and effectiveness of simulation estimators. Generation of pseudo- and quasi-random numbers with sampling methods and distributions. Variance reduction techniques such as control variates, antithetic variates, stratified and Latin hypercube sampling, and importance sampling. Discretization methods including first and second order methods, trees, jumps, and barrier crossings. Applications in pricing American options, interest rate sensitive derivatives, mortgage backed securities and risk management. Whenever practical examples will use real market data. Extensive numerical exercises and projects in a general programming environment will also be assigned. Prerequisite: AMS 512 and AMS 513 3 credits, Letter graded (A, A-, B+, etc.)

AMS 516: Statistical Methods in Finance
The course introduces statistical methods in quantitative finance. Financial applications and statistical methodologies are intertwined in all lectures. The course will cover regression analysis and applications to the Capital Asset Pricing Model and multifactor pricing models, principal components and multivariate analysis, statistical methods for financial time series; value at risk, smoothing techniques and estimation of yield curves, and estimation and modeling volatilities. Spring, 3 credits, Letter graded (A, A-, B+, etc.)

AMS 526 Numerical Analysis I

AMS 527 Numerical Analysis II
Numerical methods based upon functional approximation: polynomial interpolation and approximation; and numerical differentiation and integration. Solution methods for ordinary differential equations. AMS 527 may be taken whether or not the student has completed AMS 526. Spring, 3 credits, Letter graded (A, A-, B+, etc.)

AMS 528 Numerical Analysis III
An introduction to scientific computation, this course considers the basic numerical techniques designed to solve problems of physical and engineering interest. Finite difference methods are covered for the three major classes of partial differential equations: parabolic, elliptic, and hyperbolic. Practical implementation will be discussed. The student is also introduced to the important packages of scientific software algorithms. AMS 528 may be taken whether or not the student has completed AMS 526 or AMS 527. Spring, 3 credits, Letter graded (A, A-, B+, etc.)

AMS 530: Principles in Parallel Computing
This course is designed for both academic and industrial scientists interested in parallel computing and its applications to large-scale scientific and engineering problems. It focuses on the three main issues in
parallel computing: analysis of parallel hardware and software systems, design and implementation of parallel algorithms, and applications of parallel computing to selected problems in physical science and engineering. The course emphasizes hands-on practice and understanding of algorithmic concepts of parallel computing. Prerequisite: A course in basic computer science such as operating systems or architectures or some programming experience.
3 credits, Letter graded (A, A-, B+, etc.)

**AMS 533: Numerical Methods and Algorithms in Computational Biology**
An in-depth survey of many of the key techniques used in diverse aspects of computational biology. A major focus of this class is on how to successfully formulate a statement of the problem to be solved, and how that formulation can guide in selecting the most suitable computational approach. Examples will be drawn from a wide range of problems in biology, including molecular modeling, biochemical reaction networks, microscopy and systems biology. No prior knowledge of biology is required.
3 credits, Letter graded (A, A-, B+, etc.)

**AMS 540: Linear Programming**
3 credits, Letter graded (A, A-, B+, etc.)

**AMS 542 Analysis of Algorithms**
Techniques for designing efficient algorithms, including choice of data structures, recursion, branch and bound, divide and conquer, and dynamic programming. Complexity analysis of searching, sorting, matrix multiplication, and graph algorithms. Standard NP-complete problems and polynomial transformation techniques. This course is offered as both AMS 542 and CSE 548. Prerequisite for CSE 548: CSE 373 recommended
Spring, 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 545: Computational Geometry**
Study of the fundamental algorithmic problems associated with geometric computations, including convex hulls, Voronoi diagrams, triangulation, intersection, range queries, visibility, arrangements, and motion planning for robotics. Algorithmic methods include plane sweep, incremental insertion, randomization, divide-and-conquer, etc. This course is offered as both AMS 545 and CSE 555.
Prerequisite for CSE 555: CSE 373 or CSE 548
Spring, 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 548: Optimization techniques in biomolecular simulations**
This practical hands-on course will teach basic techniques for building mathematical models, algorithms, and software for biomolecular simulations of macromolecular interactions. The topics of this course include, but are not limited to: the basics of statistical mechanics and its connection to the sampling algorithms; the origin of and approximations for the computation of molecular forces; geometry of the molecular configuration search space and multidimensional optimization; basics of software development and programming for high performance computing (HPC). During the course, the students will develop a multiscale approach for modeling protein-protein interactions from the ground up.
Spring, 0-3 credits, ABCF grading

**AMS 553: Simulation and Modeling**
A comprehensive course in formulation, implementation, and application of simulation models. Topics include data structures, simulation languages, statistical analysis, pseudo-random number generation, and
design of simulation experiments. Students apply simulation modeling methods to problems of their own design. This course is offered as CSE 529, AMS 553 and MBA 553. 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 562: Introduction to Scientific Programming C++**
This course provides students with foundational skills and knowledge in practical scientific programming relevant for scientists and engineers. The primary language is C++ since it is a widely-used object-oriented language, includes C as a subset, and is a powerful tool for writing robust, complex, high-performance software. Elements of Python, Bash, and other languages will be introduced to complement the capabilities of C++, and essential tools for software development and engineering will be employed throughout the course (e.g., makefiles, version control, online code repositories, debugging, etc.). 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 572: Data Analysis I**
Introduction to basic statistical procedures. Survey of elementary statistical procedures such as the t-test and chi-square test. Procedures to verify that assumptions are satisfied. Extensions of simple procedures to more complex situations and introduction to one-way analysis of variance. Basic exploratory data analysis procedures (stem and leaf plots, straightening regression lines, and techniques to establish equal variance). Offered as AMS 572 or HPH 698. Prerequisite: AMS 312 or permission of instructor Fall, 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 573: Categorical Data Analysis**
Measuring the strength of association between pairs of categorical variables. Methods for evaluating classification procedures and interrater agreement. Analysis of the associations among three or more categorical variables using log linear models. Logistic regression. Prerequisite: AMS 572 Spring, 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 595: Fundamentals of Computing**
Introduction to UNIX operating system, C language, graphics, and parallel supercomputing. Fall, 1 credit, Letter graded (A, A-, B+, etc.)

**AMS 597: Statistical Computing**
Introduction to statistical computing using SAS and S plus. 3 credits, Letter graded (A, A-, B+, etc.)

**AMS 598: Big Data Analysis**
This course introduces the application of supercomputing to statistical data analyses, particularly on big data. Implementations of various statistical methodologies within parallel computing framework are demonstrated through all lectures. The course will cover (1) parallel computing basics, including architecture on interconnection networks, communications methodologies, algorithm and performance measurements, and (2) their applications to modern data mining techniques, including modern variable selection/dimension reduction, linear/logistical regression, tree-based classification methods, Kernel-based methods, non-linear statistical models, and model inference/resampling methods. 3 credits, Letter graded (A, A-, B+, etc.) To be offered starting Spring 2016

**CME 502: Mathematical Analysis and Modeling**
This course aims to provide graduate-level students with a practical approach to computational methods for the development of various modeling approaches to a variety of relevant chemical, physical and engineering processes. The course will cover linear algebra, non-linear algebraic systems, matrix eigenvalue analysis, initial value problems numerical optimization, boundary value problems; probability
theory and stochastic simulations, Bayesian statistics and parameter estimation and Fourier analysis.
3 credits, Letter graded (A, A-, B+, etc.)

**CME 526: Computational Methods**
This course aims to provide graduate-level students with an in-depth acquaintance with use of modern computational and mathematical techniques in chemical engineering including applied numerical analysis, programming algorithms using mathematical software, and applications of computational methods to the solution of chemical engineering. Topics include a discussion of the different analytical methods and algorithms and how to apply these using Matlab. In addition to the text, the student will be exposed to classic and current literature in the field.
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 500: Patterns in Programming**
This course provides an introduction to programming patterns often encountered in software systems. It presents the role of patterns and introduces patterns used by computer scientists and software engineers. The course covers a wide breadth of program types including user interfaces, numerical computing, event handling, and use of varied data structures. Patterns developed during the course are predominantly object-oriented patterns, including factory, facade, and many others. Not accepted for credit toward M.S. degree Prerequisite: permission of instructor
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 505: Computing with Logic**
The course explores logic-based computing and logic programming. It includes an introduction to programming in logic, covering basic techniques for solving problems in a logic programming system. Particular attention will be paid to user interface issues and how a logic system can provide a useful computing environment. The course covers implementation issues, emphasizing how a logic programming system generalizes both traditional programming language systems and traditional database systems.
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 507: Introduction to Computational Linguistics**
Overview of computational approaches to language use. Core topics include mathematical and logical foundations, syntax, semantics and programmatic. Special topics may include speech processing, dialog system machine translation information extraction and information retrieval. Statistical and traditional approaches are included. Students will develop familiarity with the literature and tools of the field. Prerequisites: CSE 537; CSE 541 recommended
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 512: Machine Learning**
A course on the fundamentals of machine learning, including basic models, formulations and modern methods. Topics include validation, classification, regression, clustering, component analysis and graphic models. Students are expected to have the following background: # Working knowledge of probability theory and statistics # Working knowledge of linear algebra and algorithms # Working knowledge of basic computer science principles at a level sufficient to write a reasonably non-trivial computer program in a language of preference. Fall and Spring
3 credits, Letter graded (A, A-, B+, etc.)

**CSE 519: Data Science Fundamentals**
Knowledge discovery in data is #the non-trivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data# (Fayyad et al. 1996). Large-scale data generated by humans and machines is available everywhere. Acquiring the fundamental skills on how to manage and process
these large datasets are crucial in today’s date-driven world, for producing data products that solve real-world problems. This course will cover the fundamental concepts in data science, to equip students with the key skillset toward becoming good data scientists. Major topics include scoping projects, data preparation, statistics basics, visualization, statistical learning, data mining, various types of structures. 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 529: Simulation and Modeling**
A comprehensive course in formulation, implementation, and application of simulation models. Topics include data structures, simulation languages, statistical analysis, pseudo-random number generation, and design of simulation experiments. Students apply simulation modeling methods to problems of their own design. This course is offered as CSE 529, AMS 553 and MBA 553. 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 545: Big Data Analytics**
The course will cover concepts and standard tools used to analyze, so called, Big Data. Specifically, it will cover algorithmic approaches to analyzing large datasets: MapReduce, graph analytics, text analytics, streaming algorithms, as well as modern distribution analysis platforms (e.g. Hadoop, Spark). 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 548: Analysis of Algorithms**
Techniques for designing efficient algorithms, including choice of data structures, recursion, branch and bound, divide and conquer, and dynamic programming. Complexity analysis of searching, sorting, matrix multiplication, and graph algorithms. Standard NP-complete problems and polynomial transformation techniques. This course is offered as both AMS 542 and CSE 548. Prerequisite for CSE 548: CSE 373 recommended 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 549: Computational Biology**
This course focuses on current problems in computational biology and bioinformatics. Our emphasis will be algorithmic, on discovering appropriate combinatorial algorithm problems and the techniques to solve them. Primary topics will include DNA sequence assembly, DNA/protein sequence comparison, hybridization array analysis, RNA and protein folding, and phylogenic trees. 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 564: Visualization**
The course emphasizes a hands-on approach to scientific, medical, and information visualization and visual analytics. Topics include: traditional visualization techniques, the visualization process, visual perception and cognition, basic graphics and imaging concepts, visualization of sampled, observed, and computed data, volume and flow visualization, information visualization, human-computer interaction, and the coupling of intelligent computing with visualization 3 credits, Letter graded (A, A-, B+, etc.)

**CSE 577: Medical Imaging**
This course presents an introduction to the mathematical, physical, and computational principles underlying modern medical imaging systems. It covers fundamentals of X-ray radiography, X-ray computed tomography (CT), ultrasonic imaging, nuclear imaging, magnetic resonance imaging (MRI), and functional MRI (fMRI), as well as more general concepts required for these, such as linear systems theory, the Fourier Transform, and numerical optimization. Popular techniques for the visualization, segmentation, and analysis of medical image data will also be discussed, as well as applications of medical imaging, such as image-guided intervention. 3 credits, Letter graded (A, A-, B+, etc.)
**CSE 587: Proficiency Requirement in Computer Science**

Students can get credit for an undergraduate course by registering for CSE 587. The syllabus of the undergraduate course must specify additional work that graduate students must do in order to pass the course. Graduate students taking an undergraduate course under the CSE 587 number must be graded separately from the undergraduate students. Consult the Graduate Program Handbook for additional restrictions regarding the use of this option.

2 credits – Courses eligible for this option are:

- CSE 214: Computer Science II (see also CSE 114 and CSE 219)
- CSE 230: Intermediate Programming in C and C++ (see also CSE 130)
- CSE 337: Scripting Languages
- CSE 353: Machine Learning
- CSE 373: Analysis of Algorithms
- CSE 377: Introduction to Medical Imaging

**CSE 590 Topics in Computer Science: SuperComputing**

This course explores algorithms and techniques for programming on various state-of-the-art parallel computing platforms: Shared-memory parallelism (and *Cilk*); Distributed-memory parallelism (and *MPI*); GPGPU computing (and *CUDA*); MapReduce and Hadoop; Cloud computing. During the second part of the course students will present interesting research papers in areas covered in the class as well as on cache-efficient and energy-efficient computations.

Prerequisites: Background in algorithms analysis (e.g., CSE 373 or CSE 548) and programming languages (e.g., C/C++) is required (or consent of instructor). Computer architecture background (e.g., CSE 320 or CSE 502) will be helpful, but not essential.

**CSE 591 Topics in Computer Science: Data Science**

Data Science is a rapidly emerging discipline at the intersection of statistics, machine learning, data visualization, and mathematical modeling. This course is designed to provide a hands-on introduction to Data Science by challenging student groups to build predictive models for upcoming events, and validating their models against the actual outcomes.

Spring, 3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

**CSE 595: Data Analytics - Software Stacks**

Course covers data analytics software ‹ Hadoop/HDFS/Hive/ Spanner/Spark along with parallel file systems, streaming software systems, elements of machine learning relevant to large-scale data analytics.

3 credits, Letter graded (A, A-, B+, etc.)

**CSE 610: Parallel Computer Architectures**

Topics include parallel computer systems; important parallel applications; parallel computation models; interconnection networks; SIMD and MIMD architectures; hybrid architectures; memory management; cache coherence; distributed shared memory; synchronization methods; operating systems; compilers; and programming tools.

3 credits, Letter graded (A, A-, B+, etc.)

**CSE 613: Parallel Programming**

Algorithms and technique for programming highly parallel computers. Trends in parallel and distributed computing; shared address space and message passing architectures; design issues for parallel algorithms; converting sequential algorithms into equivalent parallel algorithms; synchronization and data sharing; improving performance of parallel algorithms; interconnection network topologies, routing, and flow control; latency limits on speedup of algorithms by parallel implementations.
CSE 622: Advanced Database Systems
This course covers recent advances in data management systems and their applications to biomedical problems. Topics include XML data management, spatial data management, temporal data management, distributed and parallel databases, NoSQL databases, and MapReduce based data warehousing systems. We will discuss the foundations of data models, transaction models, storage, indexing and querying methods for these data management systems. We will demonstrate real world databases for biomedical data, geospatial data and social media data, and review recent research in the field. The course will provide projects with real world use cases and datasets.
Prerequisites: Basic data structures and database background (CSE 305 or equivalent), familiar with a programming language preferred, or permission of the instructor.
3 credits, Letter graded (A, A-, B+, etc.)

CSE 628: Natural Language Processing
The course offers computationally-oriented introduction to natural language processing (NLP). The focus is on modern quantitative techniques in NLP: algorithms and statistical approaches to word-level, syntactic, and semantic processing of natural language. The choice of topics includes practically motivated questions in NLP such as (1) can we teach computers to automatically detect authorship of a document? (2) can computers automatically suggest paraphrases (phrases with similar meaning) to help with writing?
Prerequisite: Familiarity with either Artificial Intelligence or Machine Learning is strongly recommended, but not absolutely required. Limited to CSE Graduate Students
3 credits, Letter graded (A, A-, B+, etc.)

CSE 680: Special Topics on Modeling and Simulation
This is an advanced modeling and simulation course on selected research topics. This application-oriented course tries to address issues of modeling and simulation from graphics, animation, CAD/CAM, medicine, artificial life, and virtual environments. Primary areas covered by this course include visual modeling, mathematical methods for geometry, shape design technology, computational physics for simulation, and scientific computing techniques. New topics will be added each year to reflect the latest state-of-the-art. Prerequisite: graphics/visualization background or permission of the instructor.
2 credits, Letter graded (A, A-, B+, etc.)

ESM 696: Computational Methods for Materials Scientists
Stat Mech, Random Walks and Markov Processes, Molecular Dynamics and Monte Carlo methods. Taught every other year.

LIN 626: Computational Phonology
An in-depth survey of natural phonology from a computational perspective. Topics vary by year and may include formal language theory (subregular hierarchy, finite-state transductions), computation modeling (maximum entropy grammars, Hidden Markov Models), and machine learning.
0-3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

LIN 627: Computational Semantics
A study of the computational challenges that arise in the interpretation of natural language utterances. Students are introduced to the logical description of sentence meaning and how these descriptions can be constructed in an algorithmic fashion. The course includes a significant programming component. The selection of topics varies from year to year and may include propositional and first-order logic, typed logics, model theory and model checking, mereology, intensional semantics, quantifier scope, pronoun
resolution, discourse representation, scalar implicatures, game-theoretic pragmatics, lexical semantics, and Bayesian inference.

0-3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

**LIN 628: Computational Syntax**
An in-depth survey of natural language syntax from a computational perspective. The primary focus is on combining state-of-the-art techniques from formal language theory with empirical insights from linguistic theory. Topics covered vary by year and may include tree transducers, logics for tree description, weak and strong generative capacity of natural language, lexicalized grammar formalisms, unification grammars, or the expressivity of probabilistic formalisms.
0-3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

**LIN 629: Learnability**
An introduction to learnability theory and its implications for language typology and language acquisition. The selection of topics varies and may include identification in the limit from positive text, PAC learning, lattice-based learners, Boolean function learning, neural networks, and learning algorithms for linguistic formalisms. Students will develop familiarity with the primary literature and learn important proof techniques of the field.
0-3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

**LIN 630: Parsing and Processing**
A survey parsing theory for natural language processing and its applications in psycholinguistic modeling. The course covers a wide variety of parsing algorithms for context-free and mildly context-sensitive grammar formalisms. The performance of these algorithms is carefully analyzed and set in relation to empirical phenomena of human sentence processing.
0-3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

**LIN 637: Computational Linguistics 2**
An introduction to the theoretical foundation of computational linguistics. The course emphasizes the importance of algorithms, algebra, logic, and formal language theory in the development of new tools and software applications. Empirical phenomena in phonology and syntax are sampled from a variety of languages to motivate and illustrate the use of concepts such as strictly local string languages, tree transducers, and semirings. Students will develop familiarity with the literature and tools of the field.
0-3 credits, Letter graded (A, A-, B+, etc.)

**LIN 650: Selected Topics: Graduate Seminar**
Topics will be announced each semester. The course may be repeated for credit if topic differs. 0-3 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.
Note: LIN650 will only count when it is a computational topic.

**MAR 501: Physical Oceanography**
Examines physics of ocean circulation and mixing on various scales with strong emphasis on profound effects of Earth's rotation on motions and distribution of properties. An introduction to physics of estuaries and other coastal water bodies.
Fall, 3 credits, Letter graded (A, A-, B+, etc.)

**MAR 505: General Circulation of the Atmosphere**
See description in OnRamp section.
MAR 513: Atmospheric Aerosols-Clouds, Climate, and Chemistry
Atmospheric aerosol particles have been recognized to contribute the largest uncertainties to the global radiative forcing estimates and affect air quality. This course introduces graduate students to the physical and chemical properties of aerosol particles and how those affect the particles' role in the atmosphere. Knowledge of how these particles interact with their surroundings is crucial to assess the impact of aerosols on air quality and climate. This course covers the fundamental mathematical, physical, and chemical descriptions of aerosol particles such as particle size distributions, thermodynamics of aerosols, aerosol hygroscopicity, physical and chemical particle transformation, carbonaceous aerosol, aerosol cloud interaction (cloud condensation and ice nuclei), aerosol optical properties, aerosol climate effects, and gas-to-particle (heterogeneous) reactive processes.
3 credits, Letter graded (A, A-, B+, etc.)

MAR 516: Ecosystem Science for Fisheries Management
This course will provide an overview of the science and mathematical models that are typically used to inform Ecosystem-based Fisheries Management (EBFM). The course will review single-species models, multispecies models and full system models. Advantages and disadvantages of implementing these approaches into management and policy will be explored. No modeling experience is necessary. The course requires familiarity with quantitative methods, but emphasizes current literature and case studies where EBFM has been or is being implemented as main learning elements. Offered in Fall, 3 credits, Letter graded (A, A-, B+, etc.)

MAR 528: Ocean Atmosphere Interactions
This course discusses the fundamental physical mechanisms through which the ocean and atmosphere interact. These principles are applied to the understanding of phenomena, such as the El Nino Southern Oscillation, the effects of sea surface temperature on the distribution of low-level winds and development of tropical deep convection, and the effects of tropical deep convection and mid-latitude storms on the ocean's mixed layer. Both modeling and observational aspects are discussed. Material will be taken from selected textbooks, as well as recent literature.
Prerequisite: Permission of instructor
Spring, alternate years, 3 credits, Letter graded (A, A-, B+, etc.)

MAR 547 Dynamical Oceanography I
The first course in a two-course series on basic methods and results in dynamical oceanography. This course emphasizes unstratified fluids. Topics covered include but are not limited to basic conservation equations, effects of rotation, geostrophy, potential vorticity conservation, Ekman layers, and Ekman pumping.
Prerequisite: MAR 501 or permission of instructor. Spring, 3 credits, ABCF grading

MAR 548 Dynamical Oceanography II
Continuation of Dynamics I. Course covers some of the basic effects of stratification. Topics include potential vorticity for baroclinic motion and baroclinic instability.
Prerequisite: Dynamical Oceanography I. Fall, 3 credits, ABCF grading

MAR 558: Remote Sensing
Theory and application of remote sensing and digital image analysis to marine research. Students use standard software and PCs for digital filtering, enhancement, and classification of imagery. Prerequisite: MAR 501, 502, 504, 506, or permission of instructor
Spring, 3 credits, Letter graded (A, A-, B+, etc.)
MAR 561: Quantitative Fisheries Ecology
The course covers quantitative models that are currently utilized to assess the status of fish stocks and academic pursuits of understanding single-species and ecosystem dynamics. The course builds on basic ecological models such as the density-independent exponential and density-dependent logistic models and introduces equilibrium and non-equilibrium production models and statistical-catch-at-age techniques. Recruitment and growth models commonly used in fisheries ecology are also covered. Least-squares, non-linear and likelihood methods are methods utilized in model parameter estimation. Statistical techniques such as bootstrapping and Monte Carlo methods are used to assess uncertainty in models outputs. This course is useful for students that plan academic or management careers in fisheries and wildlife research. Fall, 3 credits, Letter graded (A, A-, B+, etc.)

MAR 562: Early Diagenesis of Marine Sediments
The course treats qualitative and quantitative aspects of the early diagenesis of sediments. Topics include diffusion and adsorption of dissolved species; organic matter decomposition and storage; and diagenesis of clay materials, sulfur compounds, and calcium carbonates. The effects of bioturbation on sediment diagenesis are also discussed. This course is offered as both MAR 562 and GEO 562. Prerequisite: Permission of instructor. Fall, alternate years, 3 credits, ABCF grading

MAR 563: Early Diagenesis of Marine Sediments II
The basic principles and concepts of diageneric processes developed in MAR/GEO 562 are used to examine in detail early diagenesis in a range of sedimentary environments. These include terrigenous and biogenic sediments from estuarine, lagoonal, deltaic, open shelf, hemipelagic, oligotrophic deep-sea, and hydrothermal regions. Prerequisite: Permission of instructor
Spring, alternate years, 3 credits, Letter graded (A, A-, B+, etc.)

MAR 569: Statistics With R
Essentials of conducting statistical analyses using software developed by the R Project for Statistical Computing. R is free software that has been developed by contributors around the world and is quickly becoming a standard environment for conducting scientific data analyses. The course will cover the basic language, data management, graphics, and the application of R to a variety of statistical techniques such as ANOVA, regression, MDS and PCA, GLMs and GAMs. The class is intended to explore the capabilities of R and a basic graduate understanding of statistics is required.
Fall, 3 credits, Letter graded (A, A-, B+, etc.) May be repeated 1 time FOR credit.

MAR 572: Geophysical Simulations
This class is an introduction to numerical methods of solving differential and general nonlinear equations, which are common to many geophysical problems, as well as to advanced data analysis methods. Fundamentals of Finite-Difference Schemes; Methods for Initial-Value Problems of Linear Partial Differential Equations; Methods for Nonlinear Initial-Value Problems; Methods to Solve Elliptic Equations; Data Analysis

MAR 587: GIS: Display and Analysis of Environmental Data
Elements of Geographic Information Systems (GIS) with an emphasis on environmental applications, especially those related to marine and coastal systems. The course includes hands-on exercises to familiarize students with GIS capabilities. A project will be required.
Spring, 3 credits, Letter graded (A, A-, B+, etc.)

MAR 595: Graduate Seminar in Atmospheric Sciences
Discussion of special research topics centered on monographs, conference proceedings, or journal articles. Topics include climate change, atmospheric chemistry, radiation transfer, and planetary atmospheres. This course is intended primarily for students who have passed the written qualifying
examination in atmospheric sciences, although other students may enroll with permission of the faculty seminar leader.
Fall and Spring, 0-3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

**MAR 601: Dynamic model with MATLAB**
This course is designed to provide basic programming skills with the use of selected MatLab toolboxes to analyze marine and atmospheric science data, to perform challenging simulations, and to explore selected problems in marine and atmospheric and related fields. The course will emphasize functionalities and applications of the matrix manipulations, signal processing, statistical, and mapping toolboxes within the context of marine science problems. The goal is to give the students exposure to tools and programming techniques to enable them to work individually or in a group on a final project relevant to their research interest. Topics will include efficient MatLab programming techniques, simple numerical modeling and learning to build a classifier for recognition and measurement, separating and clustering data, graph and representation and spectral clustering.
2 credits, Letter graded (A, A-, B+, etc.)

**PHY 504 Methods in Computational Physics**
Computational Methods in Physics and Astrophysics An introduction to procedural and object oriented programming in a high-level language such as C++ or modern Fortran with examples and assignments consisting of rudimentary algorithms for problems in physics and astronomy. Students will use the UNIX/Linux operating system to write programs and manage data, and the course will include an introduction to parallel computing and good programming practices such as version control and verification. The course will prepare students for courses in algorithms and methods that assume a knowledge of programming.
Fall or Spring, 3 credits, Letter graded (A, A-, B+, etc.)

**PHY 546: Python for Scientific Computing**
Python for Scientific Computing Python has seen wide adoption in the scientific community for data analysis, simulation, prototyping and visualization. It provided a simple, yet powerful means to build applications. This seminar introduces python and its use in scientific computing. Students will learn the standard python libraries for array manipulation, visualization, numerical analysis and symbolic mathematics, as well as how to interface python with other languages, build applications, and good software engineering practices (including version control and testing). Students are encouraged to share examples for their discipline
0-1 credits, Letter graded (A, A-, B+, etc.)

**PHY 604: Computational Methods in Physics and Astrophysics II**
This course discusses numerical methods for applications in physics and astronomy starting from a short introduction to programming. Numerical methods for integration, differentiation, interpolation, root-finding, fitting, interpolation, Fourier transforms, ordinary differential equations, partial differential equation and linear algebra are discussed and an introduction to parallel computing is given. We illustrate these techniques with applications to special topics in physics and astronomy such as for example computation fluid dynamics, diffusion equations, density functional theory, N-body simulations and lattice gauge theory.
3 credits, Letter graded (A, A-, B+, etc.)

**SOC 595: Social Network Analysis**
Introduction to social network theory and methods. Topics include: power, centrality, clustering, brokerage, small worlds, preferential attachment, QAP, resampling, Monte Carlo, network experiments.
Prerequisite: Permission of the Instructor
3 credits, Letter graded (A, A-, B+, etc.)
SOC 603: Advanced Topics in Quantitative Analysis
Mathematical and statistical methods in the analysis of quantitative data.
Prerequisite: Permission of the Instructor 3 credits, Letter graded (A, A-, B+, etc.)
May be repeated for credit.