Advanced Graduate Certificate in Data & Computational Science Course Catalog

The **core** courses are JRN 501 and JRN 503 ***OR*** JRN 565; DCS 521 ***OR*** AMS 595 (for AMS majors only) ***OR*** PHY 504.

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.

OR

JRN 565: Communicating Your Science
This course is for graduate students in science, biomedical, engineering, and health disciplines who want to communicate effectively and responsively with multiple audiences, from peers and professors to potential employers, policymakers and the lay public. Students will focus on speaking about science clearly and vividly in ways that can engage varied audiences, especially those outside their own field. The class will include instruction and practice in connecting and finding common ground with an audience, defining goals, identifying main points, speaking without jargon, explaining meaning and context, using storytelling techniques, and using multimedia elements. The class will include improvisational theater exercises that help speakers pay close and dynamic attention to others, reading nonverbal cues, and responding freely without self-consciousness. As a culminating activity, students will develop and deliver an engaging short oral presentation on a scientific topic.
3 credits

AND

DCS 521/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.)

OR

PHY 504/DCS 544 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.)

OR

FOR AMS MAJORS ONLY
AMS 595/DCS 525: Fundamentals of Computing
Introduction to UNIX operating system, C language, graphics, and parallel supercomputing.
Fall, 3 credits, Letter graded (A, A-, B+, etc.)

Courses

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 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, meanvariance 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 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

Direct and indirect methods for solving simultaneous linear equations and matrix inversion, conditioning, and round-off errors. Computation of eigenvalues and eigenvectors.
Co-requisite: AMS 510 and AMS 595
Fall, 3 credits, Letter graded (A, A-, B+, etc.)

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 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 an 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.)

AMS 540: Linear Programming
Formulation of linear programming problems and solutions by simplex method. Duality, sensitivity analysis, dual simplex algorithm, decomposition. Applications to the transportation problem, two-person games, assignment problem, and introduction to integer and nonlinear 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 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 586: Time Series
Analysis in the frequency domain. Periodograms, approximate tests, relation to regression theory. Pre-whitening and digital fibers. Common data windows. Fast Fourier transforms. Complex demodulation, Gibbs' phenomenon issues. Time-domain analysis.

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.)

CHE 525: Theoretical Chemistry
This course stresses the physical theory underlying chemical phenomena. Special emphasis is given to advanced topics in electronic structure theory, molecular dynamics, condensed matter and surfaces, many-body and quantum ensemble theory, and the interaction of light and molecules. *3 credits, Letter graded (A, A-, B+, etc.)*

CHE 535: Introduction to Computational Structure 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. Fall, 0-3 credits, Letter graded (A, A-, B+, etc.)

CHE 536: Molecular Modeling of Biological Molecules
This course is designed for students who wish to gain hands-on experience modeling biological molecules at the atomic level. In conjunction with the individual interests, Molecular Mechanics, Molecular Dynamics, Monte Carlo, Docking (virtual screening), or Quantum Mechanics software packages can be used to study relevant biological system(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. Prerequisite: CHE 535 or permission of instructor. Spring, 0-3 credits, Letter graded (A, A-, B+, etc.)

DCS 569/BEE 569: Bayesian Data Analysis and Computation
An applied course in Bayesian analysis and hierarchical modeling for advanced graduate students in Ecology & Evolution or related sciences. Topics will include probability theory, Bayesian analysis, and MCMC methods such as Gibbs, sampling and Metropolis-Hastings sampling, as well as applied issues regarding the choice of prior distributions, posterior convergence, censored and missing data, and model checking and comparison. The course will be taught using WinBUGS and JAGS as accessed via the R packages R2WinBUGS and R2jags, respectively. Offered in the Fall.

BNB 567 Statistics and Data Analysis for Neuroscience: Foundations
This course will introduce students to the fundamental principles and methods of the statistical analysis of neural and behavioral data. A major focus of the course will be on how to properly design experiments to test hypotheses, how to avoid common misconceptions and errors in data analysis and how to report statistics correctly in manuscripts submitted for publication. This course will aim at providing a rigorous foundation of general statistical principles that can be applied generally, with an emphasis on material of high relevance to biology and neuroscience. A companion course ("Statistics and data analysis for neuroscience II: Applications") will turn to selected applications to neuroscience. The students will also have the opportunity to hone their statistics skills by analyzing different types of datasets (genetic, molecular, cellular, synaptic, imaging, spike and behavioral) in the MATLAB (or similar) computing environment.
2 credits

BNB 568 Statistics and Data Analysis for Neuroscience II: Applications
This course will introduce students to modern tools for data analysis that are highly relevant for biology and neuroscience. Each application is studied starting from a specific question that the researcher in neuroscience is likely to encounter during his/her research activity. The emphasis will be on practical problems and how to solve them avoiding the pitfalls of common misconceptions in statistics that may lead to statistical malpractice. The students will also have the opportunity to hone their statistics skills by analyzing different types of datasets (genetic, molecular, cellular, synaptic, imaging, spike and behavioral) in the MATLAB (or similar) computing environment.
2 credits

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 504/DCS 504: Compiler Design
This course covers advanced topics in compilation, including memory management, dataflow analysis, code optimization, just-intime 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 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 programmatics. 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 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
Principles and practice of building and administering secure systems. Authentication and access control. Operating system security. Program security, database security. Key management. Information flow. Assurance. Vulnerability analysis and intrusion detection.
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 date 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 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 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 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 538: 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.
Fall and Spring, 3 Credits, ABCF Grading

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, steaming 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 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/DCS 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.
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 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 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.)

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.)

DCS 501/CSE 550/ECE 523 Quantum Computing and Applications
This course is an introduction to and survey of the Quantum Computing, an emerging interdisciplinary field of science which has the potential to revolutionize computation over the next ten years, to transform chemistry, medicine, engineering and communications, as well as to change our understanding of physical world. The course will build intuitive approach to quantum computation and algorithms, but also will

advance relevant vocabulary and skills for faculties and graduate students in engineering, computing, applied mathematics, chemistry, physics and related sciences. The key questions of the quantum computing will be introduced. How to describe quantum systems and quantum operations? What is a quantum computer and what are the limits of quantum power? What is the difference between classical and quantum computation? Quantum teleportation? Quantum entanglement and superposition? How to mitigate errors and decoherence and transmit information through noisy channels? What are business applications and engineering challenges of the quantum computers? What are the gains in running quantum vs. classical algorithms? What are the physical principles of the current quantum computers hardware and what are technology requirements for realistic quantum computers?

DCS 504/CSE 504: Compiler Design
This course covers advanced topics in compilation, including memory management, dataflow analysis, code optimization, just-intime 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.)

DCS 522/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.)

DCS 525/AMS 595: Fundamentals of Computing
Introduction to UNIX operating system, C language, graphics, and parallel supercomputing.

DCS 544/PHY 504: 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.

DCS 569/BEE 569: Bayesian Data Analysis and Computation
An applied course in Bayesian analysis and hierarchical modeling for advanced graduate students in Ecology & Evolution or related sciences. Topics will include probability theory, Bayesian analysis, and MCMC methods such as Gibbs, sampling and Metropolis-Hastings sampling, as well as applied issues regarding the choice of prior distributions, posterior convergence, censored and missing data, and model checking and comparison. The course will be taught using WinBUGS and JAGS as accessed via the R packages R2WinBUGS and R2jags, respectively. Offered in the Fall.

DCS 572/MAR 572: Geophysical Simulation
Basic equations and boundary conditions. Linear and nonlinear instabilities. Finite difference and time integration techniques for problems in geophysical fluid dynamics. Numerical design of global atmospheric and ocean models.

DCS 613/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.

DCS 697/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.

ECO 520: Mathematical Statistics
The first semester of a one-year course in quantitative methods. Statistical methods and their properties of particular usefulness to economists. Topics include probability theory, univariate and multivariate distributions, limiting distributions, point and interval estimation, hypothesis testing. Prerequisite: Graduate standing in the Economics Department or permission of the Graduate Director. Fall, 3 credits, Letter graded (A, A-, B+, etc.)

ECO 521: Econometrics
A continuation of ECO 520. The application of mathematical and statistical methods of economic theory, including the concept of an explanatory economic model, multiple regression, hypothesis testing, simultaneous equations models, and estimating techniques. Prerequisite: ECO 520, Graduate standing in the Economics Department or permission of the Graduate Director.
Spring, 3 credits, Letter graded (A, A-, B+, etc.)

ECO 522: Applied Econometrics
A continuation of ECO 521. The application and extension of econometric techniques developed in ECO 521. Emphasis on the relationship among economic theory, econometric modeling and estimation, and empirical inference. Computer usage for calculation of estimators. Critical examination of econometric studies in current journals. Prerequisite: ECO 521, Graduate standing in the Economics Department or permission of the Graduate Director.
Fall, 3 credits, Letter graded (A, A-, B+, etc.)

ECO 531: Introduction to Computational Methods in Economics
A first course in the computational and graphical techniques for finding numerical solutions to a set of economic models (from more elementary models such as Edgeworth Box to a more general competitive equilibrium model to finding the policy function of a dynamic growth model) based on concepts and constructs presented in the 1st year graduate theory courses. Includes the foundations of programming (using a symbolic algebra language), and finding maxima of functions, finding equilibria of markets, and exploring and fitting functions graphically and through finite difference and projection methods. Emphasis is put on understanding the connections between the concepts, the algebra, the algorithm of the computation and the graphical presentation of economic models and on using the numerical models to perform experiments. Prerequisites: ECO500, ECO590, limited to Economics Department M.A. students
Offered Spring, 3 credits, Letter graded (A, A-, B+, etc.)

ECO 613: Computational Macroeconomics and Finance
A concentration on numerical methods commonly used to solve dynamic macroeconomic models. These include methods relying on dynamic programming techniques, linear approximation methods, and non-linear methods that can be applied to models with distortions and heterogeneous agents. The different

methods will be explained and their application to macroeconomics will be illustrated with examples from various areas such as Real Business Cycles, Asset Pricing with Complete and Incomplete Markets, and Recursive Contracts. Prerequisite: ECO 612, Graduate standing in the Economics department or permission of the Graduate Director
Spring, 3 credits, Letter graded (A, A-, B+, etc.)

EMP 504: Quantitative Methods
This course will lay the foundation for an understanding of basic quantitative methods for solving business questions. A working knowledge of these quantitative methods can help managers optimize true value-added for company stakeholders. In this course, we will explore probability theory, decision science and linear programming among other basic mathematical principles as a way of quantifying the decision-making process, but will not forget the basics of good management. We will also discuss several quantitative methods for analyzing and controlling cost, lead time, and quality of the goods or services being produced.
Online, 3 credits, Letter graded (A, A-, B+, etc.), Fall

ESM 511 Thermodynamics of Solids
Current knowledge regarding the thermodynamic properties of condensed phases is discussed. The thermodynamic treatment of ideal, regular, and real solutions is reviewed. Estimation of reaction-free energies and equilibria in condensed phase reactions such as diffusion, exication, and phase transformations; thermodynamic analysis of phase equilibrium diagrams.
Fall, 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, CO_2 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 CO_2 reduction.
Spring, 3 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.

EST 580: Technology Assessment

This class focuses on technologies and the systems in which they evolve to highlight different forms of evaluating technology. An overview of various methods, approaches, and tools for evaluation will be provided, including SWOT, STIP, forecasting, lifecycle assessments, and impact and risk assessments. The class will provide a context and framework for understanding policy applications of various technologies as well as broader societal implications. Challenges and opportunities of technological change will be examined in the context of societal implications, including environmental change, ethics, economics, science and engineering, and infrastructure. Students evaluate real-world technologies throughout the semester.
Online, 3 credits, Letter graded (A, A-, B+, etc.), Fall

HBH 501 - Principles of Pharmacology
Basic principles and mechanism of drug distribution, absorption, metabolism and elimination. Principles of chemical carcinogenesis and tumor promotion. Autonomic, Smooth Muscle and CNS Pharmacology. Pharmacology of specific drugs of historical interest including alcohol, antibiotics, aspirin, nicotine and morphine. Review of anticoagulants & thrombolytic agents, antiparasitic, and drugs for the treatment of allergic conditions and gout. Includes discussion of specific cases taken from clinical practice and a presentation based on a set of selected readings. Crosslisted with BCP 401
Fall, 4 credits, Letter graded (A, A-, B+, etc.)

HBH 502 - Advanced Principles of Pharmacology
Advanced concepts of drug metabolism, pharmacokinetics, biochemical and molecular mechanisms of drug action and drug resistance in human disease states. Toxicological agents and environmental pollutants. The pharmacology of autocoids, anti-inflammatories, immunosuppressants and anti-asthmatics. Rational drug design and drug receptor interactions using computer molecular modeling techniques. Includes discussion of specific cases taken from clinical practice and a presentation based on a set of selected readings. Cross-listed with BCP 402
Spring, 4 credits, Letter graded (A, A-, B+, etc.)

HBH 550 - Statistics in Life Sciences
This course covers statistical concepts and issues in the life sciences. Basic algebra is assumed as a prerequisite. Topics covered include: descriptive statistics, foundation of statistical inference, sampling distribution, point estimate and confidence internal, comparison of independent and paired samples, analysis of categorical data, correlation, ANOVA, linear regression, and nonparametric test.
1 credit, S/U grading

HBH 585 - Advanced Structural Biology/Structural Methods in Drug Discovery
This course is designed for students that want to gain theoretical and practical experience in macromolecular structure determination through NMR spectroscopy and/or X-ray crystallography. The course is organized into two modules: NMR spectroscopy and X-ray crystallography. Students may elect to take one or both modules. Emphasis will be placed on practical aspects of structural determination, including sample preparation, data collection and processing. In each of the modules, students will be guided through a complete structural determination project. A final project report per module will be required. Familiarity with Linux is desirable. Students are encouraged to contact instructors prior to enrolling. Crosslisted as BSB580 and HBH585.
Spring, 0-4 credits, S/U grading

HBH 631 - Graduate Pharmacology I
Basic principles of pharmacology will be discussed including pharmacokinetics and pharmacodynamics in both normal and various disease states. Major problems in human pharmacology will be considered including obesity, diabetes, hypertension and heart failure. Underlying physiology as well as

pathophysiologic background will be presented. Drug design and development will be discussed from both scientific and socio-economic perspectives.
Fall, 3 credits, Letter graded (A, A-, B+, etc.)

HBH 632 - Graduate Pharmacology II
This course introduces second-year graduate students to chemotherapy agents used to combat bacterial and viral infections as well as cancers. The course develops a detailed understanding of the strategies involved in identifying drug targets in these two diverse therapeutic settings. The antibacterial lectures emphasize the problem of drug resistance and the need to develop new agents to combat resistant organisms. The anti-cancer lectures begin with a comprehensive analysis of the molecular basis of cellular transformation leading to neoplastic disease. Lectures on cancer therapy emphasize the contrast between conventional cytotoxic chemotherapy and novel therapeutic approaches guided by recent developments in cancer research. Novel computational biology and structural biology approaches are featured throughout the course. Each student is expected to make two formal journal-club style presentations during the course and to actively participate in group discussion.
Spring, 0-3 credits, Letter graded (A, A-, B+, etc.)

HBH 633 - Quantitative Methods in Pharmacology
This course introduces second-year graduate students to the quantitative approaches that underlie modern research in Pharmacology. Students will be exposed to tools and techniques that are widely applied in different fields of biomedical research. Students will receive an introduction to the command line, coding and statistics, and learn to apply these tools to pharmacokinetic compartmental analysis, molecular modeling, image analysis, structural biology, biological big data analysis and genomics. Students will be actively engaged in data analysis and will be expected to participate in group discussion. Course Learning Goals and Objectives; at the conclusion of the course, students will be able to: (1) Utilize command-line tools and generate basic shell scripts; (2) Write simple programs in Python and R; (3) Understand the concept of modules and how to import them into code; (4) Generate sophisticated plots to rigorously represent experimental data; (5) Apply basic statistical principles to different experimental scenarios; (6) Understand the algorithms underlying image analysis and apply them to simple problems; (7) Apply numerical methods to solve ordinary differential equations for compartmental analysis; (8) Use basic tools for structural analysis and generate structural renderings; (9) Manipulate large datasets using Python.
Fall, 0-3 credits, Letter graded (A, A-, B+, etc.)

ISE 503 Data Management
ISE 305 deals with the design of database applications including Entity-Relationship data modeling, the relational data model, the SQL database query language, application development, and database administration. Students will complete a project that includes designing a database application and implementing it using database development tools.
Prerequisite: ISE 208 or CSE 114 or CSE 230
3 credits

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 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.)

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/DCS 697: 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
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 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 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 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 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 climactic 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 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 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 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, 2 credits, ABCF grading

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 expotential 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 are 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 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/DCS 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 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.)

NEU 536 Introduction to Computational Neuroscience
This course will introduce students to the fundamental principles and methods underlying computational modeling of neurobiological systems, spanning a range of topics from the biophysics of excitable membranes to models of learning and memory. A major focus of the course will be on the process by which a model of a neurobiological system is developed. Students will be introduced to the mathematical methods required for the modeling of such systems, as well as to tools for numerical and computational simulation. The students will also learn programming skills in the Matlab computing environment and will be required to perform Matlab projects to complement the material learned in the lectures.
3 credits,

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 522: Interstellar Medium
A study of the interstellar medium with emphasis on physical processes. Topics include kinetic theory, equation of transfer, spectral lines, non-thermal emission, ionization effects of dust, and formation and spectroscopy of molecular clouds. The components of the interstellar medium and the interactions between them are discussed in detail, as well as the process of star formation. Spring, alternate years, 3 credits, Letter graded.

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 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.)

PHY 682: Special Topics in Solid State, ***(if topic approved)***

PHY 684: Special Topics in Nuclear Physics, ***(if topic approved)***

PHY 688: Computational Astrophysics (Special Topic)
This course in computational astrophysics focuses on modeling and data analysis. Course explores analysis of astrophysical data sets using specialized computational tools and domain specific languages. Focus on model building, model checking, and model extension to capture information about the relevant physics and data generation process for a data set.
3 credits, Letter graded (A, A-, B+, etc.)

PHY 688: Astrophysical Fluids and Plasma (Special Topic)
This course focuses on the equations of hydrodynamics, viscous flows, gas dynamics, instabilities, turbulence, numerical methods for hydrodynamics, reactive flows, self-gravitating and rotation flows, and introduction to magnetohydrodynamics. Includes traditional problem sets and computational projects.
3 credits, Letter graded (A, A-, B+, etc.)

PSY 501 Analysis of Variance and Experimental Design (with PSY 508, Introduction to Computer Applications in Statistics, as a co-requisite)
The design and analysis of factorial experiments having a single dependent variable. Topics include between- and within subjects' designs, mixed-factor designs, interactions, trend analysis, and planned comparisons. Emphasis on applications in psychological research. Required of all Ph.D. students in psychology. Prerequisite: Undergraduate statistics, Co-requisite: PSY 508
Fall, 3 credits, Letter graded (A, A-, B+, etc.)

PSY 502 Correlation and Regression (with PSY 508, Introduction to Computer Applications in Statistics, as a co-requisite) Correlation, regression, multiple correlation, multiple regression, partial correlation, and introductions to some of the following topics: factor analysis, mediational analysis, structural equation modeling, relation of regression to analysis of variance, analysis of covariance, discriminant function analysis, and multivariate analysis of variance. Required of all Ph.D. students in psychology.

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

PSY 505 Structural Equation Modeling and Advanced Multivariate Methods
Thorough coverage of structural equation modeling and brief coverage of other specialized techniques used in data analysis in psychology, such as multi-level modeling and cluster analysis (topics for brief coverage vary from year to year). The course emphasizes hands-on work with real data sets, using standard statistical software packages.
Spring, 3 credits, Letter graded (A, A-, B+, etc.)

PSY 507 Meta-Analysis
This course is an introduction to research synthesis and the use of meta-analytic techniques. The content is intended to be a thorough yet practical coverage of basic principles, with an emphasis on leading students through the steps of conducting their own meta-analytic project. A basic knowledge of statistics commonly used in the social and behavioral sciences is essential. Class meetings will involve both didactic instruction and discussion of readings and homework assignments.
3 credits, Letter graded (A, A-, B+, etc.)

PSY 508, Introduction to Computer Applications in Statistics
Computer protocol and introduction to statistical packages and necessary utility programs.
Fall and Spring 0-1 credits, S/U grading May be repeated for credit

PSY 610/20-34 Computational Modeling
Topics selected on the basis of the needs of the graduate program and research interests of the staff.
Prerequisite: Permission of instructor
Fall, 0-3 credits, Letter graded (A, A-, B+, etc.) May be repeated for credit.

SOC 591.01: Contagion in Social Networks (taught by Jason Jones)
We will discuss theory, methods and applications in the study of contagion within social networks. It is NOT a prerequisite to have taken a social networks class or know anything about social networks before taking this class. We will cover all the basics in the beginning of the semester.

SOC 591.01: Computational Text Analysis (taught by Jason Jones)
In this course, we will explore the methods of automated natural language processing – in other words, using computer programs to analyze sets of text too large for any single person to read. We will discuss how this methodology has been put to use in the social sciences and digital humanities, and you will learn how to use these tools and apply them to your own research.
Spring

SOC 591.01: Computational Social Science (taught by Jason Jones)
Computational social science is a set of new methods aimed at explaining and predicting human behavior. These methods leverage the tremendous advances in computational and communication technology of the past few decades to bring more data to bear on research questions than ever before possible. In this course, we will explore these methods of computational social science and many recent applications. We will begin by reading the book Bit by Bit: Social Research in the Digital Age by Matthew J. Salganik. We will continue by reading published articles representative of computational social science work. Students will complete two major projects.
1. A templated project regarding trends in self-described identity using Twitter data. This project should result in a complete publication-ready manuscript.
2. An independent project proposal. This proposal should outline in detail how the student will complete an investigation using computational social science methods to address a research question of their choosing.

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.